Transpower Controlled Document

Guidance for new connections to the grid

Summary

The purpose of this document is to provide new connection applicants (generation or demand) with guidance on connecting to New Zealand's transmission grid, including the types of connection configurations that Transpower offers and why.

Establishing connection principles and standard designs for connection configurations will ensure consistency with good electricity industry practices and enable provision of services at acceptable levels of security, reliability, availability, and affordability.

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1 Purpose

The purpose of this document is to provide new connection applicants (generation or demand) with guidance on connecting to New Zealand's transmission grid, including the types of connection configurations Transpower offers and why.

Establishing connection principles and standard designs for connection configurations will ensure consistency with good electricity industry practices (GEIP) and enable provision of services at acceptable levels of security, reliability, availability, and affordability, i.e. reflecting efficient, least cost outcomes for consumers over time.

While some existing configurations on the transmission grid may differ from those listed in these guidelines, the pre-existing configurations are the result of historical network development. In the future only the configurations outlined in these guidelines will be used.

These guidelines should be read in conjunction with Transpower's grid connection process. All new connections are assessed through a Concept Assessment and the development of a Solution Proposal agreed between Transpower and the customer. This document provides guidance on preferred connection principles and configurations and does not replace project-specific assessments or agreements.

This document is for guidance and information purposes only. Details provided in this document are subject to the requirements of the Electricity Industry Participation Code 2010 (EIPC).

While Transpower is endeavouring to standardise grid connections as much as possible (in order to improve efficiency and accelerate connections, while maintaining a reliable and maintainable grid), Transpower reserves the right to deviate from these guidelines as it sees fit.

This document and the information in it is current as at the date of publication. Transpower reserves the right to update this document from time to time as it sees fit. Any changes to this document will be made by publishing an updated version of this document. Transpower reserves the right to apply any updates to these guidelines to existing and/or future applications to connect to Transpower's transmission network.

While Transpower will endeavour to make the wider electricity industry in New Zealand aware of such changes (e.g. through the release of newsletters) Transpower is not responsible for notifying any third party or parties of the release of an updated document. Parties using this document are responsible for ensuring they are using the most up-to-date version of this document published by Transpower.

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2 Scope

These guidelines apply to:

- all new Concept Assessments and all new Solution Proposals for grid connections for generators, electricity distribution businesses (EDBs), and industrial loads that will be directly connected
- all pre-existing Concept Assessments that have yet to progress into an investigation stage
- both customer-led and Transpower-led projects
- connections at new greenfield sites.

The principles in these guidelines must be reflected in any Concept Assessments and Solution Proposals.

The following is excluded from the scope of these guidelines:

- existing grid connections at substations. These guidelines are not intended to bring legacy connections into line with these guidelines.

Capitalised terms in this document are defined in Appendix A.

3 Intended Audience

This document is intended to communicate Transpower's expectations to the following stakeholders:

- customers – EDBs and companies with direct connections to the grid, e.g. generation developers and large industrial loads
- engineering consultants – who investigate concepts or provide detailed design for new connections
- engineers and technical managers within Transpower.

4 References

Document Owner	Document Title
Transpower	Grid connection process
Transpower	Connection Management Framework – Process Document (July 2024)
Transpower	Connection studies and engineering model requirements
Transpower	New connections general FAQ
Transpower	New customer – information checklist
Transpower	Customer contract information
Transpower	Guidance for developers establishing Solar Farms and BESS (Battery Energy Storage System) near Transpower Assets
Transpower	Guideline: Customer-led New Connections (September 2024)
Transpower	Consenting approach for customer projects

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New Zealand Government	Electricity Industry Act 2010, and its Regulations
Electricity Authority	Electricity Industry Participation Code 2010
Electricity Authority	Default transmission agreement (previously called the benchmark agreement) as set out in Schedule 12.6 of the EIPC
Prepared by Transpower and approved by the Electricity Authority	Connection Code set out as schedule 8 to the default transmission agreement
Electricity Authority	Transmission Pricing Methodology

5 Background

Transpower's customers' key driver when designing connections to the grid has often been the lowest capital cost solution. This approach was generally acceptable in a low electricity demand growth environment where Transpower experienced a small number of new customer connection requests. While this approach can minimise upfront expenditure it does not always optimise grid maintainability, future expandability, or whole of life cost.

However, in today's environment new connection requests (especially for wind, solar, and BESS generation) have increased and are predicted to increase further. Transpower is also seeing an increase in the number of new demand grid connection requests and expects these to increase further in the coming years. This growth requires connection solutions that can be delivered consistently, efficiently and at scale.

Transpower is also finding that some solutions designed and built within the last few years are requiring expansion or reconfiguration much sooner than expected as demand and generation growth accelerates. Therefore, future expansion capability and flexibility is becoming increasingly important as the economy electrifies at a rapid pace.

While the initial capital cost is still an important element, Transpower's historical approach of exploring bespoke connection solutions now needs to adapt and become more standardised and efficient. Greater standardisation supports faster project delivery, reduced engineering and design effort, improved maintainability, more efficient procurement, consistent operational outcomes, and improved scalability as the volume of new connections increases. Standardisation also helps ensure the transmission network remains cost-effective, maintainable, constructable, operable, reliable, and available throughout its lifecycle, with flexibility to expand where needed. The intent is not to eliminate engineering judgement or project specific solutions but to establish a consistent set of preferred connection arrangements that reflect good electricity industry practice and support efficient development of the transmission network.

Transpower's strategy, outlined in *Transmission Tomorrow,* includes a strategic priority to enhance its social licence to operate. As a natural monopoly, state-owned enterprise, and lifeline utility under the Civil Defence Emergency Management Act 2002 it is important that Transpower focuses on sustaining public confidence in its operations. One dimension of this is to recognise Te Tiriti o Waitangi and the importance of te ao Māori.

Many of Transpower's assets are located on land that is owned by, or significant to, Māori. Transpower recognises the important role that iwi and hapū play in caring for and protecting

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these areas as kaitiaki in accordance with tikanga Māori. Transpower acknowledges this connection and works to minimise the impact of its work on the mana and mauri of the environment.

6 Connection Principles

6.1 Overview

This section outlines 12 principles, and their rationale and design implications, that Transpower apply when working with customers to develop new demand or generation connections to the grid. Any new connections made outside of these guidelines require endorsement from Transpower governance.

The high-level over-arching principles, in no particular order, cover:

#	Principles
1	Substation design
2	Protection design
3	Future expansion and ultimate configuration plans
4	Ability to secure outages
5	System performance
6	New terminal site selection
7	Consenting approach
8	Land ownership and property rights
9	Asset ownership boundaries
10	Proximity to existing substations
11	Hard Tee connections
12	Special protection schemes
13	Revenue metering and power quality monitoring

6.2 Substation Design

Station connections are to be designed in a manner which:

- allows the associated primary plant to be operated with minimal impact on other end users
- allows the associated primary plant to be maintained, and outages scheduled, with minimal impact on other end users
- takes into account the electrical, and physical, location of the connection in relation to the rest of the transmission system around it
- allows Transpower to use reasonable endeavours to accommodate the needs of third parties, such as telecommunications companies with cell towers on Transpower sites, with regards to the impact of the proposed connection. Accommodating the needs of third parties will not indirectly and unduly hinder any present or probable future access to the transmission system by other users

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- ensures a primary, and an alternative, source of supply are factored into the design, wherever possible, to ease outage restrictions once new connections are added to the network
- balances up front equipment capital costs against the longer-term operational costs and risks.

6.2.1 Rationale

The principles applied for new demand or new generation:

- allow the Grid Reliability Standards to be met
- ensure the obligations outlined in the following are met:
  - EIPC
  - Default transmission agreement
  - Connection Code
- ensure consistency with GEIP.

6.2.2 Specific design requirements

Any new connection to the grid is unique in terms of its physical and electrical location and its impact on the power system. These guidelines therefore establish Transpower's preferred connection principles and configurations rather than prescriptive requirements for every circumstance. From experience, Transpower has developed standard primary plant concept designs (and associated secondary protection design packages) that provide an efficient and cost-effective development pathway for most projects.

Transpower will consider deviations from both the primary and secondary arrangements only if system performance is not compromised. Deviations will generally only be in respect of existing (brownfield) sites.

N security connections for demand are not preferred because they pose challenges for Transpower when scheduling outages (refer to the principle on Ability to Secure Outages). This type of connection may be acceptable if the demand can be back-fed locally by the EDB or a third party, or if the customer has specifically requested an N security connection and accepts the associated outage, maintenance and reliability implications.

Feeder circuit breaker ratings

Protection grading difficulties can arise if the feeder with the generation connected is required to have a rating comparable to that of the bus coupler or incomer circuit breakers.

Any proposal to use feeder circuit breakers with ratings approaching that of the supply transformers will require a demonstrated protection study showing at least one fast differential protection on the feeder with compliant grading, selectivity, and performance of the backup feeder protection, and will be subject to Transpower's approval. Where adequate protection grading cannot be achieved with normal main and backup protection, additional protection measures must be provided.

Customer high voltage cable connections

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Transpower's design and installation standards will apply to any customer High Voltage (HV) cable circuits (rated at 11 kV and above) that are to be terminated in Transpower Restricted Access Areas.

Specifically, for 220 and 110 kV cable connections, sufficient space should be included in the design to allow for equipment testing during commissioning, e.g. Transpower expects pre-livening checks, or ongoing maintenance.

Geographic information system (GIS) and associated scan data for all installed cables must be captured and provided to Transpower in accordance with its published standards.

For greenfield sites

It is a requirement that new connections adopt Transpower's standard designs and connection types (as set out in Section 7), in addition to:

- using standard equipment, i.e. circuit breakers, current transformers, voltage transformers etc, and substation layouts
- ensuring outdoor areas of substations are separated for the customer and Transpower
- ensuring customer and Transpower facilities are operationally separated, including control rooms, switchyards, and controlled access areas, so that normal operational and maintenance activities do not require either party to obtain routine access through the other's designated area.

Noise limits

Where noise generating equipment such as transformers are installed within a new Transpower substation development, any potential operational noise effects must be addressed at an early stage of site selection, layout, and consenting. New substations will be designed and sited to achieve noise outcomes at nearby noise-sensitive[1] locations as follows:

- Night-time (typically 10:00 pm – 7:00 am): 45 dB LAeq
- Daytime (typically 7:00 am – 10:00 pm): 55 dB LAeq.

Where customer and Transpower equipment are located on adjacent sites and are consented or designated separately, the parties will need to collaborate to achieve the required noise outcome at the receiving environment. This is because operational noise from both sites contributes to the cumulative noise level experienced by nearby receivers. For example, if each site is independently designed to achieve a noise level of 45 dB LAeq at the same receiver, the combined noise level would be approximately 48 dB LAeq. Accordingly, a coordinated acoustic assessment and design approach will be required to ensure the overall noise outcome is achieved.

[1] A noise sensitive location is typically a residential dwelling but could also include a healthcare facility, a school, a childcare facility or a place that provides overnight accommodation.

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Landscaping

Site selection and design should provide sufficient space around the substation for landscaping and visual mitigation where required. The extent, location and form of landscaping should respond to the site's landscape and visual context, nearby sensitive receptors, planning requirements, operational and safety constraints, access, underground services and future maintenance requirements. Where the customer is responsible for developing the site, responsibility for establishing and maintaining required landscaping should be agreed as part of the project arrangements.

Lighting

Substation lighting must be designed to meet Transpower's guidelines and information for switchyard and grounds lighting (TP.DS 40.03).

For existing sites

It is often not possible to apply standard design packages to existing sites. Therefore, the connecting customer should discuss with Transpower when it is acceptable to deviate from those designs.

The design that is implemented may depend on the criticality of a site to supply a region, the current level of site/equipment resilience, and the available system reconfiguration options (e.g. back up from other lower voltage circuits, or closing a system split) in the event of a natural disaster or other significant loss of supply event.

6.3 Protection Design

Connections are designed in a manner to enable the deployment of a protection system which:

- provides a level of performance, security, and maintainability which is consistent with GEIP
- is co-ordinated with the transmission network protection system and any other existing protection systems in the area (including existing protection schemes within the connecting customer’s site as applicable)
- can be operated in a manner that provides agreed levels of performance for the connection and for the power system as a whole.

6.3.1 Rationale

The principles applied for new demand or new generation connections:

- ensure the obligations outlined in the following are met:
  - EIPC
  - Default transmission agreement
  - Connection Code
- enable the requirements in the EIPC technical codes for co-ordination of protection schemes to be met

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- ensure that protection schemes operate effectively and predictably to isolate faulted equipment from the grid and ensure safety of industry personnel and the general public.

6.3.2 Specific design requirements

Transpower utilises standardised protection design packages which are mandatory for all new connections.

For greenfield sites

For all new greenfield substations (including GIPs, GXPs, and switching stations) the use of Digital Substation design packages is mandatory for designing all protection schemes, substation protection communication networks, and standard digital substation control and facility buildings.

Where protection functions are shared between new greenfield substations and existing neighbouring substations (e.g. line protection relays), Digital Substation design principles must also be applied to the relevant protection equipment in the existing substations.

The Digital Substation design packages do not currently cover all possible substation configurations. This limitation does not constitute an acceptance of alternative non-standard protection design approaches for new greenfield sites. Where a required configuration is not available within the existing Digital Substation design suite, e.g. double selectable bus or other non-standard arrangements, the appropriate approach is for new or extended Digital Substation standard designs to be developed in accordance with Transpower's standards.

Any deviation from the Digital Substation or other standard design packages for new connections requires explicit agreement with Transpower. The only exception to the use of the Digital Substation design packages is where Transpower does not require the use of a Digital Substation in a location where Transpower has very little presence, e.g. at the end of a Hard Tee connection.

For Digital Substation installations Transpower will limit customer equipment in its building to one cabinet.

For brownfield (i.e. existing legacy) sites

For existing substations, it may not be practical to fully implement Digital Substation design packages due to physical, operational, or integration constraints. In such cases, protection solutions will aim to align with Digital Substation principles to the extent reasonably practicable, while maintaining a focus on simplicity, maintainability, and system performance.

Where deviations from the Digital Substation and other standard design packages are required at legacy sites, the solution is not to be considered a precedent for new connections and will not be used to justify alternative design approaches for greenfield developments.

Transpower's standard approach is to provide separated control rooms and yards. For Digital Substation installations, Transpower's preference is to limit customer equipment within its building to a single cabinet. Exceptions may be agreed where there is no practical alternative.

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Telecommunications for both greenfield and brownfield sites

Transpower will normally require duplicate signalling communications paths for the standard differential line protection scheme. Specifically, 220 kV sites require a 'Profile A' and 110 kV sites require a 'Profile B+' design which will have a bearing on the cost. Some 110kV sites may need Profile A due to protection or criticality requirements.

For Profile A: all network services must be fully duplicated and connected via physically diversified paths, and they must meet the latency requirements of line protection.

For Profile B+: the site has two diverse communication paths but only requires non-duplicated equipment, where the equipment must meet the latency requirements of line protection.

Other

If the protection system becomes dis-proportionally complex, e.g. to enable back up protection at legacy sites, then it may be appropriate to invest in more primary equipment to make the protection less complex. An example would be requiring two breakers in a series rather than a complex protection arrangement with one breaker.

Where the co-ordination of protection schemes identifies shared services, an operational agreement covering the operation and maintenance of the assets and associated shared services is required between the connecting customer (asset owner) and Transpower (Grid Owner).

6.3.2.1 Connecting inverter based resources

Connecting an inverter based resource (IBR) to the grid requires specific consideration of protection system performance. Due to their power-electronic interfaces and configurable fault response, IBRs can affect the operation of distance, directional, and backup protection on both faulted and non-faulted parts of the transmission network.

The impact of IBR fault current contribution on protection performance will be assessed by comparing fault currents with and without the proposed IBR (including other existing or committed IBRs), as seen by any distance or directional protection element (under balanced and unbalanced faults). The assessment will consider cumulative effects and will not assume that protection adequacy is preserved as additional IBRs connect in the future.

If the IBR fault level contribution is:

- less than 15 per cent[2] of the pre-existing system fault current (from synchronous generation sources), material impacts on existing distance, directional, and backup

[2] $\frac{I_{IBR}-I_f}{I_f} > 0.15$, where I_f is the fault current without any IBR contributions, and I_{IBR} is the fault current with the IBR contributions.

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schemes are not anticipated. However, normal protection co-ordination and Wide Area Protection Study (WAPS) assessment is still required.

- equal to or greater than 15 per cent of the pre-existing system fault current (from synchronous generation sources), further protection assessment is required and mitigation must be implemented. This will typically require duplicated differential current protection on affected circuits and transformers (if not already in place), or other equivalent measures agreed with Transpower.

Given the evolving nature of inverter technologies, models, standards, and behaviour; applicants must engage with Transpower at an early stage to confirm the scope of protection assessment and the appropriate mitigation strategy for the connection.

New connections will require IBR compliance with IEEE 2800 with regard to negative sequence current injection. Developers should engage with Transpower early to understand incremental positive and negative sequence reactive current requirements from IBR during faults.

6.3.2.2 Islanded operation using inverter based resources

Unintended islanding operation (default requirement)

When operating in generating mode, IBRs will incorporate inbuilt anti-islanding functionality. In the event of unintentional islanding, the IBR must be capable of detecting and clearing faults within the islanded section. All earth faults must be cleared within 5 seconds, in accordance with the Electricity (Safety) Regulations 2010.

Where inadvertent islanding is possible, protection and control schemes will be coordinated with auto reclose functionality. Auto reclose schemes will incorporate synch check or equivalent functionality to prevent reclosing into an out-of-synchronism island and to verify system synchronism prior to reclosing.

Intended islanding operation (where agreed)

In remote or electrically weak parts of the grid, Transpower may consider the use of IBRs incorporating energy storage to support intentional islanded operation, where this is explicitly designed to improve resilience under extreme or prolonged system conditions.

Any intentional islanded operation will be subject to explicit agreement with Transpower and will be supported by appropriate control, protection, and operational arrangements to ensure safe formation, stable operation, and orderly resynchronisation. Intentional islanded operation will not replace normal transmission protection requirements unless specifically agreed with Transpower.

6.4 Future Expansion and Ultimate Configuration Plans

New connections, including any augmentation or enhancement to the existing transmission network, are to be designed in a manner which:

- does not hinder the long-term future development of the transmission system, nor preclude the next development step, e.g. expanding the substation to connect in additional circuits
- does not hinder foreseeable future developments, e.g. reconductoring or duplexing of existing transmission circuits
- considers access to the transmission system at that location by other users
- considers buffer zones or setbacks for future projects

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- ensures consistency with GEIP.

6.4.1 Rationale

Transpower factors in the likely future needs when building a new transmission substation, by having an ultimate configuration in mind.

This principle:

- is consistent with minimising the overall footprint of the electricity network; there are wider societal, environmental, and economic costs of new lines and substations
- anticipates the Transmission Pricing Methodology where upfront capital costs and ongoing costs can be apportioned to subsequent connecting parties, i.e. reducing the 'first mover' disadvantage
- leaves options open with the ultimate configuration plan in mind. This approach means that minimal assets are needed to make the connection initially. The assets are laid out in a way that enables future stages to be added to head towards the ultimate configuration when it becomes economic, and without having to relocate existing assets or substantially rework the site
- enables new connections to support electrification at pace (demand or generation) to meet New Zealand's climate-related goals and support a competitive electricity market
- enables co-optimisation of transmission and/or distribution network investment for the lowest overall cost to consumers, while not imposing unreasonable costs on the first mover
- enables a limit to be set for how much demand or generation is concentrated at a site (for resilience purpose).

6.4.2 Specific design requirements

Broadly:

- a new GIP near an existing demand centre should make provision for demand offtake
- new GXP sites for demand should provision for future generation (or battery) connections
- the site should be laid out with the ultimate configuration in mind
- where there are 2 or more 220 kV circuits in close proximity, there is a requirement to orient the new GXP/GIP in line with existing transmission lines to allow the second circuit to be connected if this becomes necessary and to support future conversion to breaker and half configuration (as illustrated by the staging in Section 7.1.2).

The ultimate configuration (loop-in-loop-out, breaker and half etc) depends on the voltage level and site and is assessed on a case-by-case basis.

The Single Line Diagram and layout for a site should allow for expansion, i.e. without having to re-arrange (or physically move) high value primary equipment, such as transformers and circuit breakers. However, re-terminating transmission lines is acceptable.

For new GIPs/GXPs, that are situated mid-way along a transmission corridor with multiple circuits, consideration should be given to preserving sufficient space for future circuit bussing

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where this could enable higher system transfer limits or improved utilisation of the transmission network.

Where Transpower determines that future circuit bussing may be required, it may request that additional land be secured as part of the development. Transpower will require secure long term property rights over the additional area required for future transmission developments. Depending on the property arrangements, this may include Transpower reimbursing the cost of the additional land or property rights and acquiring ownership where appropriate. The funding arrangements are supported by a mechanism in the Transmission Pricing Methodology.

For GIPs the requirements include:

- expansion provision (for demand) is required if:
  - the GIP is in proximity to a demand growth centre, i.e. within 25-30 km, or
  - the GIP is using less than 70 per cent of the existing transmission line capacity and there is developable land within 20 km,
- additional space will be provisioned if generation (or BESS) is inverter based, in case a filter needs to be added later to meet power quality obligations. The space allowed should assume a filter rating of between 10-15 per cent of the inverter MVA rating.

For GXPs the requirements include:

- for industrial direct connect customers: expansion provision is required if developable land within 25-30 km is available for future generation development.
- for new EDB sites: GXPs should always make provision for future generation connections, and the capacity limit is typically 360 MVA determined by limiting each site to 3 x 120 MVA continuously rated transformers
- for existing brownfield EDB sites: EDB demand supplied from the site should generally be limited to approximately 360 MVA. Where practical additional EDB demand should be diversified to alternative sites to reduce concentration of supply risk. The guideline does not preclude dedicated industrial load or other connections being supplied by separate feeders where appropriate.

In this principle, references to 'provision' do not mean 'build'. Rather, it means to ensure there is sufficient land (refer to dimensions provided in standard design packages), and the layout is such that it can be easily expanded (and access provided) when the time comes.

The connecting customer will purchase the land needed for longer term configuration, and the additional land (over and above the connecting customer's immediate needs) would be covered under FMD2 provisions in the Transmission Pricing Methodology**.** However, the customer is only required to build what is needed today, including the substation platform.

New connections on specific circuits

New connections (generation or demand) on the Whakamaru to Brownhill circuits are not permitted as a default position. While these circuits are currently operated at 220 kV, they are built for 400 kV operation, and Transpower wishes to preserve that optionality for the future.

In assessing any exceptions to the default position stated above, the key consideration is whether a proposed connection would create irreversible constraints on future uprating or

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materially increase the complexity, cost, or outage requirements associated with conversion to 400 kV operation. Connections that would limit feasible future corridor use, constrain substation layouts, or introduce dependencies that are difficult to unwind are therefore not permitted.

Similarly for the New Plymouth to Stratford A circuit, which is built for 220 kV but presently operated at 110kV, connections must not compromise future uprating potential. Any proposal must demonstrate that it preserves the ability to transition the circuit to its intended voltage without requiring substantial rework or creating long term operational constraints.

6.5 Ability to Secure Outages

A proposed grid connection must be capable of being constructed, operated, maintained, renewed, and replaced using outages that are readily obtainable; and without creating unacceptable system security risk, strong concurrency prohibitions, or material constraints on the wider grid.

Transpower considers the following requirements in relation to outages:

- the need for (and ease of) maintenance outages for existing and new assets when determining new connections to the grid
- avoiding multiple dependent maintenance outages that simultaneously reduce security for multiple GXPs, i.e. ensure new connections do not exacerbate existing outage risks
- the grid is to remain stable and in a satisfactory state during a maintenance outage. This means that there are to be no interruptions to load, except where there is only one circuit supplying an area, or where a customer has explicitly agreed to demand management, curtailment, or other operating restrictions during planned or unplanned outages
- in the event of an unplanned outage coinciding with a planned maintenance outage, the grid is to remain stable and in a satisfactory state, except that loss of injection or offtake is allowed
- the need for (and ease of) outages in the future to replace, refurbish, or enhance the existing grid.

Customers implicitly accept that when they request a low resilience (or N security) connection:

- planned outages are necessary at regular intervals to conduct routine periodic maintenance, and these outages will potentially interrupt their operations
- planned outages are necessary from time to time to replace or refurbish assets that are near or at their end of life, and these outages will potentially interrupt their operations
- wider power system needs are continuously re-evaluated and interconnection asset enhancement projects (e.g. thermal uprating of existing transmission circuits for the benefit of the system as a whole) are likely, which will necessitate longer duration outages which may impact customer operations. Additional costs to manage those impacts are the responsibility of the low resilience customer
- lower resilience solutions (while having lower initial upfront capital cost for the customer) often require additional operational constraints and extra commercial conditions, e.g. indemnifying Transpower against event charges, new risks, or increased whole of life operating costs

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- reduced reliability performance following unplanned outages or equipment failures.

6.5.1 Rationale

Planned maintenance on assets, and asset renewal at end of life, is carried out to ensure assets perform reliably and safely. While individual outage constraints may appear reasonable in isolation, the cumulative effect across the transmission system can materially reduce outage flexibility and increase operational complexity.

With increased demand for electrification (and higher asset utilisation) there is greater reliance on the grid for energy, with reduced tolerance for unplanned interruptions and increased expectations of reliability and availability.

The available windows for performing maintenance (or enhancement, and renewal/ replacement activities) were traditionally in the summer months. However, these windows are now shrinking because of the higher demand for electricity at all times of the year and the expected increase in grid solar generation connections, where their peak energy production period is also in the summer.

The EIPC requires Transpower to consult on planned maintenance, enhancement and renewal/replacement outages with affected parties (via reference to the outage protocol). It is not possible to contract out of this requirement as part of a new connection agreement. Therefore, it is preferable to avoid connection types which unduly increase the difficulty (and complexity) of securing outages.

In some regions of New Zealand, securing planned maintenance, enhancement or renewal/replacement outages for critical assets requires co-ordination with 18 different affected parties. This is becoming increasingly impractical to manage efficiently.

Maintenance, enhancement, and renewal/replacement outages naturally constrain the grid. Constraints can lead to higher market prices, lower reliability, and other operational challenges, e.g. complex switching activities to avoid cascade failure following a credible contingency with an asset on planned outage (N-1-1 condition). Therefore, when developing new connections, it is desirable to minimise the need for additional outages that could have significant market and reliability impacts on other customers.

If the grid is constrained and market prices are high, this can create pressure to defer necessary maintenance, enhancement, or renewal/replacement which could in turn increase longer term reliability risks. In addition, with wind and solar generation, constraints could increase energy spill, i.e. the intentional release or non-use of excess renewable energy, which may ultimately require additional generation investments to ensure there is adequate energy available.

6.5.2 Specific design requirements

The design requirements include:

- Minimise the use of Hard Tee connections; refer to Section 6.11
- Transpower's preference is to reduce the number of 4 terminal and 3 terminal connections if there are economic opportunities to do so
- For stations in remote locations, e.g. more than 100 km from a maintenance hub, there should be the ability to remotely isolate and earth

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- For connections onto critical grid backbone circuits, using connection types that enable maintenance on all GIP assets without causing interruption to through transmission, e.g. a loop-in-out with a bypass breaker where all 220 kV bus and feeder breakers can be isolated without impacting through transmission
- For connections that have minimal or moderate effect on outages, i.e. Outage Impact Rating (OIR) of 1 to 3, feedback on the connection from Transpower (Operations team) is not required. A classification system for OIR, scale of 1 (low impact) to 5 (high impact), is provided in Appendix C
- For new connections (greenfield or at existing brownfield sites), input from Transpower (Operations team) must be sought if the impact is assessed as OIR 4 or higher, i.e. connections that may have a high impact during outages.

6.6 System Performance

Connections are designed to:

- ensure system configurations provide reliability, security, and maintainability consistent with GEIP
- ensure new connections do not significantly impact through transmission capacity or reduce regional load limits
- minimise adverse impacts on other customers, and do not materially degrade the quality of service to other grid users
- preserve Transpower's ability to operate, maintain and develop the transmission system efficiently
- comply with EIPC obligations.

6.6.1 Rationale

New connections (generation and demand) will influence system performance and may increase utilisation of existing transmission assets. However, it remains necessary to ensure that Transpower can meet its:

- obligations under the EIPC, in its role of Grid Owner
- Principal Performance Obligations (PPOs) under the EIPC, in its role of System Operator.

6.6.2 Specific design requirements

6.6.2.1 System monitoring and observability

Developers of large or system-significant connections, including inverter-based resources and high-demand loads, should engage early with Transpower regarding potential system monitoring requirements.

Where a connection is expected to materially affect system performance, such as system strength, inertia, or transient behaviour, Transpower may require additional monitoring capability, which could include Phasor Measurement Units, to support the secure and efficient operation of the power system.

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6.6.2.2 New large demand connections

For very large new loads (including data centres) in the upper North Island region, Transpower has a strong preference for terminal site locations south of Ōtāhuhu to support efficient utilisation of the transmission network and manage future upgrade requirements. Developers are encouraged to engage with Transpower early in the assessment process to understand these preferences and the potential network implications of alternative locations. Alternative locations may be considered where the customer can demonstrate that co-located generation, energy storage, demand flexibility, or other measures can deliver broadly equivalent transmission outcomes.

6.6.2.3 Generation (or BESS) connections on supply busses

Generator and BESS connecting to supply busses must operate on voltage droop control with reactive power (Q) priority. Control settings will be coordinated with supply transformer tap-changer voltage control systems to:

- provide adequate voltage support
- avoid excessive tap operations
- avoid control interactions
- avoid unacceptable voltage steps following generator trips.

6.6.2.4 Transformers

Grounding

All high voltage (>66 kV) power transformers connected to the grid must have a YN (star) high voltage winding with the high voltage star point either solidly grounded or with a neutral earthing resistor as advised by Transpower. This is to ensure the high voltage grid remains effectively earthed to avoid transient over-voltages during unbalanced faults which can cause a health and safety risk or damage to equipment.

Point on Wave switching

To ensure power quality is maintained for other grid users, transformers connecting to the grid will require Point on Wave (PoW) switching if:

- the transformer is expected to normally remain in service, and
- energisation is expected to cause greater than 10 per cent Root Mean Square (RMS) voltage dip across any of the phases or between any two phases at the point of connection with a residual flux assumption of 0.6pu. If the transformer is expected to be regularly energised more than once every 3 months, the maximum allowable voltage dip limit is reduced to 6 per cent. In addition, transformer energisation should not cause the 220 kV HVDC terminals at Haywards and Benmore to experience more than a 6 per cent voltage dip.

Sympathetic inrush requirements are expected to be less onerous and therefore only assessed where considered material.

Geomagnetically induced current monitoring and mitigation

There is a need to maintain or improve the grid's resilience to HVDC link return currents and geomagnetically induced currents from solar weather events. This is done by installing

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neutral earthing resistors and/or blocking capacitors on grid connected high voltage transformers, particularly in the South Island.

Transpower will consider the size of the neutral earthing resistors and/or the requirement for blocking capacitors once the project has a transformer specification. The current flowing through the transformer earthing circuit will be monitored and made visible within the national SCADA system.

6.6.2.5 Static reactive plant

Static reactive plant is considered to switch more frequently, so the transient voltage change limit is ±6 per cent in the worst phase. The static voltage change limit is ±2.5 per cent, where the effects of generator voltage control can be taken into account.

6.6.2.6 GIPs

For regions that have significant local generation, a modest reduction in regional transfer capacity may be acceptable where the impact is small relative to overall system capability. For example, if the calculated system impact, e.g. reduction in grid transfer capacity into a region, is less than 10 per cent of the transfer capacity, then this is manageable and does not put any additional obligations or costs on a developer.

The calculated system impact should take into consideration the likelihood of future transmission capacity upgrades, e.g. thermal upgrades.

The technology selected for renewable generation may have a material impact on system on system strength requirements, system stability, and influence the connection arrangement required. Generation plant should be capable of stable operation under credible N-1 network conditions and the minimum expected short circuit ratio at the point of connection, without requiring operational restrictions, gain scheduling, or gain supervision[3].

Where the short circuit ratio (SCR) at the point of connection is sufficiently low and there is a material risk to stable operation (i.e. typically for SCR less than 3), Transpower may require bussing of circuits (or future provision) or other mitigation measures to achieve the required level of system performance.

6.6.2.7 Maintaining through transmission and network resilience

Through transmission capability is important for both system resilience and outage flexibility. Connection designs should preserve Transpower's ability to rapidly restore through transmission following equipment failures or outages. Transpower's standard designs include

[3] Gain scheduling – detecting system strength and adjusting control parameters, greatly increases the difficulty of coordinating control parameters across multiple generators. Gain supervision – reducing gains when oscillations are detected, should be used to cover for unforeseen scenarios, but should not be expected to operate during routine operation.

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bypass circuit breakers on loop-in-loop-out connections with significant through transmission on 220 kV circuits.

Specifically:

- the 220 kV circuits into the upper South Island, i.e. between the Waitaki Valley and Islington, require a bypass circuit breaker
- the 220 kV circuits into the lower South Island, i.e. between Roxburgh and Invercargill or North Makarewa, require a bypass circuit breaker
- the 220 kV circuits between the central North Island and Auckland do not require bypass circuit breakers, although Transpower do require provision for hard bypass. A 'hard bypass' refers to pre-strung conductors between line gantries awaiting jumpers, i.e. short lengths of conductor
- for regions supplying a demand of more than 250 MW from only two 220 kV circuits (e.g. Hamilton), a bypass circuit breaker solution is required otherwise Transpower requires provision for hard bypass
- hard bypass provision is required for 110 kV and below circuits, i.e. the installation of jumpers on line structures or gantries that allow bypassing within 24 hours.

For new connections, Transpower may require property rights, easements, access provisions or site layout restrictions to preserve future options for restoring through transmission or bypassing the site when required. The specific property requirements will be determined on a project by project basis. This enables a practical and cost effective solution to restore through transmission during an adverse event (e.g. a weather event) or emergency, improving system resilience and operational flexibility.

6.7 New Terminal Site Selection

A 'terminal' is a site where a substation or station is installed, as opposed to a site which may only have a single piece of equipment, e.g. a transmission tower. Terminal site selection and positioning for new connections, i.e. where Transpower is constructing a substation, will assess the following threats to resilience, which are aligned to Transpower's grid resilience strategy:

- seismic
- volcanic
- tsunami
- space weather
- land instability
- flooding
- severe wind and tornadoes
- snow and ice
- increased temperatures
- bush fire
- common mode failure
- third party activities (including cyber and physical threats).

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6.7.1 Rationale

Substations typically have large pieces of high value equipment; therefore, site selection must ensure these assets (and ultimately the transmission service security) are not subject to unmanaged risk.

Transpower wants to ensure that new terminal sites are located with long term resilience in mind, given:

- its expanding knowledge and awareness about natural hazards and evolving climate-related risks
- the anticipated higher reliance on electricity as a source of energy in the future, as the New Zealand economy continues to electrify.

6.7.2 Specific design requirements

Developers are encouraged to engage with Transpower early in the terminal site selection process, i.e. before purchasing land or securing environmental approvals, to support alignment with Transpower's standards and to enable improved project outcomes. Early engagement can help identify site constraints related to land size, topography, orientation, environmental sensitivities, and constructability, and reduce the risk of selecting a site that is unsuitable for a substation.

Transpower encourages the use of the layouts associated with the standard designs for substations. However, Transpower appreciates that it may not always be possible to acquire the right sized land or the right geography for the ideal layout, so compromises may need to be made.

New sites are not to be constructed, nor assets positioned, on land that is:

- on a flood plain
- at risk of material land instability risk (i.e. slips, liquefaction, or subsidence)
- in a tsunami zone
- on an active fault line, or
- in a sea level rise zone.

Any sites proposed in locations that present the risks above will only be approved in exceptional cases.

Designations for new GXPs and GIPs should be established to cover the full anticipated lifecycle of the assets and make reasonable provision for future maintenance and upgrade needs and expansion, including potential connections by additional parties. This approach supports efficient network development and reduces the need for repeated consenting processes.

If the terminal site to be owned by Transpower forms part of, or could impact, the interconnected grid, then Transpower's design standards must be met for any customer-owned connection assets built on the site.

Transpower's design standards must also be met for all connection assets owned by Transpower.

For customer-owned connection assets built on a Transpower owned terminal site, the site selection and layout must be consistent with Transpower's resilience requirements and long-

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term development needs. These requirements take precedence over ownership arrangements.

6.8 Consenting Approach

Transpower has developed a preferred approach to consenting to better support customers in obtaining their environmental approvals in a timely manner. Transpower's preferred consenting approach for new GIPs is:

- new GIP (fixed term): the connecting customer obtains a resource consent in its name for the GIP
- new GIP (perpetual): the connecting customer obtains a resource consent in its name for the GIP, and Transpower lodges a Notice of Requirement (NoR) to designate its portion of the site as soon as possible after construction
- new GXP: will require a designation in Transpower's name. The process can be led by Transpower or the customer, where appropriate
- changes to existing transmission lines: Transpower will generally arrange any consents required.

There will continue to be flexibility in Transpower's consenting approach. From time to time, it may be appropriate to agree to an approach outside of the preferred approach. Any deviation from the preferred approach will be treated as an exception.

6.8.1 Rationale

The preferred consenting approach:

- enables the connecting customer to lead the consenting process and have greater control over project timeframes
- supports customers in obtaining their environmental approvals in a timely manner
- continues to enable Transpower to build, operate, and maintain its assets.

6.8.2 Specific design requirements

Where the connecting customer is leading consenting for assets that Transpower will construct and/or own or maintain, consenting agreements will be utilised at the start of the project to define:

- the consenting approach
- roles and responsibilities
- Transpower's minimum requirements.

Where the connecting customer leads the consenting for assets that Transpower will construct and/or own and maintain, there will be a number of touch points during the process to ensure approvals are fit for purpose and meet Transpower's minimum requirements.

Transpower support for a customer's consenting activities is normally provided during a Transpower investigation project. Where a customer plans to progress consenting before a Transpower project starts, Transpower's ability to provide support may be limited and the risk of inadequacy of any consents obtained will sit with the customer. Customers considering

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this approach should engage with Transpower first to understand what support or advice can be provided.

6.9 Land Ownership and Property Rights

Transpower requires a long-term registered lease or outright ownership of the land for the Transpower switchyard area and associated buffer areas. The land should be unencumbered. Transpower's standard lease terms are available on its website.

Lesser forms of property rights may be acceptable under certain scenarios, provided the costs and risks to Transpower are acceptable.

Perpetual registered easements are required, on terms acceptable to Transpower, for:

- rights of way access to the new Transpower switchyard
- any new or modified transmission lines or cables
- the addition of earth-peaks and earth-wires to the existing transmission line (usually 1km either side of GIP/GXP)
- low voltage local electricity substation supply
- water/drainage or other utility easements, if required
- the management of Earth Potential Rise (EPR), if required; and
- diverse telecommunications fibre cable routes over any property between the switchyard and the nearest legal road.

Transpower may also require:

- a Facilities & Services Agreement (a licence to occupy) to address any facilities or services that may be required; and
- a registered land covenant to secure the Facilities & Services Agreement.

The connecting customer may be liable for future asset decommissioning and land reinstatement costs.

If a lease is preferred, then Transpower may need to recognise future asset decommissioning liabilities in its financial accounts and accordingly may seek to secure future decommissioning liabilities.[4] The same approach applies to associated easements which are not perpetual, i.e. provide for surrender or expiry. Where this situation exists, Transpower would include relevant terms and conditions in the Transpower Works Agreement (TWA) or the Transpower Development Agreement (TDA) (as applicable) with the connecting customer agreeing that they are responsible for those asset decommissioning and land reinstatement costs, and for the customer to provide payment or security for those costs.

[4] Decommissioning liabilities are explained on Transpower's website more fully: https://www.transpower.co.nz/connections/help-planning-your-connection#Futuredecommissioningliabilities

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6.9.1 Rationale

Transpower needs to have secure property rights to inspect, maintain, replace, upgrade and refurbish its assets.

The intent behind recognising future asset decommissioning liabilities, e.g. in the case of abandonment by the developer or connecting customer, is to ensure that any related decommissioning and reinstatement costs do not need to be passed on to other electricity consumers.

6.10 Asset Ownership Boundaries

In general, interconnection assets are owned by Transpower, and connection assets can be owned by Transpower or the connecting customer.

However, ownership boundaries across connection assets can be negotiated:

- for generator connections, the generator (or developer) will typically own the high voltage connection circuit breaker
- for demand connections, Transpower will normally own the high voltage circuit breaker that connects the transformer to Transpower's busbar.

Where a new connection involves building new 220 or 110 kV lines or cables:

- for a single customer with no reasonable possibility of future expansion, either by additional customers connecting at the hub, or ultimately for through transmission, then the customer will own the assets associated with that connection
- Transpower will own the assets where there is potential to expand the connection to another site, e.g. as part of a long-term grid upgrade, or the assets are of potential long-term strategic importance for the grid. The new circuit(s) will be built to Transpower's standards, with any uplift cost to meet those standards, or any strategic capability requirements, to be funded by Transpower.

Transpower may agree to own a connecting customer's transformers if those assets fit its standard transformer specifications. However, customers should note that Transpower will have operational control over those assets and may connect additional customers if the need arises, without the existing customer's consent.

As a general principle, Transpower prefers customer to own any 33 kV or 11 kV transformers associated with their connection.

6.10.1 Rationale

It is recognised that asset failures, e.g. circuit breakers, can impact other customers and through transmission.

There is a natural incentive for generators to own and maintain their own circuit breaker because the consequence of a failure could lead to damage to the generator. Furthermore, Transpower prefers not to have to maintain specialised generator transformers, as asset

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management decisions on generator transformers are best made by the generators themselves.

For demand connections it is highly likely the connecting customer will have a N-1 security connection, with the balance of incentives being on Transpower to maintain the incomer circuit breaker to avoid any impact on through transmission, or on other customers on the bus, in the event of a circuit breaker failing. Transpower's preference is to own the high voltage incomer circuit breaker; however, the demarcation will be agreed with the customer, i.e. Transpower could also own the supply transformers.

If there is a reasonable potential for connection assets to become interconnection assets in the future, then it is Transpower's preference to future proof the connection assets to serve a wider purpose with a long-term view of minimising costs for consumers, improving resilience, and optimising the level of transmission investment and the grid's footprint. For example, a windfarm that is mid-way between two existing substations, where the future grid envisages an interconnection, will require transmission to be designed and built to accommodate a double circuit, although the connection may only be strung with one circuit initially. This type of future proofing could also lower the costs for the developer if the assets become interconnecting in the future.

The selected asset ownership boundary influences metering and protection arrangements and responsibilities, operational control, maintenance obligations, testing requirements, and outage coordination. Transpower therefore prefers clear physical, operational and access boundaries between Transpower-owned and customer-owned assets. Where practical, facilities should be arranged so that routine operation, maintenance, testing, replacement and access activities can be undertaken without either party needing routine access through the other's designated areas. This reduces operational complexity, outage planning requirements, safety risks and ambiguity regarding responsibilities.

6.10.2 Specific design requirements

If the connection assets are customer owned and maintained, then the customer determines the build standard and requirements.

Any assets owned by Transpower will be designed, installed, and maintained to Transpower's standards.

If there is a reasonable possibility that lines or cables, which are also connection assets, could become interconnection assets in the future, then:

- Transpower will be the asset owner
- those assets will be designed, installed, and maintained to Transpower's standards
- those assets that are specified and rated to Transpower's requirements, and are higher than the customer's requirement, will see Transpower funding any incremental costs.

Transpower expects customer and Transpower facilities to be physically and operationally separated, including switchyards, buildings, control rooms, stormwater infrastructure and controlled access areas. Shared facilities or access arrangements should only be adopted where there is a demonstrated benefit and the responsibilities of each party are clearly

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defined. This may not be achievable at brownfield sites due to existing constraints. As a minimum, clear physical and operational demarcation should be provided so that asset ownership, operational responsibilities, access requirements and safety obligations are unambiguous. Ownership boundaries are determined in accordance with Transpower's Asset Boundary Policy and are subject to Transpower approval.

6.11 Proximity to Existing Substations

In general, the point of connection (or supply) to the grid should connect to an existing or committed substation if the point is within a 10 km radius (for 220 or 110 kV connections) of the substation.

However, a new substation is permitted if the existing substation cannot accommodate a new connection, e.g. Penrose is now a site which is too constrained to accommodate new connections at either 220 kV or 33 kV, or there are practical considerations, e.g. environmental, or resilience, which preclude this.

All new connections to Transpower's transmission line infrastructure will be, at a minimum, via a purpose built 'loop-in loop-out' substation located as close as possible to, and not further away than 1 km (negotiable up to 10 km) from, the proposed point of 'cut-in' on the transmission line infrastructure.

6.11.1 Rationale

This principle is:

- consistent with minimising the overall footprint of the electricity network, which ties into wider societal, environmental, and economic costs relating to new lines and substations
- consistent with the need to electrify the New Zealand economy at pace
- based on economic considerations, e.g. as at 2026, 220 kV double circuit costs on average between $3-4 million per km (though it does depend on many factors). Anything more than 10 km outweighs the cost of building a new GIP/GXP, which cost approximately $30 million to establish.

6.11.2 Specific design requirements

Any design requirements will depend on the site.

Transpower may reserve bays at existing critical stations if there is a confirmed need to support the long-term development of the grid, e.g. high likelihood or approved projects.

6.12 Hard Tee Connections

Hard Tee connections for new generation or demand connections on the core grid into a major region are **not** permitted.

Hard Tee connections are considered by exception only and must meet all of the requirements listed below, for both new generation or demand connection:

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- on regional (non-core) transmission lines
- when the connecting customer underwrites any Transpower system event charges
- where a standard connection option, e.g. loop in/loop out, breaker-and-a-half, is not reasonably practical
- the length of the Hard Tee connection is relatively short, e.g. less than 5 km (or less than 5 per cent of the total line length) and so does not materially affect the line fault rate, and
- the proposed Hard Tee connection is in close proximity to a nearby substation (typically within 10km), where connection is otherwise not practical.

However, a Hard Tee connection will not be accepted where:

- the Hard Tee connection requires expensive and complex protection upgrades
- there already exists a Hard Tee connection on the circuit
- the connection materially compromises Transpower's ability to secure outages, maintain assets, or operate the transmission system safely.

6.12.1 Rationale

The transmission utilities that Transpower surveyed consider that Hard Tee connections significantly reduce reliability and either do not support their future use on their main network or restrict their use to less critical lower voltage parts of the transmission network.

Disadvantages of a Hard Tee include:

- the added length of the Hard Tee reduces the reliability of the transmission circuit
- distance protection is difficult to implement on a Hard Tee. A three terminal line current differential protection is preferred but requires duplicated high-speed communications on diverse routes between three terminals. Therefore, this may lead to complex and costly protection (and telecommunication) upgrades at existing substations
- there is less operational flexibility. Maintenance or a fault on the transmission line disconnects the generator (or demand)
- there are higher long term operational costs (e.g. switching) and complexity to arrange and implement outages, as well as higher operational risks (e.g. driving long distances between sites) for the lifetime of the connection
- fault location methods (e.g. travelling wave, impedance based) are significantly less accurate on Hard Tee connected circuits.

6.13 Remedial Action Schemes

Special protection schemes (SPS), also known as remedial action schemes (RAS) or system integrity protection schemes (SIPS), provide a fast, automated mechanism for managing transmission constraints. RAS monitor defined system conditions and automatically take corrective action when network limits would otherwise be exceeded. This enables higher utilisation of assets while maintaining system security.

RAS operate on a seconds timescale and are distinct from the System Operator's dispatch and reserve management tools, which manage system operation over longer time scales.

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RAS are generally intended to complement, rather than substitute, efficient network development and customer investment where those solutions are practical and more economic.

6.13.1 Rationale

The rationale below discusses only generation and load reduction RASs.

Generation constraints are generally managed through market dispatch, which is a form of involuntary generation reduction. Similarly, a RAS can also cause a form of involuntary generation reduction. Consequently, a RAS is often appropriate for generators and can be an economic solution where they enable greater utilisation of existing assets for generation dispatch while maintaining system security.

RAS can be an effective means of managing capacity constraints associated with load. A RAS may be used either as an interim measure until new assets are commissioned or as a long-term measure where the cost of reinforcement cannot be justified. They may be particularly relevant where electrification creates large step changes in demand and the demand can be automatically tripped by an RAS.

However, RAS are not always the preferred solution. Increased utilisation of existing assets reduces outage flexibility and makes the transmission system more difficult to operate, maintain, or expand. The level of difficulty may require investment in primary equipment to provide a more effective long-term solution, where practical and economic.

6.13.2 Specific design requirements

Transpower seeks to minimise the number of independent RAS operating on the core grid. Multiple overlapping or interacting RAS increases operational complexity and risk, particularly where operators must understand different arming states, outage conditions, or corrective actions.

Within the interconnected part of the 220 kV core grid, Transpower will limit the number of RAS to avoid the possibility of unforeseen interactions. At present there is the Aviemore–Benmore circuit overload protection scheme in the South Island, and the Tokaanu Bus splitting scheme in the North Island, to increase flexibility for generation dispatch in the electricity market. Transpower does not anticipate additional RAS to increase generation flexibility. Transpower may consider RAS to enable maintenance outages or mitigate low probability extreme events, where it is not economic to invest in primary assets.

A RAS will be designed so that:

- the scheme has clear operating criteria, deterministic triggers, and corrective actions that reliably achieve the desired outcome
- the scheme maintains system security, with any failure of the RAS (or individual RAS components) not creating more severe power system consequences than the contingency or condition being managed
- safe operation does not rely on routine operator intervention, or manual actions.
- the scheme behaves consistently under normal system conditions, planned and unplanned outages, and abnormal configurations, unless a different behaviour is explicitly defined, assessed, and approved

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- where practical, the scheme remains normally enabled to minimise operator intervention and operational risk, unless otherwise agreed with Transpower
- the System Operator is able to model the RAS within its realtime tools and understand its operating conditions, triggers, and corrective actions
- the RAS operating state, actions and outcomes shall be observable through the System Operator's operational tools.

A RAS Concept Statement is required and will define the scheme logic, monitored quantities, operating conditions, corrective actions, communications requirements, and any operational procedures.

The RAS Concept Statement will be reviewed by System Planning, Protection Engineering, and the System Operator, to confirm that the scheme can be modelled, operated, maintained, and coordinated with the wider power system.

Transpower uses standard design packages to implement RAS. These packages currently include transformer overload protection schemes (TOPS) and circuit overload protection schemes (COPS), although alternative architectures may be considered where justified. The ongoing need for such schemes will be reviewed in accordance with Transpower's RAS policy.

RAS communication between substations

A COPS may detect a circuit overload at one substation and require all control action at another substation. This requires high availability communication. To maximise the scheme's availability and minimise the risk of load shedding under transmission contingencies, the scheme and its communication channels must be robust, so that generation can be run back reliably without putting load at risk. This may include 'profile A' communication systems and physically diverse communication paths to achieve the required level of reliability and availability.

New generation in constrained parts of the grid may trigger communication network upgrades to be paid for by the connecting customer, or for incremental costs to bring an existing upgrade forward, if material, to be paid for by the connecting customer.

6.14 Revenue Metering and Power Quality Monitoring

6.14.1 Revenue metering

All points of connection to the grid will require one or more EIPC compliant metering installations to measure the total flow of electricity into and out of the grid for each connecting asset owner.

For generation connections (GIPs), the metering obligations sit with the connecting customer. For load connections (GXPs), the obligations sit with Transpower as the Grid Owner. Typically, the party with the EIPC obligation will own the metering assets but this is not mandatory.

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Transpower metering installation All Transpower owned metering installations should follow the standard design. Ideally the metering cabinets, current transformers and voltage transformers should be in assets or areas under Transpower's control.

Metering installation should be at the point of connection to the grid, i.e. the boundary between Transpower and the connecting customer. Where this is not possible or it is impractical, the metering may be located elsewhere. When this occurs, the metering configuration must be done in such a way that it accurately represents the flow at the point of connection and, if necessary, includes corrections for line, cable and transformer losses.

In situations where the GIP and GXP connections share a common bus and the GIP is downstream from Transpower's metering, then Transpower will require its own metering on the GIP. This is required so the supply to the load connection (GXP) can be determined using Transpower's metering installations.

In situations where metering components, typically current transformers and voltage transformers, are provided by the connecting customer, Transpower will remain responsible for the metering installations, including their maintenance calibrations and ongoing compliance. There should be an agreement that defines the roles and responsibilities of both parties and any components provided by the connecting customer must meet Transpower's requirements.

Transpower's revenue metering will have exclusive use of one current transformer core. Voltage transformers are typically shared; however, if there is an option for metering to have exclusive use of a voltage transformer or winding this should be considered. There is no EIPC requirement for backup voltage transformer supplies; however, where there are multiple calibrated voltage transformers electrically connected to the same bus the voltage selection scheme in the standard design should be used.

6.14.2 Power quality metering

All load connections with Transpower-owned revenue metering should have at least one power quality meter. The meter will be the same make and model as the revenue meter but with a power quality configuration. The power quality meter will be installed in the spare position in the revenue meter rack.

In situations where Transpower does not own the revenue metering, but the connection includes inverter based resources (at a GIP), Transpower will install power quality metering at the point of connection.

Transpower's GIP power quality metering does not require certification as the data collected is not used in the settlement process. It is desirable to have exclusive use of a current transformer core; however, unlike revenue metering this is not mandatory. Where a current transformer core is shared the supply to each party should be separated as close to the current transformer as possible.

If the voltage source is from a capacitive voltage transformer, then an error correction device should be fitted to improve the accuracy of the harmonic measurements.

6.14.3 Local service metering

Substation local service supplies are typically part of transmission losses. Where the substation's local service supply is sourced from downstream of the main connection metering, the measurements must be corrected to remove the local service from the supply to the connecting customer.

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There are also instances where Transpower will make a local service supply available to another connecting customer. This local service supply is not part of transmission losses and should be added to the connecting party's supply.

In both the cases outlined above, compliant revenue metering is required on the local service supply.

Where a local service supply comes from a distribution network it will be an Installation Control Point (ICP) and Transpower will have a commercial arrangement with a retailer for the connection. In this situation the metering is the responsibility of the retailer. Transpower does not provide the meters or current transformers for local service ICPs.

Where a local service supply comes from a connecting customer, such as a generator, it is their decision if Transpower's supply needs to be metered, and their meter data adjusted.

7 Standard Connection Designs for New GIP/GXP

A substation configuration outlines the way physical assets are arranged to enable the required system performance and customer performance expectations to be met. A substation's configuration can include some, or all, of the following components:

- Circuits, overhead lines, or cables
- Busbars
- Transformers
- Circuit breakers
- Instrument transformers
- Disconnectors and earthing switches
- Control, protection, and metering systems.

The simplified Single Line Diagrams set out in Section 7.1 should be used as a guide. They are standard, commonly used configurations for GXP or grid switching station applications and are those most likely to be approved by Transpower without significant engineering input. These configurations could also be used for GIPs; however, it is recognised that the level of service that they provide may be in excess of what a typical generation customer may require.

The Customer Connection Design Packages website provides access to the standard designs and associated resources. These include companion guides, consenting and conceptual drawings, designer logs, and links to substation and tower 3D models. The 3D models can also be found within the Customer Connection Configurations project on Transpower's Model Management System.

Section 7.2 provides an indication of Transpower's preferred substation connection arrangements based on six key criteria.

Finally, Section 7.3 provides the general arrangements for connecting new substations into existing 220 kV and 110 kV transmission lines, encompassing both single and double circuits.

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7.1 Standard Designs for New Substations

Unless otherwise agreed with Transpower, all new GXP and GIP developments will use Transpower's standard designs incorporating disconnecting circuit breakers (DCBs). All circuit, feeder, and transformer bays will use DCBs. Bus couplers will be configured using back-to-back DCBs. Half breaker bays will use conventional circuit breakers.

New 220kV GXPs/GIPs

Unless otherwise agreed with Transpower, all new GXPs/GIPs connecting to Transpower's 220 kV circuits will use a substation layout configured for:

- a single circuit with bypass arrangement;[5] or
- a double circuit in a breaker-and-a-half configuration.[6]

To facilitate the above, new Transpower GXPs and GIPs are generally expected to be established beneath or adjacent to existing transmission line circuits, with the site layout providing for future staged expansion to an ultimate breaker-and-a-half arrangement.

Where applicable, for new GIPs, it is preferred that generation connections are brought in as 220 kV feeder bays, with the connecting customer to build, own, and operate their own transmission circuits, including associated step-up transformers at the remote end.

For new GXPs, connecting customers are expected to engage with Transpower early during site selection to collaboratively identify feasible GXP location(s).

Staging options are provided in Sections 7.1.1 and 7.1.2.

New 110 kV GXPs/GIPs

All new GXPs/GIPs connecting to Transpower's 110 kV circuits will use a substation layout configured for:

- a loop-in-loop-out (LILO)[7] arrangement.

In the case of 110 kV connections, maintaining through transmission is not expected to be a critical requirement, so the substations do not have to be future proofed with provision for bypass circuit breakers and do not have a requirement for being established beneath or adjacent to existing transmission line circuits.

Staging options are illustrated in Section 7.1.4.

[5] Refer to standard design package 4 (TP. DG 25.09).

[6] Refer to standard design package 5 (TP. DG 25.10).

[7] Refer to standard design package 2 (TP. DG 25.06).

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New 66 kV or 33 kV Connections

For new 220kV and 110 kV GXP/GIP developments, Transpower's default and preferred approach is for the customer to design, build, own, operate, and maintain all associated 33 kV or 66 kV systems and assets. Under this arrangement, Transpower's default ownership demarcation will be at the 33 kV or 66 kV incomer terminations to the customer's switchgear.

For brownfield sites, it is preferred that the ownership demarcation arrangements remain consistent with the existing site demarcation arrangements. Exceptions to this if required can be discussed and agreed with the customer on a project-specific basis.

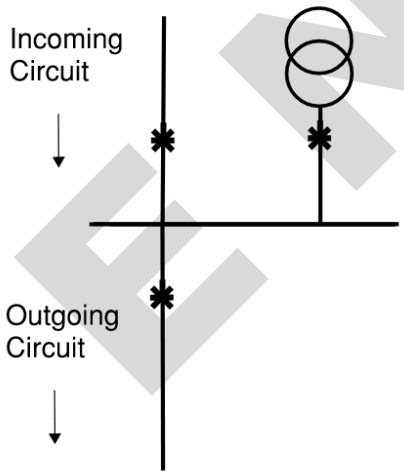
7.1.1 Single circuit with bypass circuit breaker

This configuration is recommended for new 220 kV GXP/GIP sites where only a single 220 kV circuit is available or initially required. The configuration comprises a single circuit connected to two buses, with either an installed bypass circuit breaker or provision for a future one, enabling key equipment or line circuits to be taken out of service without interrupting through transmission capability, while also facilitating future expansion.

Standard staging opportunities to achieve this configuration are illustrated below. Any alternative staging approaches will be subject to discussion and agreement with Transpower.

Stage 1: A single circuit loop-in-loop-out connection

This arrangement consists of two line bays, a single bus and a single customer transformer or feeder. The bypass circuit breaker bay is initially configured as an outgoing line bay.



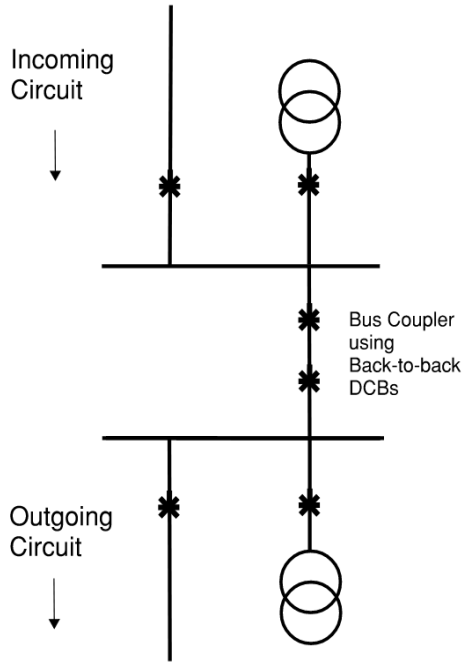
Stage 2: A single circuit loop-in-loop-out with bus coupler

The substation is expanded by adding a second bus and a second customer transformer or feeder.

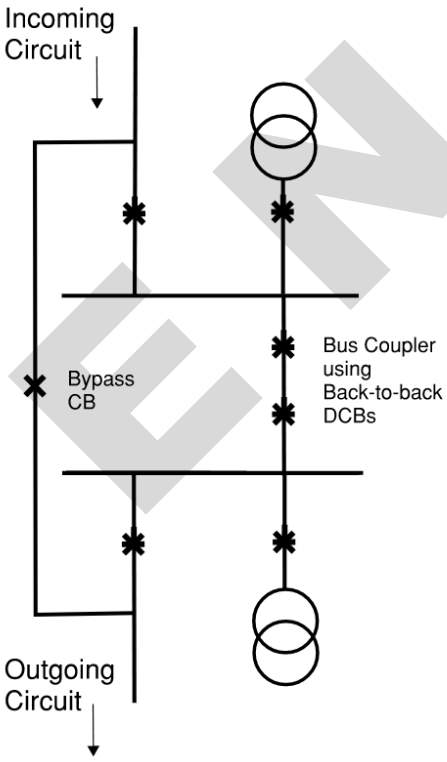
The bus coupler using back-to-back DCBs is installed between the transformer or feeder bays.

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Stage 3: Bypass circuit breaker installed to achieve the ultimate configuration



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For GXPs/GIPs developed under double circuit transmission lines, layouts will be arranged to facilitate future bussing of the second circuit, enabling eventual conversion of the single circuit bypass arrangement into a double circuit, breaker-and-a-half configuration.

The installation sequence of a second bus, bypass circuit breaker or bus coupler between Stages 1, 2 and 3 will be driven by the project-specific requirements and power system needs associated with the connection.

7.1.2 Double circuit in breaker and a half

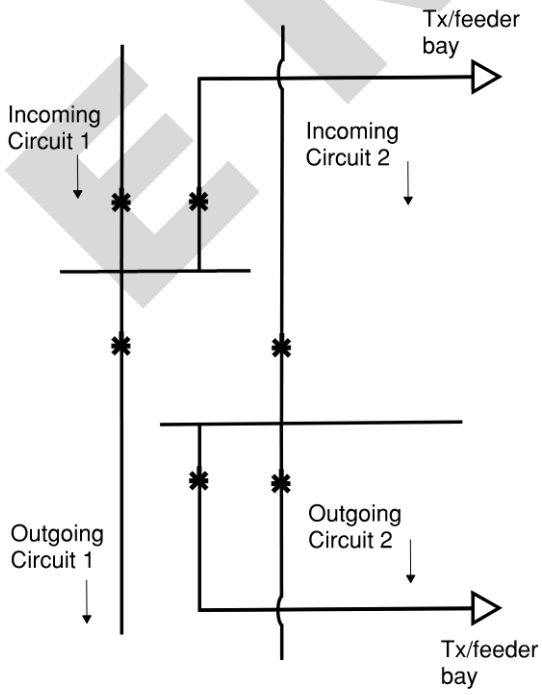
This standard design will be suitable in situations where:

- a customer requires a double circuit connection from the outset
- there are two or more 220 kV circuits available to connect
- through transmission is critical
- bussing of multiple circuits at this location may be required for system configuration reasons
- the substation is situated near a location where multiple lines cross over each other, i.e. removes cross overs.

A two-stage approach to realise a double circuit connection in breaker and-a-half is provided below. Any alternative staging approaches will be subject to discussion and agreement with Transpower.

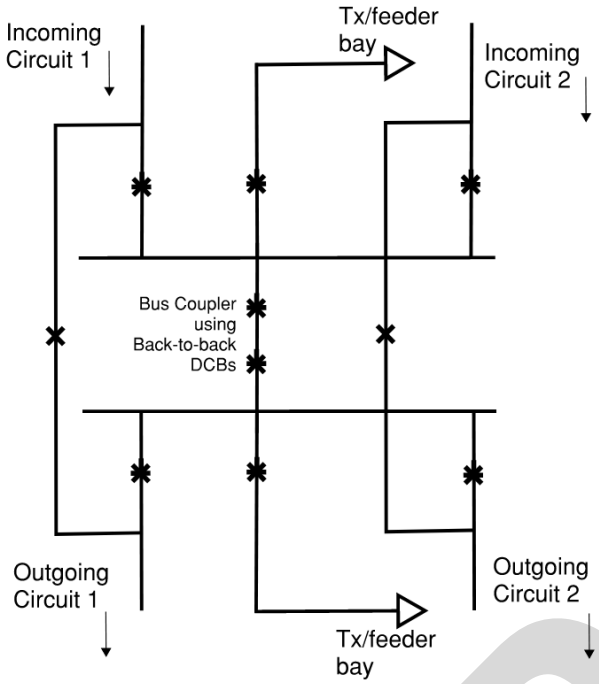
Bus coupler requirements in 220 kV double circuit breaker-and-a-half configurations will need to be assessed and confirmed on a project-specific basis in consultation with Transpower.

Stage 1: Each circuit is connected in a loop-in-loop-out configuration to separate buses. Customer transformer (Tx) or feeder connected to each bus.



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Stage 2: Converting the loop-in-loop-out of both circuits into breaker-and-a-half to achieve the ultimate configuration



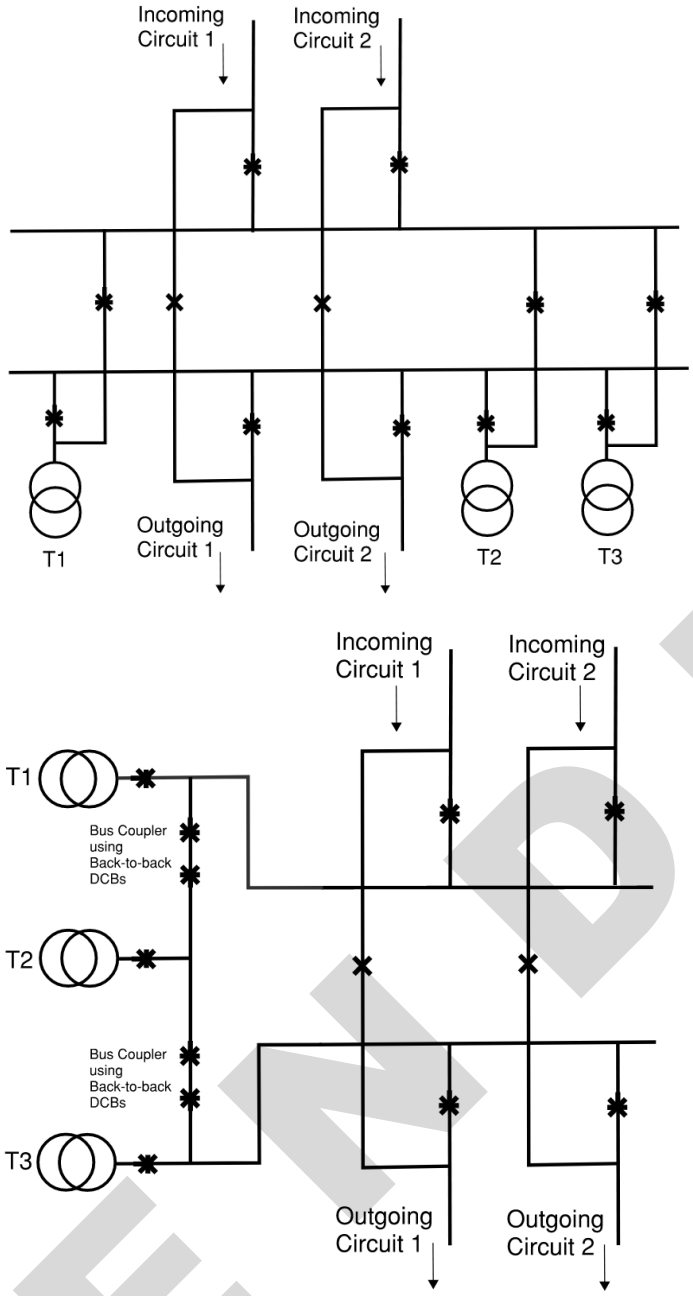
For double circuit, breaker-and-a-half configurations, variations to the standard arrangements may be developed where higher capacity or supply security is required. These arrangements shall remain consistent with Transpower's standard DSS breaker-and-a-half designs and be subject to the availability of suitable standard DSS protection packages. Any such modified arrangements or configurations shall be agreed and developed in consultation with Transpower on a project-specific basis.

Examples of modified arrangements are shown in the diagrams below. The staging of these arrangements will depend on the required connection capacity and supply security.

Examples 1&2: 3 transformer GXP configurations to achieve 240 MVA N-1 using standard 120 MVA supply transformers

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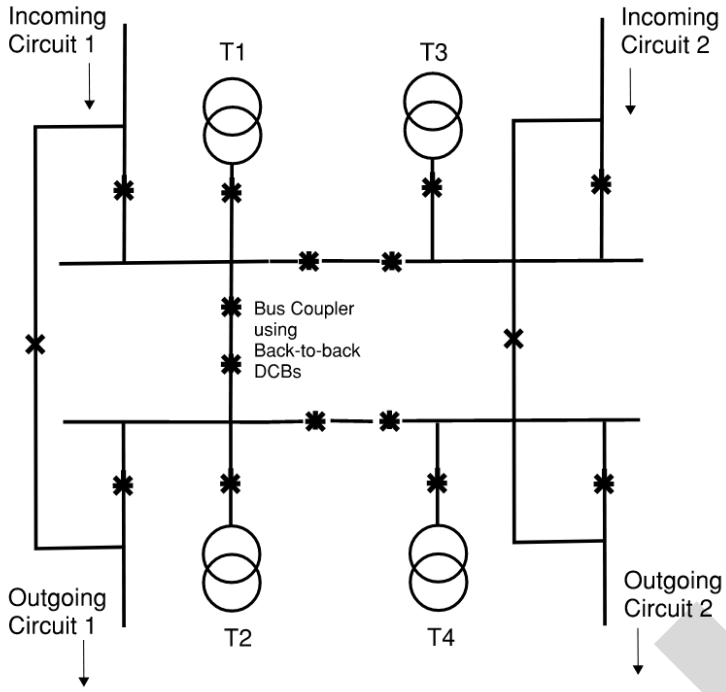
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Example 3: 200 MW initial / 300 MW ultimate N-1 demand supply arrangement using standard 120 MVA supply transformers

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7.1.3 Hard Tee

Hard Tee connections are by exception if and only if the requirements in Section 6.11 are met.

The following diagrams illustrate how Hard Tee connections may be implemented and staged over time to lead to the ultimate configuration of either a double Hard Tee or a loop-in-loop-out arrangement. The examples assume that two circuits ultimately available to support future development options.

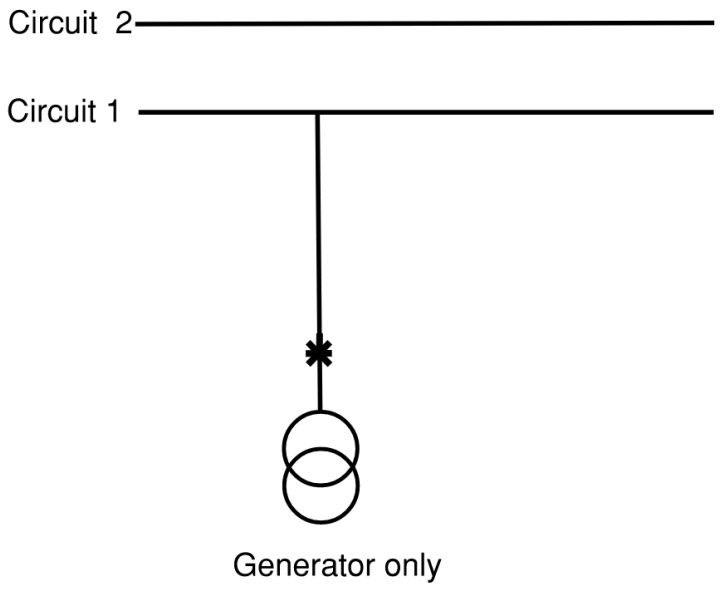
For 220 kV connections, and with potential future conversion to loop-in-loop-out arrangement in mind, the ultimate site layout should be consistent with the standard loop-in-loop-out concept design package 1 (TP. DG 25.05).

For 110 kV connections, and with potential future conversion to loop-in-loop-out arrangement in mind, the ultimate site layout should be consistent with the standard loop-in-loop-out concept design package 2 (TP. DG 25.06).

Stage 1: Hard Tee connection to a single line (generator only)

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In this stage a single Hard Tee connection is shown for a generator connection with N security.

A single N security connection for demand is not preferred because it can be difficult to schedule outages, particularly if there is no means of back up. It may be acceptable if the customer has back up to supply the load during outages or faulted conditions.

If further expansion is likely, the initial Hard Tee connection can be designed with future expansion in mind to facilitate progression to a Double Hard Tee or Loop-In-Loop-Out arrangement. This may include relatively low cost provisions for a future second circuit (e.g. the Tee line can be built with double circuit towers and bonded circuits) resulting in a relatively modest incremental cost (estimated 10-15 per cent).

Stage 2: Double Hard Tee connection

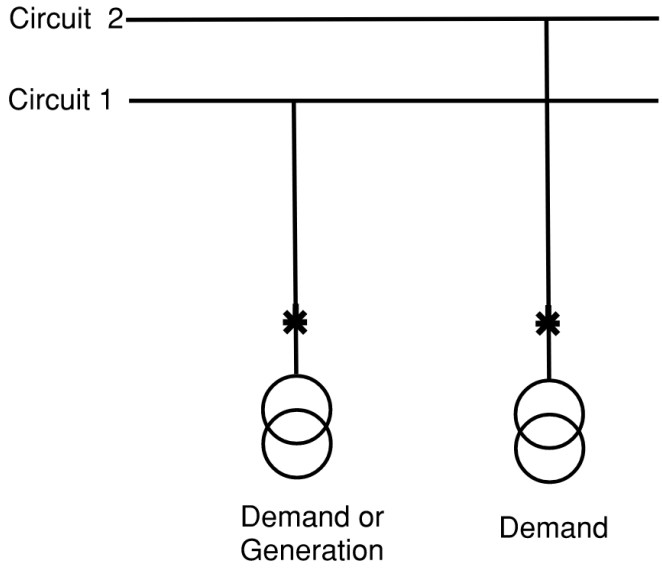
Stage 2 is suitable for a generation connection if:

- there are similar conditions to Stage 1,
- the next connection is for generation only, of a similar rating/type to the existing generation, i.e. coherent,
- the additional generation improves circuit loading balance, and
- there is not enough capacity on the first circuit connection.

In this situation the generating plants connected on each Hard Tee are isolated from each other as a natural run back scheme to prevent overloading during a line outage.

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Starting with Stage 2, without first doing Stage 1, is suitable for a demand connection if:

- there are similar conditions to Stage 1,
- connection is for demand with N-1 security, i.e. coupled on the low voltage bus,
- additional load (or generation) connections are likely in the future, i.e. requiring a 220 (or 110) kV bus to be installed,
- total demand is less than 50 MW, and
- a loop-in-loop-out arrangement, e.g. Stage 3 and beyond, would immediately lead to disproportionate system upgrade costs.

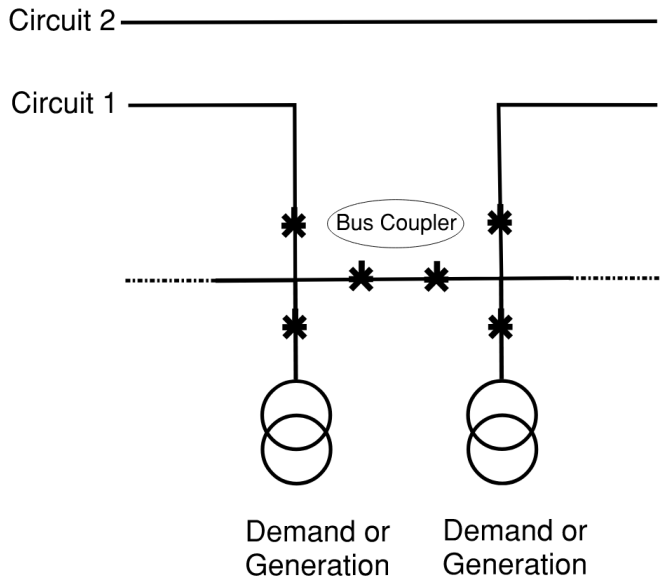
Stage 3: Loop-In-loop-out arrangement with generation + demand, or demand only

Stage 3 is suitable if:

- there are similar conditions to Stage 1,
- connection is for demand with N-1 security, i.e. coupled on the low voltage bus,
- there is a high likelihood that the bus will need to be extended in the future, e.g. connecting in a second line, or additional generation/demand, or reactive support connections, and
- total demand is greater than 50 MW.

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7.1.4 Loop-in-loop-out connections at 110 kV

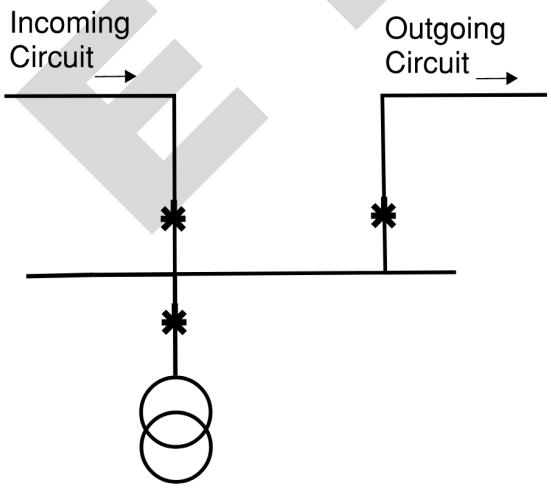
This standard design arrangement is suitable in situations where:

- there are up to two circuits available to connect
- through transmission is not critical
- bussing of multiple circuits at this location may be required for system configuration reasons.

The following diagrams illustrate how the LILO + bus coupler at 110 kV (an ultimate configuration) can be staged over time according to the need.

Standard conceptual designs suitable for consenting purposes are available for this 110 kV arrangement (refer to standard design package 2 (TP.DG 25.06)).

Stage 1: Single transformer initially (solid bus)

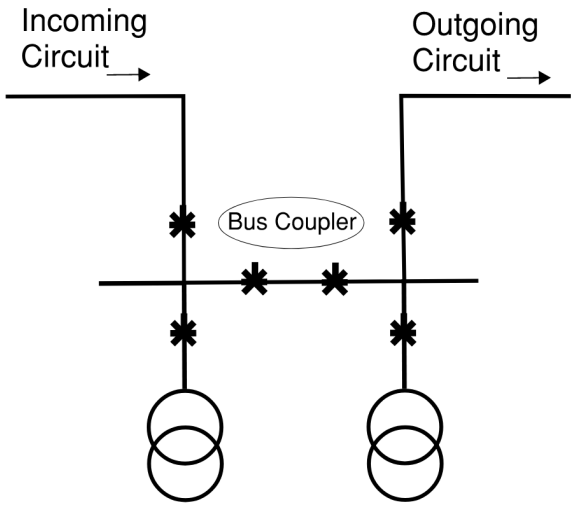


Stage 1 would be built for economic reasons if, for example, the need for a bus coupler was more than five years away.

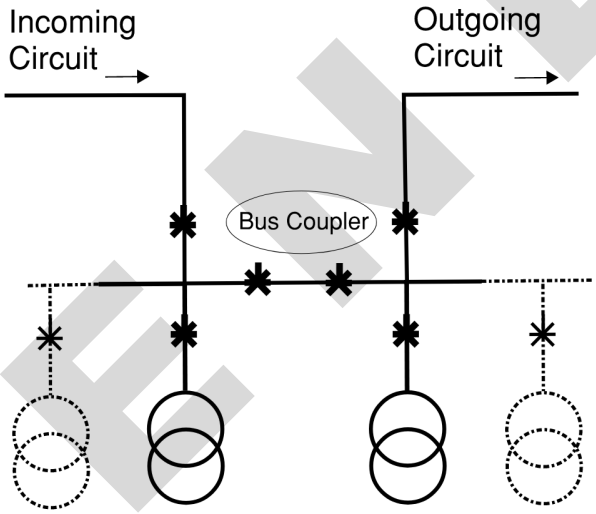
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If an expansion to Stage 2 is expected within less than five years, then Transpower requires the installation of the full bus coupler, i.e. back-to-back disconnecting circuit breakers, immediately.

Stage 2: Standard loop-in-loop-out with full bus coupler



Stage 3: Expansion (dashed lines) by extending the bus at either end with additional transformers (or lines).



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7.2 Configuration Selection Matrix

The following table sets out Transpower's preferences, against key criteria, for the ultimate configuration for greenfield sites. Less developed configurations may be acceptable as intermediate stages where they retain a clear and practical pathway to the preferred and ultimate configuration.

Substation bus ultimate configuration	Core grid circuits	Through transmission is critical	Availability required during maintenance	Future expansion likely to 2 or more 220 kV circuits	Outage availability important	Generation or demand connections > 250 MW
Hard Tee	Not offered	Not offered	By exception[8]	By exception	By exception	Not offered
Single circuit LILO	Not offered	Not offered	By exception	Not offered	By exception	By exception
LILO + bus coupler	Preferred	Not offered	Preferred	By exception	Preferred	By exception
LILO + bus coupler + bypass	Preferred	Preferred	Preferred	Preferred	Preferred	By exception
Breaker and a half	Preferred	Preferred	Preferred	Preferred	Preferred	Preferred

[8] By exception: means this configuration is generally discouraged and should only be considered where alternative configurations are not reasonably practicable, subject to Transpower's agreement.

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7.3 Standard Designs for Connecting into Transmission Lines

In general:

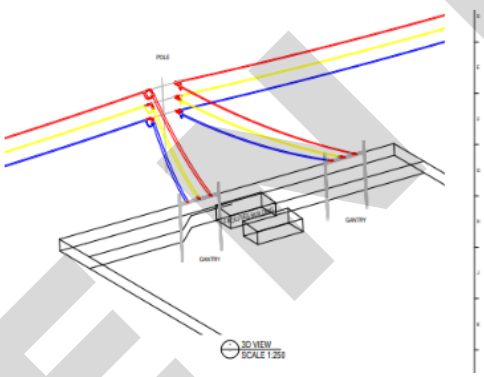
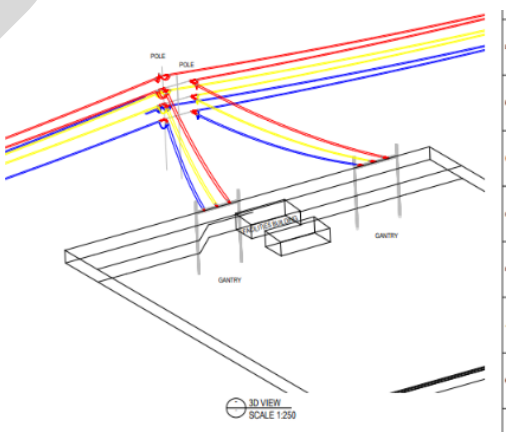
- The selected connection arrangement will provide for safe construction, inspection, operation, and maintenance of both the transmission line and substation assets, including adequate climbing access, working clearances, and access corridors for future maintenance and asset replacement activities.
- Transpower's preference is to avoid under crossings wherever possible.

7.3.1 Designs for connecting substations that are in line with the circuit

Line design guidance corresponding to substations in line with the circuit, i.e. for standard design packages 4 (TP. DG 25.09) and 5 (TP. DG 25.10), is presently being developed.

7.3.2 Designs for connecting substations that are perpendicular with the circuit

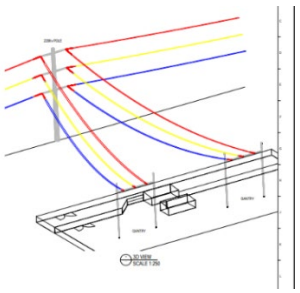
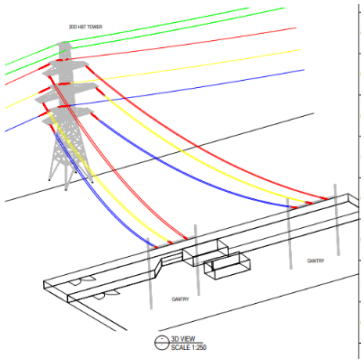
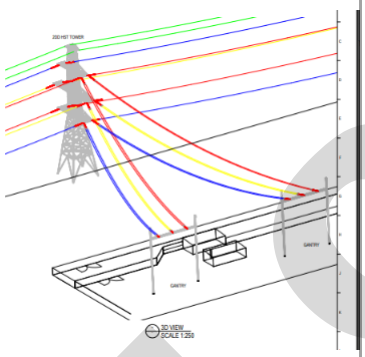
Refer to the companion guide, , which applies only to the Transpower standard 110 kV single circuit substation design package (with two line options as set out below) to be used for customer and Transpower projects for connection consenting and conceptual design purposes.

	Single Circuit	Double Circuit
110 kV Pole design		
	Transpower Redeye - App-C2-GIP_110kV_GIP-SC_REV1.pdf - Working Documents	Transpower Redeye - App-C1-GIP_110kV_GIP DC_REV1.pdf

Refer to the companion guide, Standard 220 kV Substation Design for Customer Connection Consenting and Conceptual Design Purposes (TP.DG 25.05), which applies only to the Transpower standard 220 kV single circuit substation design package (with three line options as set out below) to be used for customer and Transpower projects for connection consenting and conceptual design purposes.

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	Single Circuit - Pole	Single Circuit - Tower	Double Circuit - Tower
220 kV Pole and tower designs			
	Technical Standards and Specifications - App-C-2-GIP_220kV_GIP-SC-POLE_REV4.pdf - Working Documents	Technical Standards and Specifications - App-C-3-GIP_220kV_GIP-SC-2DDHST_REV4.pdf - Working Documents	Technical Standards and Specifications - App-C-1-GIP_220kV_GIP-DC-2DDHST_REV4.pdf - Working Documents

7.4 Case Studies

Refer to Appendix D for case studies associated with new GIPs or GXPs.

8 Connecting to Existing Substations

8.1 Transpower Owned Legacy Substations

This section is applicable to generation connections. For reference, a catalogue of existing substation types is provided in Appendix B.

The customer can be connected at a spare bay or a new bay with an overhead line, underground cable, or transformer. The overhead line or underground cable connection is shown in the figure below. 'X' is used to denote a conventional circuit breaker in the figure. The colour coding (indicative ownership that may be refined in detailed design stages) is:

Blue – Transpower assets

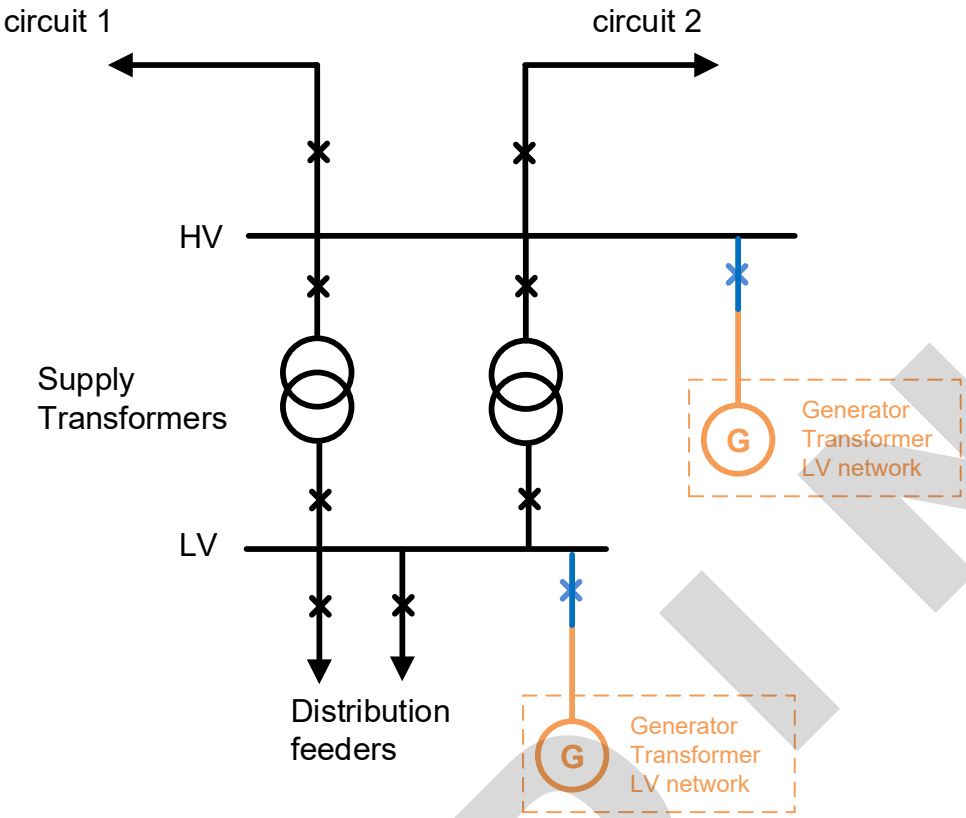
Orange – customer assets.

For some connections the customer will request more than one substation bay. For simplicity, the Single Line Diagrams shown in this section illustrate the generator connection with one substation bay being utilised.

Since the overhead line, underground cable, and transformer are dedicated connection assets they are usually owned by the customer, however in some instances they could be owned by Transpower.

Generators can connect at HV (and MV) or LV busses

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Considerations for this connection type include:

- a spare bay is needed in the Transpower substation. If a spare bay is not present the substation may need to be expanded
- the ownership boundary could be on the customer's site or in the Transpower substation, depending on which party owns the connection assets
- an assessment of transformer export capacity should be completed if the proposed connection is downstream of existing supply transformers because thermal constraints may arise when generation is high
- some 33 kV and 11 kV busbars are owned by the EDB. In that situation it is expected the customer will organise the connection with the EDB and Transpower will provide oversight where necessary.

8.2 Deeply Embedded Connections

Deeply embedded connections are usually connected at lower voltages, e.g. 33 kV or 11 kV, and are electrically further from the Transpower ownership boundary.

Due to the capacity and location of these connections they often have less impact on the grid.

If the new connection will significantly impact the power flow or fault level on the distribution network feeders (which connect to the grid) then Transpower must:

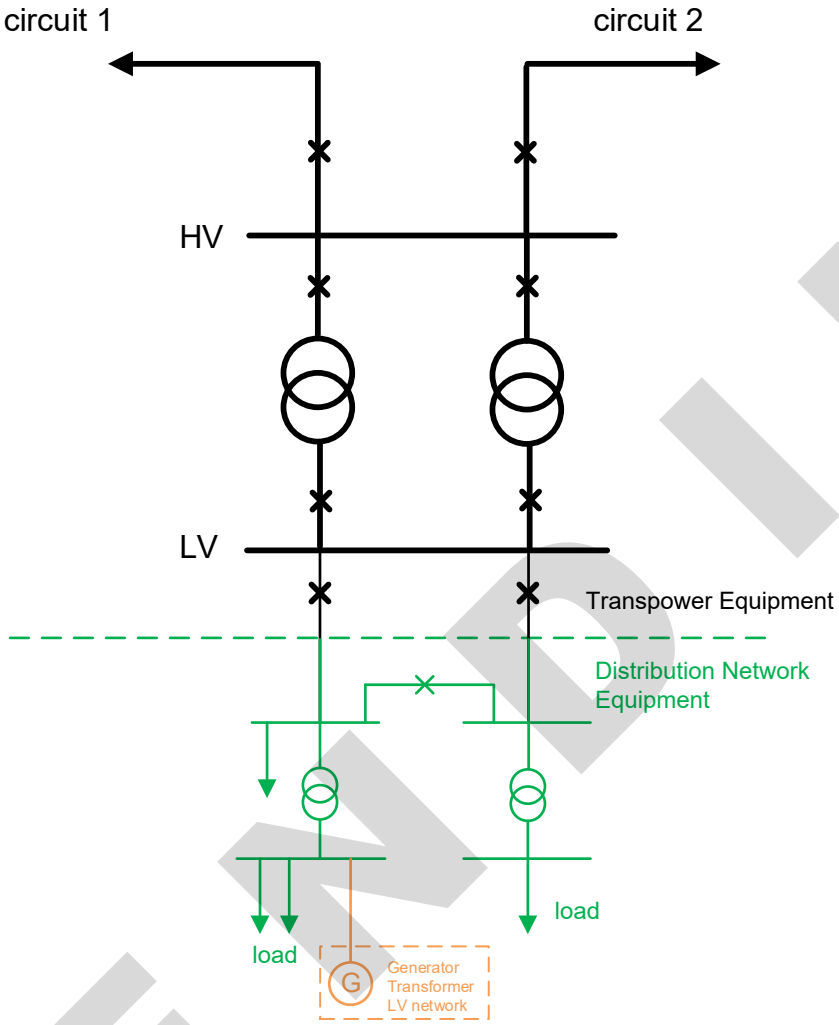
- ensure protection systems are co-ordinated between all asset owners and Transpower
- ensure that the EDB complies with all requirements in their transmission agreement.

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The figure below illustrates a deeply embedded generation connection (typically via either an overhead line or an underground cable).

Illustration of deeply embedded generation connection



9 Appendices

9.1 Appendix A – Definitions

Any terms listed in the table below are used in this document and are what Transpower generally mean when using those terms.

Term	Definition
Concept Assessment (CA)	A CA is the second step in Transpower's connection process. It normally involves a desktop study to explore the feasibility of the connection project, identify benefits, disbenefits, and risks for the options considered, and where possible, provide indicative cost and duration ranges.

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Term	Definition
BESS	Battery Energy Storage System.
Solution Proposal	A solution proposal is the fourth step in Transpower's connection process. It is a joint discussion with the customer to confirm project requirements, timeframes, risks and assumptions before starting an investigation or any preliminary design activities.
Connection assets	Connection assets refer to assets specifically designed to connect a customer (or multiple customers) to the electricity grid. These assets can include lines, transformers, cables, circuit breakers etc. Connection assets can be owned by Transpower or the connecting customer.[9]
Connection Code	The connection code sets out the technical requirements and standards for Transpower and for designated transmission customers to connect to the grid. The connection code is prepared by Transpower and approved by the Electricity Authority.
core grid	The core grid consists of assets outlined in Schedule 12.3 of the EIPC.
developer	A developer of a generation, battery, or demand project.
Digital Substation	A Digital Substation takes the various elements required of a traditional substation and interconnects these using optical fibre, instead of using hundreds of individual copper cables. 'Digital Substation' refers to the technology that supports distributed substation protection and automation, based on the international standard IEC 61850. This standard outlines the "vendor-agnostic engineering" required to configure Intelligent Electronic Devices for electrical substation automation systems and the communications between them. Digital Substations encompass both primary and secondary equipment.
Earth Potential Rise	The potential (difference) between the local earth and the earth at a remote point due to the flow of electric current from line to earthing system to earth.
EDB	Electricity distribution business.
EIPC	Electricity Industry Participation Code 2010. The code is made and administered by the Electricity Authority. It is a set of rules that governs nearly every part of New Zealand's electricity industry.
Good electricity industry practice (GEIP)	With respect to transmission, GEIP means the exercise of that degree of skill, diligence, prudence, foresight and economic management, as determined by reference to good international practice, which would reasonably be expected from a skilled and experienced asset owner

[9] The term 'connection assets' in this document is not used as meaning the same as the term 'connection assets' as defined in the EIPC.

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Term	Definition
	engaged in the management of a transmission network under conditions comparable to those applicable to the grid consistent with applicable law, safety, and environmental protection
Grid	The grid means the system of transmission lines, substations, and other works, including the HVDC link, used to connect grid injection points and grid exit points to convey electricity throughout the North Island and the South Island of New Zealand.
Grid exit point (GXP)	A point of connection to the grid where electricity may flow out of the grid.
Grid injection point (GIP)	A point of connection to the grid where the net flow of power is onto the grid.
Grid Reliability Standards	Standards for reliability of the grid, as set out in part 12 of the EIPC.
Hard Tee (connection)	A connection arrangement where a generator or load is directly connected to an existing transmission line at an intermediate tee point, creating a three-terminal line configuration without routing the transmission line through a dedicated switching station or substation.
Interconnection assets	Interconnection generally refers to the main grid network, except those parts of the grid specifically required for the connection of a transmission customer (or customers). The interconnected grid is comprised of interconnection assets.
IBRs	Inverter based resources, such as battery, wind or solar, that are interfaced (in part or fully) with the grid via power electronic inverters.
N security	A connection point that does not have redundancy in the event of a primary equipment, e.g. line or transformer, outage. Typically, these are smaller rural points of service or small generators.
N-1	A defined grid reliability standard whereby the failure of a major transmission component, e.g. circuit or transformer, does not interrupt supply to consumers. Transpower's core grid is required to be operated to N-1.
Single Line Diagram	A drawing that shows a simplified layout of a three-phase electrical system by using single lines and symbols.
SPS Concept Statement	A high-level agreement between System Planning and the System Operator on the functionality required from a SPS to ensure the scheme can be integrated into the System Operator's tools and procedures.

9.2 Appendix B – Existing Substation Bus Configuration Catalogue

For reference, the following table catalogues the 14 types (and respective numbers) of busses Transpower currently has (as of June 2025) across all locations.

New connections at legacy brownfield sites will, to a large extent, have to work within existing constraints of the site and in that sense will be non-standard.

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For new greenfield connections, Transpower intends to standardise on a smaller subset which include the connection types indicated with an *.

Bus configuration	Numbers
Double selectable	23
Double T-connected	18
Double transformer feeder	13
H bus with bus coupler*	44
H bus with line bypass breakers*	1
H3 configuration	3
One and a half circuit breaker*	11
Ring bus	2
Sectionalisable single bus	40
Single bus	17
Single T-connected	7
Single transformer feeder	4
Split bus	3
Triple selectable	2
TOTAL	**186**

9.3 Appendix C – Outage Impact Rating Classification

New connections should not materially increase the impact of outages on existing grid assets or create additional dependencies that reduce system security during planned or unplanned outages. This applies to both greenfield and brownfield sites.

The outage impact rating (OIR) is classified on a scale of 1 to 5 for existing asset outage blocks, see the table below, to determine when Transpower's (Operations team) feedback should be sought on a new connection.

The ratings are used to gauge when Transpower should be consulted on a particular connection option as part of developing Concept Assessments or Solution Proposals. The ratings are not intended as a pass or fail criteria for assessing options.

Impact Rating	Definition	Typical Characteristics / Indicators
1. Routine (no issues)	An outage that can be readily obtained with no material system security, customer, or operational impact.	• Can be scheduled anytime • No seasonal or load constraints • No concurrency restrictions • No system reconfiguration required.
2. Minor constraints	An outage that is generally available but subject to	• Preferred or avoided seasons, e.g. avoid winter/dairy season • Minor coordination requirements

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Impact Rating	Definition	Typical Characteristics / Indicators
	minor operational, seasonal, or local constraints.	• Localised constraints, e.g. no work in yard.
3. Significant (moderate/co-ordinated)	An outage that has material operational implications and requires active coordination to manage system security or customer impacts.	• Concurrency restrictions (beyond N-1) with parallel circuits • Seasonal or load-sensitive windows • Some reduction in security, e.g. conditional N-1 • Coordination with generators, customers required.
4. Difficult (high impact)	An outage that is difficult to obtain and materially constrains system operation, security, or customer supply.	• System splits or major reconfiguration required • Bus outages or loss of redundancy • Temporary outage blocks, (e.g. commissioning • Strong concurrency prohibitions (beyond N-1) • Warnings requiring increased planning rigor.
5. Very Difficult (critical)	An outage that presents extreme operational difficulty and is only achievable under exceptional circumstances due to high system or customer risk.	• Severe system security risk • Significant or widespread customer impact • Extensive generation/load agreements required • Very limited or rare timing windows • Potential national or market implications.

9.4 Appendix D – Case Studies

Example of where it may be acceptable to not connect into an existing site that is less than 10 km away

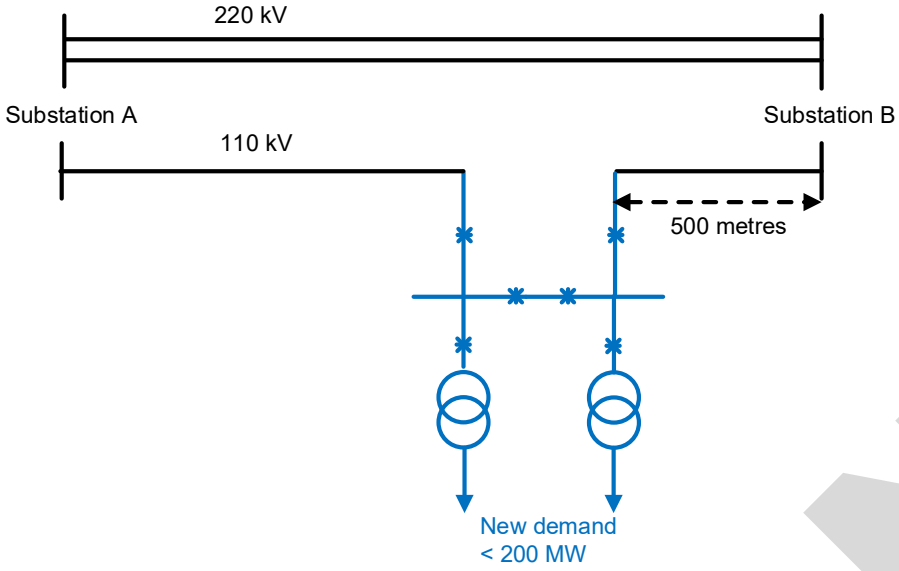
A large industrial centre was planned in a location within 1 km of a major substation, and in close proximity to 220 and 110 kV circuits.

Because of the close proximity, options were explored to supply the load directly from the major substation. However, due to the congested nature of that substation site this was not practical. In addition, given the concentration of load already there, diversifying away from that substation was viewed as a positive from a risk/resilience perspective.

Connections into the 220 and 110 kV lines were explored. For a power level less than 200 MW, an effective option was a standard loop-in-loop-out connection on the 110 kV circuits between the major substation and a smaller substation to provide N-1 capacity (limited by the capacity of the circuit which was cabled into one of the substations); refer to the figure below.

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For higher off take levels, i.e. > 200 MW, a more costly 'breaker and a half' 220 kV connection would be required to provide secure N-1 capacity, and adequate reliability for through transmission on a core grid circuit.

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Example of a situation where Transpower would allow a Hard Tee connection and where provision for future load connection in a generator station would be useful.

A customer wanted to connect a 25 MW industrial load near an existing generator that was already Hard Tee connected on a regional 110 kV spur line.

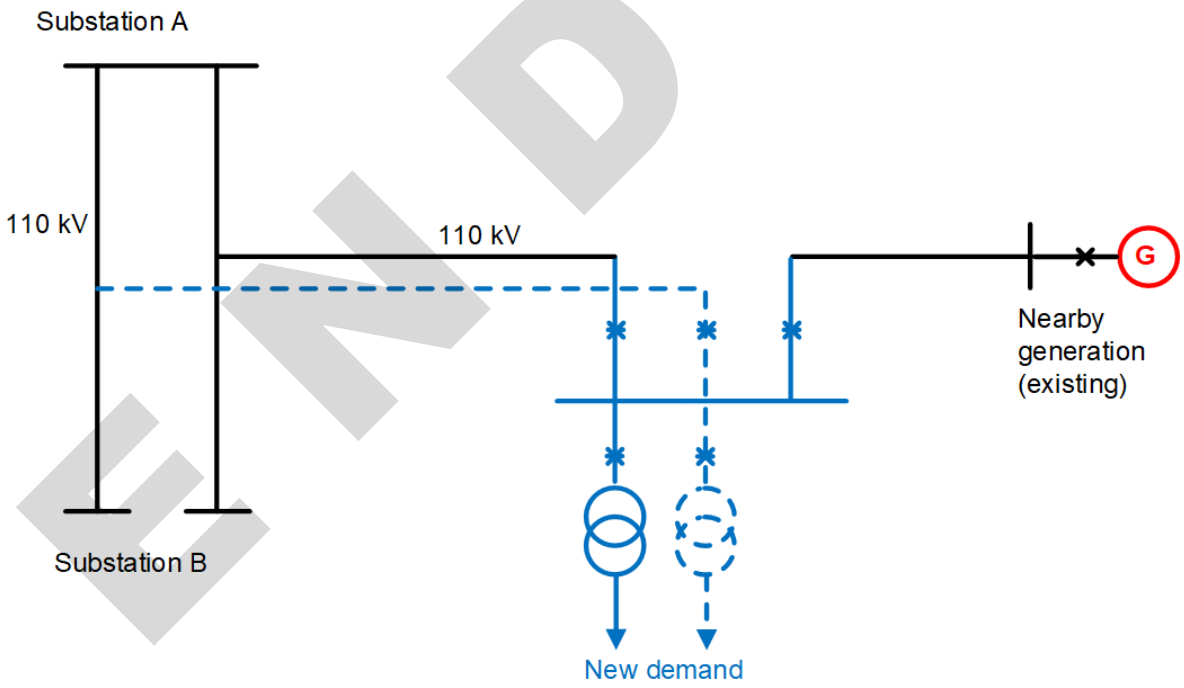
A loop-in-loop-out connection into the existing Hard Tee'd circuit (refer to the solid blue lines in the figure below) was offered to the new customer.

The generator owned the existing Hard Tee connection, so any new connection would require agreement with the existing generator.

In addition, the new load was situated near the generation so the new customer would be incentivised to discuss leveraging off the existing generator's connection assets to reduce the connection costs (if that were practical).

An additional separate Hard Tee connection on the other 110 kV circuit (refer to the dashed blue lines in the figure below) was also offered as an option to provide higher levels of reliability and better load sharing. However, this would likely have higher costs because of the need for a new and relatively long (~7 km) 110 kV circuit.

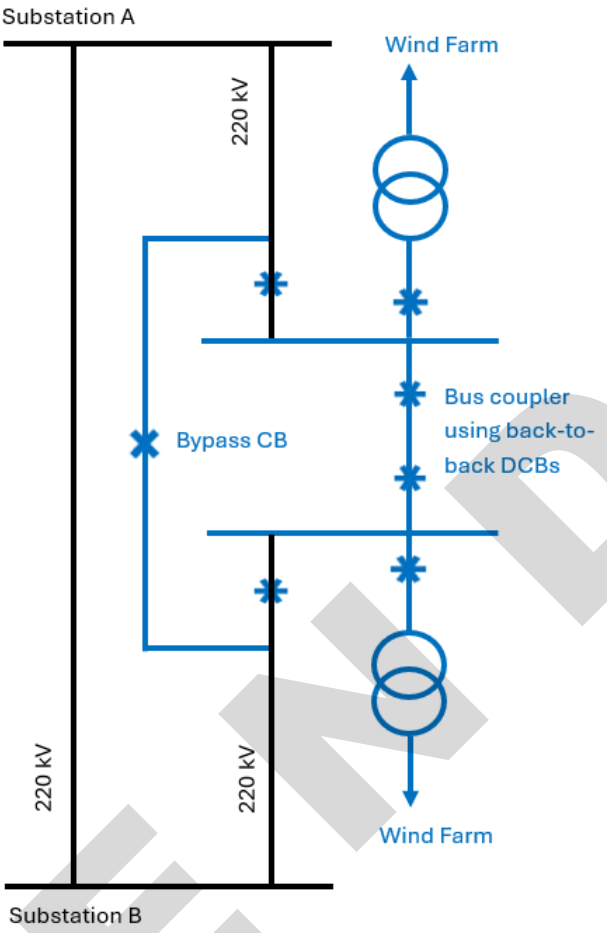
A Hard Tee solution in this situation would have been acceptable because of the lack of criticality of the existing 110 kV spur line.



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Example of how through transmission reliability requirements influence the connection type

A new 250 MW wind farm was proposed for connection to a key 220 kV transmission circuit supplying a major load centre. Due to the criticality of the circuit, the connection design needed to minimise any impact on the reliability and availability of through transmission. The connection arrangement shown below was identified as a viable option, as it enables maintenance of the 220 kV busbar without requiring outages of the through transmission circuit.



Example of how the need for high reliability through transmission influences connection type and how taking a holistic approach leads to better overall outcomes.

A developer proposed a 250 MW wind farm connected about 5 km away from an existing 220 kV double circuit which was important for inter-regional transmission flows.

Deviating the line by 5 km, i.e. loop-in-loop-out, would have increased the length of the transmission line. However, this was not considered significant being a relatively small percentage of the overall line length and not having a material impact on system performance.

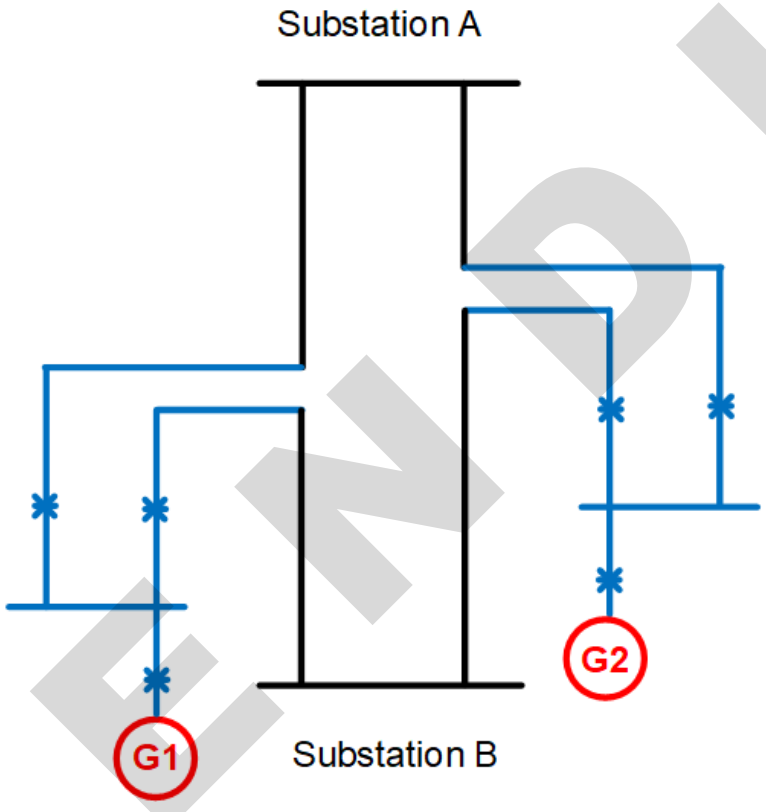
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However, a single loop-in-loop-out connection on a single circuit would unbalance the flows on the transmission corridor, reducing the overall transfer limit, which would likely have meant curtailment (energy spill) under some conditions for the wind farm. A connection to both circuits, allowing the flow to be balanced, was possible although a more expensive solution.

At the same time, a solar and BESS developer was looking to reuse an existing loop-in-loop-out connection on a different 220 kV circuit that crossed the double circuit. Planning analysis showed that it was beneficial for the connection to be transferred across to one circuit on the double circuit line. The reconfiguration was beneficial for both connecting parties because it would reduce the likelihood of curtailment under high power transfer conditions.

While the 220 kV lines were important for through transmission power flows, reliability analysis showed that loop-in-loop-out connections were acceptable and that a bypass breaker design was not required for either installation. Hard Tee connections were not considered because the connections were to the 220 kV grid backbone with significant through transmission and inter-regional power flow.



10 Document Information

10.1 Summary of Changes

Document History			
Issue No.	**Affected Section**	**Change**	**Date**

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Document History			
1	Whole document	New document	Nov 2026

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