Transmission 2040
(Grid Development Strategy)

Work Package 2 – Grid Planning Guidelines

Consultation Material

November 2008

Executive Summary

This document describes the planning criteria to be used for developing the long-range grid development plans, under the Transmission 2040 project.

The criteria are derived from the existing Transpower Grid Planning Criteria and Grid Reliability Standards specified under the Electricity Governance Rules, with attention focused on long-term strategic development of the transmission system.

The proposed planning criteria provides context for analysing power system development options:

- in relation to power system quality, stability and dynamic performance to be expected from the power system; and
- for assessing the reliability of power system during high impact low probability events and during maintenance outages.

The document consists of two main sections:

1. criteria for power system security, reliability and supply quality to be used with Transmission 2040 project
2. asset capacity and capability criteria to be used for Transmission 2040 project.

Transpower welcomes feedback on the proposed criteria, especially in relation to the questions raised under different sections in the document.

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1 Document Overview

What is the purpose of this document?	This document sets out the technical criteria to be used by Transpower in carrying out the power system analysis for the Transmission 2040 project in relation to: • power system security, reliability, and supply quality; and • asset capacity and capability
Context	Transpower is the owner and operator of the National Grid in New Zealand. It is in the process of developing a long-term strategy for the development of the transmission system in consultation with the stakeholders. This set of guidelines was adopted from the existing Transpower Grid Planning Criteria and Grid Reliability Standards as outlined in the Electricity Governance Rules, with attention focused on long-term strategic development of the transmission system. Long term grid planning studies will mostly concentrate on the power transfer capability of the transmission system. This document also includes criteria for assessing the power system stability and power quality as the planning process will address these issues, at least in high level, where appropriate. These guidelines do not relate to Transpower's role as the System Operator.
Structure	This document consists of the following sections: Section 1: Provides an overview to the purpose and structure of this document Section 2: Provides the context of this document in relation to the existing New Zealand regulatory and approval framework Section 3: Defines some of the key terms used in transmission planning Section 4: Discusses and sets out power system security, reliability and supply quality criteria to be used for the Transmission 2040 project Section 5: Discusses and sets out asset capacity and capability criteria to be used for the Transmission 2040 project

2 Industry and Regulatory Context

Electricity Industry	New Zealand National Grid plays a major and very critical role by reliably transferring power generated at generating stations to consumers. Generation is mostly located away from major load centres in the central parts of the North and South Islands. Power transferred through the transmission system to the end consumers who are either directly connected to the transmission system or are connected via the distribution grids owned and operated by the regional distribution lines companies. In determining the future development of the national grid, in the context of long term investments, the following functions of the transmission system are considered: • providing a reliable electricity supply to the consumers • enabling an efficient energy market, which will result in energy delivered to the consumers at least cost. • supporting the economic growth of the country as a whole by providing a resilient power transmission grid comparable to that can be found in other developed countries. Transpower also considers the need to provide a transmission system that balances the cost of investment against the benefits gained from those investments.
Electricity Governance Regulations and Rules (EGR's)	The industry is governed by the Electricity Governance Rules (EGRs) which came in to effect from 1 March 2004. The Electricity Commission is tasked with the development and enforcement of the governance rules. The Commission regulates the operation of the electricity industry and markets, to ensure electricity is produced and delivered to all consumers in an efficient, fair, reliable and environmentally sustainable manner. The Electricity Governance Rules and Regulations describe how Transpower may recover the costs of investments in the transmission system. The Rules include a standard for maintaining the supply reliability to the consumers (Grid Reliability Standard - GRS) and criteria for investing in the grid where for maintaining or improving the reliability (Grid Investment Test - GIT). The Grid Investment Test also provides criteria for assessing investments which will improve the economic benefits to the market participants. The GRS and GIT allow consideration of the reliability of the power supply and future grid investments taking a two-limb approach: • assessment of grid reliability under a deterministic (N-1) criteria, when the grid reliability affects a significantly large quantity of connected consumers (currently set at 150 MW) • assessment of grid reliability and grid investment based on the cost-benefit economic framework, when the reliability impacts on a smaller quantity of connected consumers (currently set below 150 MW) Key elements of the GRS as they apply to the Transmission 2040 project are the economic test and the deterministic 'safety net' (N-1).

Application of the EGRS for Transmission 2040	Power system planning analysis for the Transmission 2040 project will follow an approach similar to that outlined in the EGRs in determining the reliability of the supply to the connected loads in the future and in analysing the potential investment options. Transpower will apply the N-1 deterministic criteria in accordance with the existing EGR's when the grid reliability impacts on a large quantity of consumers (e.g. more that 150 MW). When the reliability of the transmission system impacts a smaller quantity of consumers (i.e. less than 150 MW), then Transpower will use a cost-benefit based economic criteria for determining the most efficient investment and the investment "need date". A deterministic (N-1) criteria will be considered as a signal on the 'first cut' basis to indicate the need for assessment of grid investments, for non-core grid investments (presently defined as less than 150 MW). For the Transmission 2040 project, Transpower will assess and propose investments for improving the resilience of the transmission system. This will include: • Allowances for equipment being out of service for maintenance; and • Allowances for high impact low probability events. The Transmission 2040 analysis will highlight any investments that are made on the basis of these extended criteria.

Q.1 Do you agree with the approach proposed for application of Grid Planning Criteria (including GRS and GIT) for the Transmission 2040 studies?

3 Definition of Terms

Transmission System	The *transmission system* is defined as that part of the power system primarily intended for the conveyance of bulk electricity.
Reliability	The ability of the electric system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages.
Security	The ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.
Quality	The ability of the power system to deliver power to loads within defined limits for : • steady state voltage and frequency • voltage variations • frequency variations • harmonic voltage content (and often harmonic current content)
Secure State[1]	The *transmission system* is in a *secure state* if: • transmission equipment is operating within normal ratings when all equipment is in service; • transmission equipment is operating within short term ratings during contingencies; • voltage quality is maintained as set out in Table 1; • load curtailment is not required to maintain N-1 security level for any operating condition; and • cascading (uncontrolled) outages will not occur.
Satisfactory State[1]	The *transmission system* is considered to be in a *satisfactory state* if: • transmission equipment is operating within normal ratings when all equipment is in service; • transmission equipment is operating within short term ratings during contingencies; and • voltage quality is maintained as set out in Table 1.
Network Element	Any of the following: • Overhead Line; • Cable; • Transformer; • Generator; • Circuit Breaker; or • Bus Section.

[1] The transmission system is normally in the secure state. When a fault occurs, it changes into the satisfactory state. When in the satisfactory state, another fault may cause equipment overloading or cascade outages. From the satisfactory state the System Operator will endeavour to return the power system to a secure state as quickly as possible and preferably within about 30 minutes. Returning the system to a secure state may require rearranging generation, rearranging the grid orReduction of load.

4 Security and Reliability

This section sets out power system security, reliability and supply quality criteria of power system analysis for the Transmission 2040 project.

4.1 Security Criteria

Security criteria	Transpower will carry out the initial power system analysis for the entire transmission system using the deterministic N-1 security criteria. Transpower may then refine the investment options using economic analysis of costs and benefits for assets similar to those presently defined as non-core grid.
Credible contingencies	The EGR's[2] provide the following list of events to be considered as single credible contingencies under an N-1 analysis: • a single transmission circuit interruption; • the failure or removal from operational service of a single generating unit; • an HVDC link single pole interruption; • the failure or removal from service of a single bus section; • a single interconnecting transformer interruption; and • the failure or removal from service of a single shunt connected reactive component.
Pre-event Conditions	Transpower will carry out the power system analysis on the basis that, with all assets that are reasonably expected to be in service, the transmission system is in a satisfactory state following an N-1 event. Transpower will also study the impact of some critical transmission and generation assets not being in service, on case by case basis, and may revise the investment proposals to mitigate these impacts if it is economical. The impact may be assessed assuming the following pre-event conditions may exist: • a long term outage of a single shaft generating unit; • a long term outage of a single item of dynamic reactive plant; • a long term outage of a single three phase interconnecting transformer; • a long term outage of an entire generating station where there is only one transformer connecting it to the *transmission system*; or • the unavailability of a reasonable amount of installed generation capacity within a region.

[2] From Part A "Interpretation" of EGR's – 1 May 2008

	These pre-conditions may occur due to plant being maintained as a result of a major failure (e.g. for single shaft generating units), plant being out of service due to the long lead times involved in obtaining a replacement item following a fault (e.g. interconnecting transformers) or for dry year conditions when some hydro generation may not be available.
High Impact Low Probability events (HILP)	Transpower may consider less frequent but more extreme contingencies or overlapping multiple contingencies, also known as High Impact Low Probability (HILP) events, on a case by case basis. Examples of HILP events that may be considered are: • the failure of a bus coupler; • the loss of both transmission circuits of a double circuit line; and • the loss of a diameter in a breaker and a half bus. Transpower may develop or revise the investment proposals to mitigate these impacts if it is economical.
System security during planned outages	Transpower will consider the impact of maintenance outages in the power system analysis for the Transmission 2040 project. Having taken into account other options available to Transpower for obtaining outages for maintenance, it may develop or revise the investment proposals to facilitate maintenance of assets if it is economic compared to other non-transmission alternatives.

Q.2 Do you consider the list of credible contingencies outlined above are appropriate for assessing the security provided by the grid in the long term?

Q.3 Are the pre-event conditions described above acceptable for high level assessment of the reliability expected from the grid in the long term?

4.2 Steady State Analysis

What is Steady State Performance?	The transmission system is considered to be in a 'steady state' when it has reached a point of stable operating equilibrium. The transmission system is usually in a steady state under normal operating conditions (all or most of the equipment in service). It will also settle to a steady state following a disturbance (e.g. an outage) if the post disturbance system is stable.
What steady state performance criteria does Transpower use?	For the Transmission 2040, Transpower will consider the transmission system to be in a **secure state** in the normal operating condition or in a **satisfactory state** once the system has settled to a new operating condition following a disturbance. Transpower will assess the transmission system based on the above criteria after any voluntary load curtailment, such as that afforded by a Grid Support Contract, is taken into account.
Voltage Quality	The criteria for voltage quality in steady state operation is defined by: • Steady state voltage (pre and post contingency); and • Step change in voltage *Pre-contingency and Post-contingency Steady State Voltage* Transpower will design the system to maintain the normal steady state voltage at busbars as specified in Table 1 or as specified in a contractual agreement with its customer.

Nominal Voltage (kV)	Maximum Voltage (kV)	Minimum Voltage (kV)
400	420	380
220	242	198
110	121	99
66	69.3	62.7
50	52.5	47.5

Table 1: Steady state voltage limits

Step Change in Voltage

The voltage step change is the sudden voltage change between the pre-switching voltage and the voltage in the period immediately after transient decay and AVR action of generators but before any manual or slow control action – e.g. manual tap changing, automatic tap changing, manual switching of capacitor banks under normal operating conditions. The allowable step change in voltage depends on the frequency of switching – infrequent or routine.

R **Number of events per hour**	**Vdyn/Vn** **(%)**	
	MV	**HV**
r ≤ 1	4	3
1 < r ≤ 10	3	2.5
10< r ≤ 100	2	1.5
100 < r ≤ 1000	1.25	1

Table 2: Step Change in Voltage for Routine Switching

V_n is the normal system operating voltage at a busbar.

V_{dyn} is the step change in voltage at that the same busbar.

MV refers to 1 kV < V_n ≤ 35 kV

HV refers to 35 kV < V_n ≤ 230 kV

Vdyn/Vn – Maximum voltage change for normal operating conditions

Transpower will design the system to ensure that the step change in voltage at busbars with connected customers, for routine switching of equipment to control voltage (e.g. switching of capacitor banks or circuits), does not exceed the values given in Table 2.The number of events per hour is assessed with all equipment in service and will consider all sources which cause a voltage disturbance (e.g. all capacitor banks in a region, not considering just a single capacitor.) The usual voltage criterion is to limit the voltage step change to 2.5%.

For infrequent switching, including switching with equipment out of service, there are no standards specifying the allowable step change in voltage. Transpower proposes to use a 5% maximum step change in voltage in this instance.

Short Circuit Levels

Transpower will use the maximum short circuit levels for the Transmission 2040 power system analysis as shown in Table 3 below.

There are a limited number of locations, where the maximum fault levels will exceed the planned maximum short circuit levels shown and

Transpower will design the equipment at these locations accordingly.

As the number of circuits, generators and transformers connected to the power system increases to meet the load growth, fault level also increases. The number of locations where it will not be possible to meet the target fault levels of Table 3 is expected to increase in the future.

Nominal Voltage	Maximum short-circuit Power and Current Limits	
kV	MVA	kA
400	22,000	31.5
220	12,000	31.5
110	6,000	31.5
66	1,800	16
50	1,350	16
33	1,400	25
22	950	25
11	475	25

Table 3: Maximum Short circuit levels

Q.4 Do you anticipate a need to operate the grid to a different voltage quality (step change in voltage) in the long term?
Q.5 What kind of fault level management measures are expected to take place in the systems connected to grid (eg within distribution networks)?

4.3 Harmonics

Context in relation to Transmission 2040	The long-range grid planning studies under the Transmission 2040 project will not assess the harmonic levels in the power system. However, it will recognise the need to mitigate the impact of harmonics on power system operation and on connected parties. In this regard, Transmission 2040 will highlight the long-term approach Transpower will be taking in managing impacts of harmonic penetration into the power system. The harmonic related criteria Transpower is currently using for grid planning is given below for the completeness of this document.
Harmonic Criteria	Transpower will use the criteria set out in NZECP 36 (New Zealand Electrical Code of Practice for Harmonic Levels) in analysing the voltage and current harmonics in the transmission system.

4.4 Transient Stability

Context in relation to Transmission 2040	Long range grid planning studies under Transmission 2040 project will not assess the transient stability of the transmission system in detail. The studies will assume that all the connected synchronous machines (now and in the future) will operate stably. However, it will recognise the technologies and approaches that are available presently and in the future for enhancing the transient stability of the transmission system. Transmission 2040 studies will address transient stability of transmission paths at a very high level on a case by case basis, if it is apparent that the capacity of a part of a transmission network will be constrained by the transient stability of the system. The transient stability-related criteria Transpower is currently using for grid planning is given below for information and for completeness of this document.
What is transient stability?	Transient stability refers to all generators remaining in synchronism following a disturbance such as a circuit fault or loss of a generator.
Fault Types	Transpower will design the transmission system to ensure that it remains stable for the following disturbance types: • a sudden disconnection of any plant including a generating unit; • a 3-phase fault on a circuit close to a substation cleared in main protection clearance time by opening the circuit breakers at each end of the circuit to disconnect the circuit; • a single-phase-to earth fault on a circuit cleared by the back-up protection operation of the circuit breakers at each end of the circuit; • a 3-phase fault on a transformer followed by disconnection of the transformer; • a single-phase-to earth fault on any circuit cleared by circuit breaker failure protection of the relevant back-up circuit breakers; • a 3-phase fault on a bus section cleared by the bus zone protection operation of all circuit breakers connected to the faulted bus section; and • a single-phase-to earth fault on a circuit close to a substation cleared in main protection clearance time by opening the circuit breakers at each end of the circuit and reclosing on fault with subsequent reopening of the circuit breakers at each end to disconnect the circuit.[3] Transpower may also examine the following disturbances in order to assess the impact of the events, but they may not necessarily have an influence on investment decisions: • a 3-phase fault on a circuit close to a substation cleared in main protection clearance time by opening the circuit breakers at each end of the circuit and reclosing on fault with subsequent reopening of the circuit breakers at each end to disconnect the circuit ;[3] • a 3-phase fault on any circuit cleared by circuit breaker failure protection of the relevant back-up circuit breakers; and • a 3-phase fault on a circuit cleared by the back-up protection operation of the circuit breakers at each end of the circuit.

[3] The impact due to this disturbance may be reduced by altering the auto-reclose time to a longer delay

Fault Clearing Times	Transpower will use the following fault clearing times in simulation studies for the Transmission 2040 project: • Main protection for 220 kV circuits: 120 milliseconds; • Main protection for 110 kV circuits: 200 milliseconds; • Main protection for 66 kV circuits: 200 milliseconds; • CB failure time: 350 milliseconds (see Note 1) ; and • Auto Reclose time: 1.5 seconds (see Note 2). Notes: 1. Many parts of the 110 kV and 66 kV systems do not have CB Fail protection. The back-up protection time is then the actual remote back-up protection time, plus an engineering margin to allow for changes in protection settings as they are reviewed and reset as a result of system developments and changed circuit loadings. 2. The actual auto reclose time will be used or, if this is not readily available (e.g. new transmission developments), a default time of 1.5 seconds will be used. The auto reclose time will be adjusted so that the auto reclose occurs at the maximum swing angle. 3. The actual fault clearing times are usually shorter than the fault clearing times given above. However, the actual fault clearing times will not normally be used in studies, as the actual times will change (increase or decrease) over time as protection settings are reviewed and reset as a result of system developments and changed circuit loadings.

Q.6 Do you agree with the fault types to be considered in assessing the transient stability of the grid?

4.5 Small-Signal Stability

Context in relation to Transmission 2040	Small signal stability of a transmission system in general is governed by the characteristics of the transmission system as well as the generators and other dynamic devices connected to the power system. Considering the wide range of generation technologies and dynamic devices that may be connected to the transmission system in the long term, it will not be possible to assess the small-signal stability of the power system under the Transmission 2040 planning studies. However, it will recognise the technologies and approaches that are available presently and will be in the future for enhancing small-signal stability of the transmission system. Transmission 2040 studies will address the small-signal stability of transmission paths at a very high level on a case by case basis, if it is apparent that the transmission capacity of a part of a transmission network will be constrained by the small-signal stability of the system. Small-signal stability-related criteria Transpower is currently using for grid planning is given below for information and for the completeness of this document.
What is small signal stability?	Small signal stability refers to the reduction in amplitude of electro-mechanical oscillations caused by small changes on the power system. Small changes may be caused by varying load or generation and switching of circuits and capacitors. Following a small change in the power system or a fault, the rotor angles between synchronous generators may oscillate with respect to each other. These are referred to as electro-mechanical oscillations. If these oscillations are not damped in a reasonable time, or if they grow rather than reduce, voltage variations at buses between the generators, large current flows between the oscillating generators, and in some cases large torsional stress in generators (particularly thermal generators) may occur. The power oscillations on the network may also cause unwanted protection tripping.
Assessment of Small-Signal Stability	The small signal behaviour of the network must be acceptable for both normal system operation and in the immediate post fault period. Linear analysis (eigenvalue analysis) is used to identify the electromechanical behavioural modes present in the system under normal operating conditions and to confirm that the damping (i.e. sigma) of all modes is within the required criteria. Transient stability studies are also used to confirm that the system exhibits no prolonged electro-mechanical oscillations following a fault disturbance. These studies do not identify individual system modes explicitly but rather show the system oscillatory behaviour after a fault event. This behaviour will be a ring-down oscillation composed of various proportions of different system modes depending on the fault location. In assessing the small signal stability from the transient response, the ring down oscillation is treated as if it were a single system mode. However, this assessment is approximate and more suitable for initial screening of small-signal stability performance.
Linear analysis criteria	Two steady state network conditions are assessed. 1) The intact network 2) The network with a single *network element* out of service.

These are steady state conditions with generators operating at full MW output, and with the expected operational excitation (i.e. onerous leading power factor conditions are not imposed for the assessment unless such conditions represent the normal operating conditions). All stability controllers, such as power system stabilisers, are assumed to be in service where these are available.

Outage conditions must be assessed as this represents the network after a single switching event (i.e. without a fault). The system must be secure for normal switching operations, and such switching events often precipitate small signal problems where lightly damped oscillation modes exist.

If the *network element* removed from service is a bus section then reconfiguration of the network to re-connect as much of the system as possible is assumed, and any generation disconnection normally associated with the bus section outage is applied.

The acceptable pole-zero envelope is shown in Figure 1.
Damping of a mode is acceptable if it is better than -0.143 Np/s (an oscillation decay time constant of 7 seconds or less). Damping of a mode is also acceptable if the oscillation magnitude halves every 5 cycles. As shown on the pole-zero envelope the second criteria will be less onerous for frequencies below 1 Hz.

For frequencies above 1 Hz, the 7 second time constant criteria will be less onerous. The table below shows the number of cycles available at various frequencies for halving of an oscillation magnitude which would remain compliant with the 7 second decay time constant :

1.1 Hz : 5.5 cycles
1.2 Hz : 6 cycles
1.3 Hz : 6.5 cycles
1.4 Hz : 7 cycles
1.5 Hz : 7.5 cycles

Transient analysis criteria.

For assessment of small signal stability following a system event, the network conditions, the faults and the fault clearing times considered are as for the transient stability in sections **Error! Reference source not found.**.

For a fault event, it is recognised that more than one network element may be disconnected. This is more onerous than testing the steady state network with one network element out of service, and the application of a system fault also affects the resulting oscillatory behaviour of the system.

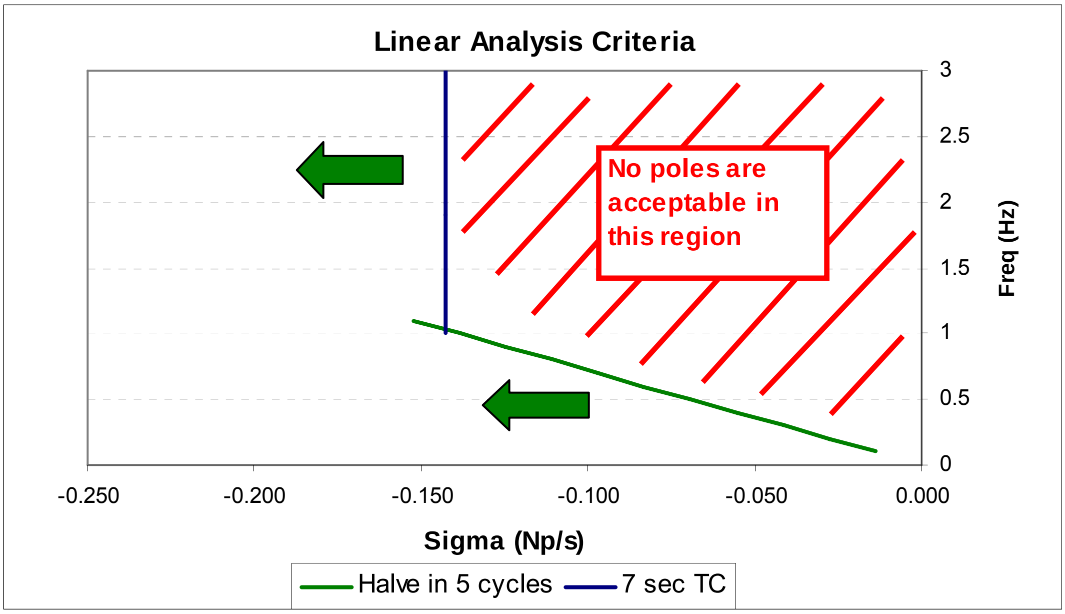
In addition the interaction of system modes may produce a time response that has a different decay time to any of the underlying system modes.
The damping criteria requirement is therefore less onerous in this case.

The acceptable pole-zero envelope is shown in Figure 2 .
Damping of an observed oscillation is acceptable if it is better than -0.083 Np/s (an oscillation decay time constant of 12 seconds or less). Damping of an oscillation is also acceptable if the oscillation magnitude halves every 5 cycles. As shown on the pole-zero envelope the second criteria will be less onerous for frequencies below 0.6 Hz.

For frequencies above 0.6 Hz, the 12 second time constant criteria will be less onerous. The table below shows the number of cycles available at various frequencies for halving of the oscillation magnitude to remain compliant with the 12 second decay time constant :

0.7 Hz : 6 cycles
0.8 Hz : 7 cycles
0.9 Hz : 7.5 cycles
1.0 Hz : 8.5 cycles
1.1 Hz : 9.5 cycles
1.2 Hz : 10 cycles
1.3 Hz : 11 cycles
1.4 Hz : 12 cycles
1.5 Hz : 12.5 cycles

Figure 1: Small Signal Stability – Linear Analysis Criteria



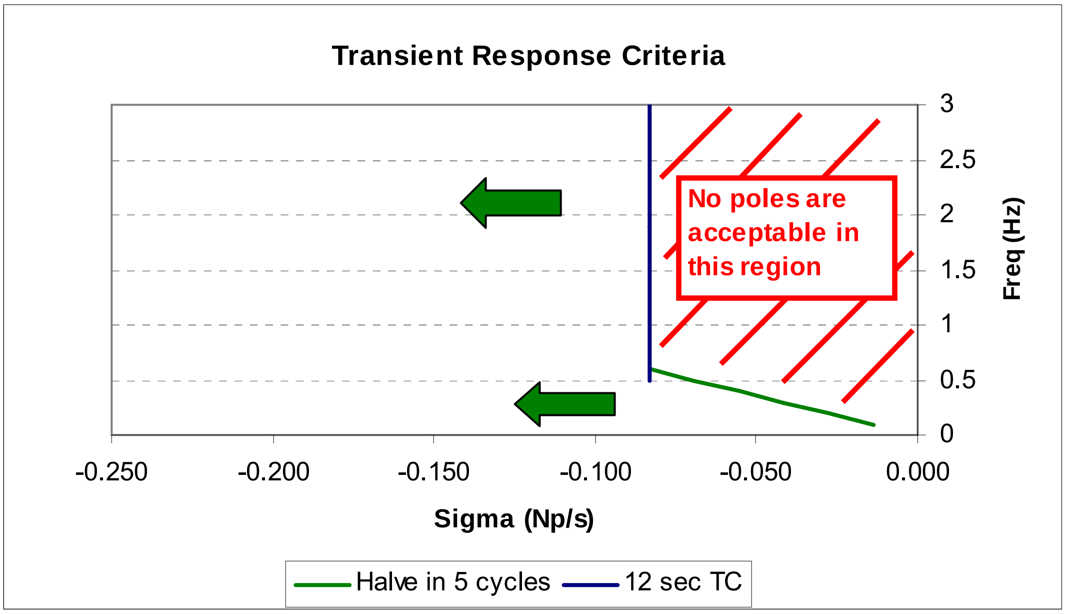


Figure 2: Small Signal Stability – Transient Response Criteria

Q.7 Do you agree with the assessment approach and proposed criteria for assessing small signal stability?

4.6 Voltage Stability

Context in relation to Transmission 2040	Long range grid planning studies under the Transmission 2040 project will not assess the voltage stability of the transmission system in detail. However, they will recognise the technologies and approaches that are available presently and in the future for enhancing the voltage stability of the transmission system. Transmission 2040 studies will address voltage stability of transmission paths in very high level on case by case basis, if it is apparent through power flow studies that the capacity of a part of the transmission system will be constrained by the voltage stability. Voltage stability related criteria Transpower is currently using for grid planning is given below for information and for the completeness of this document.
What is Voltage Stability?	Voltage stability refers to the ability of the transmission system to maintain control of the voltage after a disturbance, avoiding either an uncontrolled voltage drop (potentially leading to a blackout) or uncontrolled high voltages (potentially leading to damage to end user or transmission system equipment).
Fault Types and Fault Clearing times	Transpower will consider the same disturbances and fault clearing times as for transient stability (See section 4.3).
Voltage Stability Margin	Transpower will design the *transmission system* to maintain at least a 5% stability margin under all operation conditions, ie the transmission system will perform satisfactorily under transient, steady state and dynamic performance tests, while supplying a load equal to 105% of the pre-contingency load connected to the transmission system.
What is a Steady State Voltage Performance Test?	The steady state voltage stability test is used to identify the maximum demand (load limit) of a region to ensure long term voltage stability. This test is primarily focused on the performance of on-load tap changers, generator and synchronous condenser reactive limits, and to ensure sufficient quantities of shunt capacitor banks are connected.
Steady State Voltage Performance Criteria	Transpower will design the transmission system to meet the following criteria: • All dynamic voltage regulation devices (e.g. generators, SVCs, synchronous condensers, HVDC, etc) are within their reactive power limits pre- and post-contingency, to regulate the voltages of the controlled buses to set values[4]; and • For buses that are not directly controlled by a dynamic reactive plant, the minimum acceptable voltage level is given Table 1.
What is a Transient Voltage Performance Test?	The transient voltage stability test is used to identify the maximum demand (load limit) that can be supplied with satisfactory performance to a region for a period up to 10-20 seconds after a disturbance. This test is primarily focused on the issues of reacceleration current from decelerating and stalled induction motors, transient over voltages caused by load tripping during the fault[5], and the performance of dynamic reactive devices such as generators, synchronous condensers, SVCs, fast acting mechanically switched shunt capacitor banks, and STATCOMS.

[4] Keeping all synchronous condensers, SVCs and STATCOMS within their reactive power limits pre and post contingency is consistent with the recommendation made in the CIGRE report "*Criteria and Countermeasures for Voltage Collapse"* October 1995

[5] Some load within the distribution network is almost always lost during the low voltage period of a fault due to, for example, motor contactors opening.

Transient Voltage Performance Under Voltage Criteria

Transpower will design the transmission system to meet the following criteria:

- Voltage must be greater than 0.5 pu following a credible contingency which removes an item of equipment from service without a transmission system short circuit fault. All load is assumed to stay connected during the event and load is assumed to recover to its pre-disturbance level;
- Voltage must recover to above 0.8 pu in less than 4 seconds following a credible contingency; and
- Motor current must be maintained at a suitable level according to the typical setting of motor over-current protection, to avoid unnecessary loss of load, and reduce risk of cascade tripping and voltage collapse.

Transient Voltage Performance Over Voltage Criteria

Transpower will design the transmission system to meet the following two temporary over voltage criterion:

- Voltage criteria for low voltage buses where pre-event voltage is regulated to approximately nominal value shall be as defined by the curve in Figure 3. The defining features of the curve are:
  - Voltage must not be greater than 1.3 pu; and
  - Voltage must not be greater than 1.1pu after 0.9 seconds.

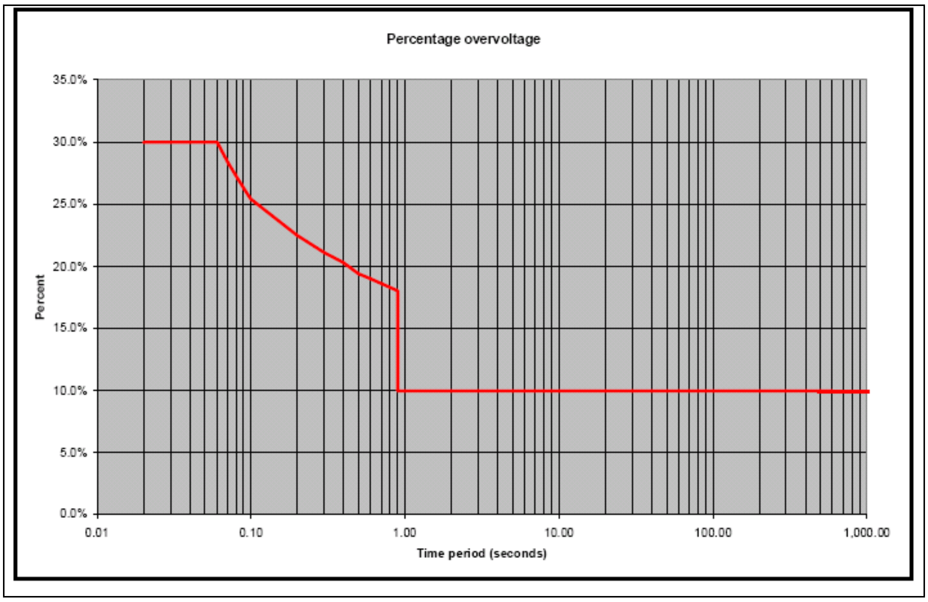


Figure 3: Transient Voltage Performance Over Voltage Criteria[6]

- Voltage criteria for high voltage buses, where pre-event voltage is not necessarily regulated to nominal voltage. The connected assets including, generation must be capable of withstanding the temporary over voltage (TOV) criteria envelope shown in Figure 4[7]

[6] Over voltage criteria is specified similar to that is in Australian National Electricity **Rules** 6th of March 2008.

[7] This criterion is derived from the HVDC Upgrade Project document "Define Transient Stability Fault Recovery Criteria" – 9 April 2008.

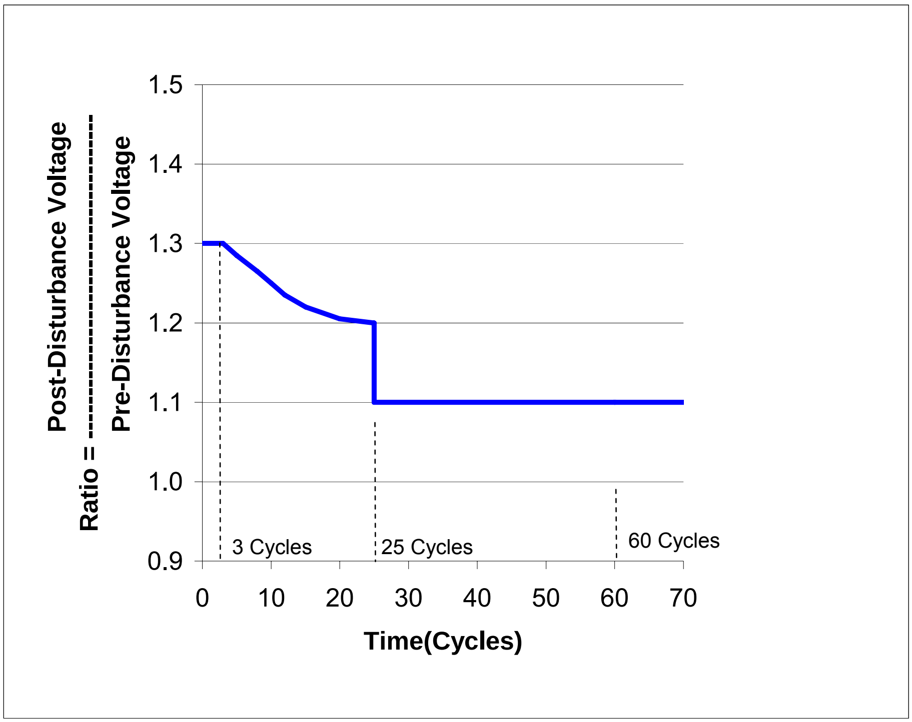


Figure 4: Temporary Over-voltage Criteria

This TOV criterion is expressed as a ratio of Pre-Disturbance to Post-Disturbance voltage and is experienced at the point of common coupling, not the generator terminals.

Q.8 Do you consider the under/over voltage criteria proposed are appropriate for the long term planning of the grid?

4.7 Fault Ride-Through

Context in relation to Transmission 2040	Planning studies will assume that all connected non-synchronous generators (present and future) will be capable of riding through the faults in the transmission system. The criteria Transpower presently uses for assessing the ability of the connected non-synchronous generators to ride through faults is described below for information and for the completeness of this document.
What is Fault Ride-Through?	Fault ride-through is a requirement for non-synchronous generators. The criteria are equivalent to the transient stability requirements for synchronous machines. Fault ride-through refers to the requirement for the generator to remain connected and generate following a period of low voltage at the point of connection to the power system for defined faults. Non-synchronous generators are typically used in wind farms, but may also be used on other, small scale, generation such as some hydro or landfill methane generators.
Status of Fault Ride Through criterion	The requirements for fault ride-though are being developed by interested stakeholders at present, and are expected to be refined. The present practice for fault ride-through is described in the following sections.
Fault Types	Transpower will consider the same disturbances as for transient stability (See section 4.3).
Fault Clearing Times	The fault durations include those for transient stability studies given in section **Error! Reference source not found.**. In addition, fault ride-through is also required for main and back-up clearance of faults on the supply bus and feeders. This is often the most onerous fault location for fault ride-through as the fault duration is typically very long compared with faults on the transmission system, even though the voltage depression is often less severe. The actual fault clearing times will be used, plus an engineering margin to allow for changes in protection settings as they are reviewed and reset as a result of system developments and changed circuit loadings.
Low Voltage Fault Ride-Through	Transpower will assume that after the fault is cleared, the post contingency voltage will be at 0.9 pu. The non-synchronous -generators, such as wind farms, must remain connected during the fault and resume pre-fault generation output rapidly after fault clearance. This applies to each fault location, type and fault clearing time; it is not necessary for the non-synchronous generators to ride through the “envelope” defined by the combining the voltage/time curves for all faults.
High Voltage Fault Ride-Through	The connected assets including generation must be capable of withstanding the temporary over voltage (TOV) criteria envelope shown in Figure 4 in section 4.6 of these guidelines.

5 Asset Capacity and Capability

5.1 Equipment Ratings

Where do existing equipment ratings come from?	Transpower's standard "TP.GG 01.10 – Equipment Ratings" defines Transpower's policy on equipment ratings. Transpower's Asset Capability Information (ACI) database contains the actual equipment ratings for transmission equipment including, lines, transformers, switchgear, protection and reactive equipment - synchronous condensers, capacitors, reactors and SVCs.
Line Ratings	Transpower uses the LATTA formula to determine transmission line conductor ratings based on the following:[8]: • Wind speed 0.61m/s; • Winter temperature 20°C (10 May-20 October); • Summer day temperature 30°C (20 October-10 May, 07:00-20:59 hours); and • Summer night temperature 20°C (20 October-10 May, 21:00-06:59hours).
Transformer Ratings	Transpower will design the system using the following transformer ratings : • The continuous rating is based on the manufacturer's nameplate rating; • The short term rating is the 24 hour rating with a design ambient temperature of 15°C for winter (10 May-20 October); and • The short term rating is the 24 hour rating with a design ambient temperature of 25°C for summer (20 October-10 May). The continuous rating is used pre-contingency and the short term ratings are used following any contingency.
Transmission Cable Ratings	Transpower will design the system using the following transmission cable ratings: • The continuous rating is the design rating of the cable; • The short term rating is the 24 hour rating with a design ambient temperature of 15°C for winter (10 May-20 October); and • The short term rating is the 24 hour rating with a design ambient temperature of 25°C for summer (20 October-10 May). The short term rating is used pre-contingency and the short term ratings are used following any contingency.
Generator Ratings	Transpower will use the rating of all generating units connected to the transmission system provided by Generators as part of their Asset Capability Statement.

[8] For transmission lines the 15 minute rating may also be used in transmission studies, where the potential post-contingency overload of circuit(s) may removed by generation re-dispatch. The 15 minute rating can be calculated in ACI using both the pre- and post-contingency current.

Ratings of Planned New Equipment	For planned new transformers, where Transpower does not have any better information, it will assume in the planning studies that they will have a short term rating of 120%[9]

Q.9 Do you expect equipment ratings based on a finer rating criteria (eg monthly) will provide significant reduction in the grid capacity required, if in the future summer peak demand approaches the winter peak demand?

[9] In the long term it is envisaged that a Transformer Rating Tool will be approved for calculation of short term ratings of transformers. At that time the above 120% assumption will be discarded

