TRANSPOWER

Grid Protection Assessments for Distributed Energy Resources

This document provides interim guidance as to how Transpower is conducting protection assessments for applications for connection of new distributed energy resources embedded within the distribution network.

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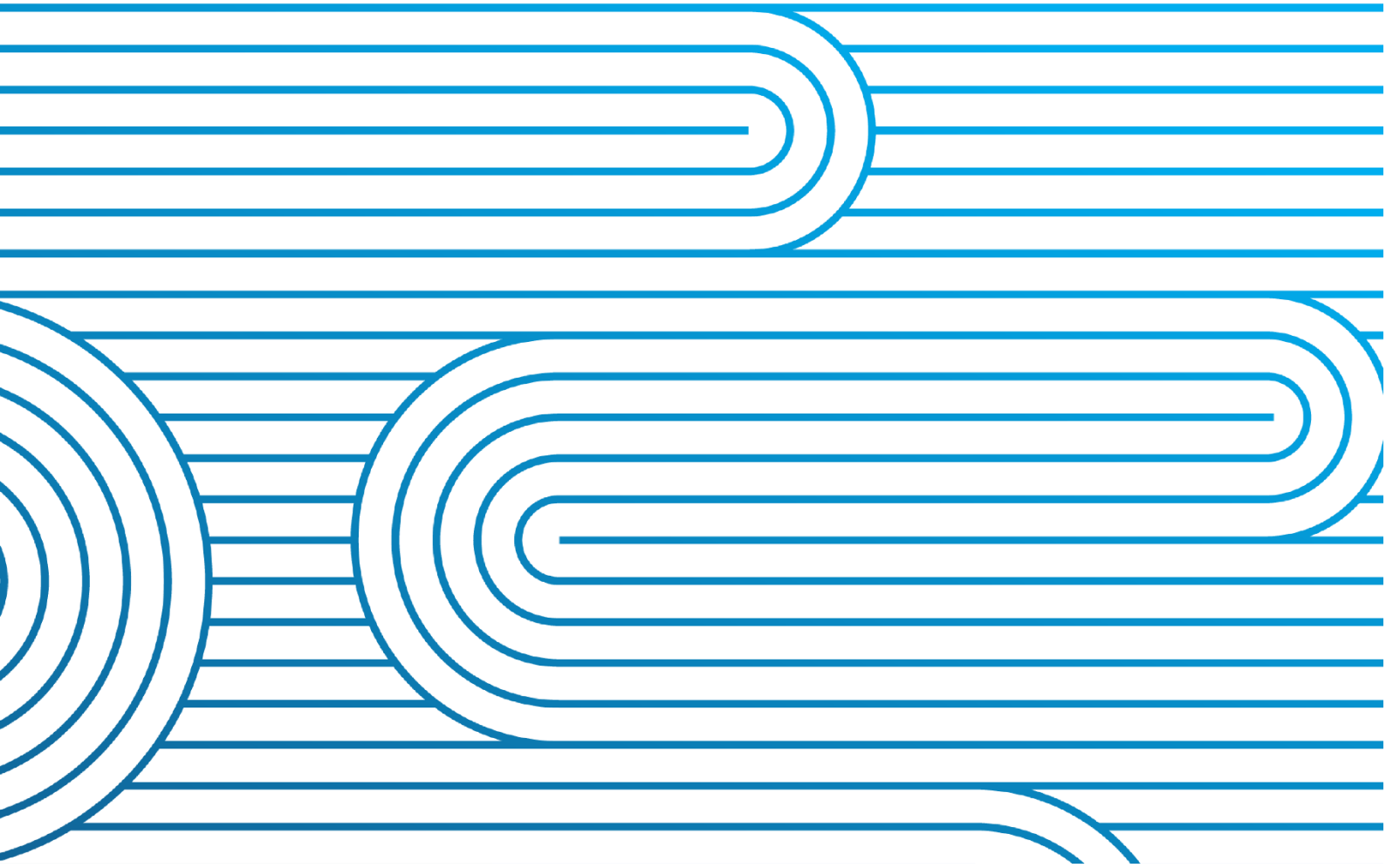

Contents

1 Introduction

1.1 Purpose

The purpose of this document is to provide high-level guidance as to what Transpower is looking for when conducting protection assessments of new distributed energy resource (DER) connections.

1.2 Scope

This document only applies to DER connections that are embedded within Connected Party networks.

It does not apply to:

- DERs connecting directly to Transpower assets.
- Connections that require the installation of new primary assets by Transpower.
- Connections that require the installation of new secondary assets by Transpower.
- Connections that require major modifications to existing secondary assets by Transpower.

If you are uncertain whether your connection is within the scope of this document, contact customer.solutions@transpower.co.nz.

This document does not supersede Transpower standards, policies, and guidelines.

1.3 Definitions and abbreviations

Term	Definition
DER	Distributed Energy Resource
EIPC	Electricity Industry Participation Code
IBR	Inverter-Based Resource
Transpower connection point	The point(s) at which the DER connects into the Transpower grid (via the distribution network).

AS/NZS 4777.1	AS/NZS 4777.1:2024 Grid connection of energy systems via inverters – Part 1: Installation requirements
AS/NZS 4777.2	AS/NZS 4777.2:2020 Grid connection of energy systems via inverters – Part 2: Inverter requirements
TP.AP 01.02	Transpower Protection & Automation Relay Setting Process
TP.GP 01.06	Transpower General Design Policy for System Protection and Automation
TP.GP 01.07	Transpower General Policy for Autoreclose

2 Grid protection assessments

Grid protection assessments must demonstrate that:

- All Transpower assets have adequate main and backup protection.
- Connection of the DER does not adversely affect protection operation.
- EIPC requirements are met, notably for protection coordination and sync-check facilities.

Presenting evidence of this in a clear, understandable manner will aid in the protection assessment of your DER connection being approved in a timely manner.

2.1 Minimal grid protection assessment

Small DERs that are not expected to have any meaningful impact on grid protection may submit a minimal grid protection assessment. This assessment is largely by inspection rather than calculation, other than a basic short-circuit calculation for faults at the Transpower connection point.

Minimal grid protection studies do not need to be performed by an Engineering Consultant from the Transpower protection panel.

2.1.1 Eligibility

To be eligible for a minimal grid protection assessment, your connection must meet the following requirements:

- **DER rating:** The DER rating is not more than 5 MW if inverter-based generation, or 3 MW if conventional generation.
- **Fault level change:** The DER connection does not change the maximum three-phase and phase-to-earth fault levels at the Transpower connection point by more than 5%.

  You may use the maximum fault levels published in the Transmission Planning Report against the DER's maximum terminal fault contribution to demonstrate compliance with this requirement in lieu of a detailed short circuit study.
- **Adequate main protection:** All Transpower-owned assets have main protection that will fully isolate a fault on that equipment (including DER fault contribution) based on the grid contribution alone.

  This requirement can be deemed to be met for fault locations where, after all grid infeeds have cleared, the following requirements are met:

  - The remaining generation connected to a fault is less than 33% of the minimum load still electrically connected to the faulted equipment.

- The DER has interface protection.

The requirement can also be met by demonstrating that the DER will disconnect within Transpower target clearing time for a fault on the asset. Anti-islanding other than undervoltage is not acceptable for protection against short-circuit faults.

- **Adequate backup protection:** All Transpower-owned assets have backup protection that will fully isolate a fault on that equipment (including DER fault contribution) based on the grid contribution alone. Note that backup protection must account for failure of a main protection to operate, or for a CB-fail event.

  This requirement can be deemed met for fault locations where, after all grid infeeds have cleared, the following conditions are met:

  - The remaining generation connected to the fault is less than 33% of the minimum load still electrically connected to the faulted equipment.
  - The DER has interface protection.

  The requirement can also met by demonstrating that the DER will disconnect within Transpower final clearing time for a fault on the asset. Anti-islanding other than undervoltage is not acceptable for protection against short-circuit faults.

- **Earth references:** No new earth references are introduced into the distribution network at the voltage level of the Transpower point of connection.

- **Out-of-sync auto-reclose:** The DER will not be affected by an out-of-sync auto-reclose.

  This requirement can be deemed met if an out-of-sync auto-reclose is improbable, either due to diversity of connection to the bulk grid or sync-check features. Connection to the bulk grid via at least three circuits that do not share towers for more than 5% of their total length is considered to be adequate diversity.

- **Interface protection:** The DER has interface protection that will disconnect the DER within 2 seconds in the event of an island forming.

  The interface protection must include an undervoltage element set with a pickup voltage of not less than 0.70 pu (as measured at point of connection in the distribution network), and a time delay of not more than 2.7 seconds.

  DERs that meet the interface protection requirements of AS/NZS 4777.1, and the anti-islanding and cease power generation requirements of AS/NZS 4777.2 are considered to meet the requirements for interface protection.

After a minimal grid protection assessment has been performed, Transpower may still require a more detailed protection assessment be completed if:

- There are unusual features of the DER connection or Transpower network that warrant further study.
- Collectively, a number of small DER connections over time have created a significant impact on the grid protection systems.

2.1.2 Report content

A minimal grid protection assessment report must include a grid protection coordination statement with the following assurances by the Customer:

- An assurance that protection is coordinated across the grid interface.
- An assurance that adequate main and backup protection is provided for nearby grid faults (listing the specific locations where main or backup protection is provided by the Customer or DER for faults on Transpower assets).
    - At a minimum, this must include backup protection for the bus at the Transpower connection point.
- An assurance that the DER will be not be affected by an out-of-sync auto-reclose (or that an out-of-sync auto-reclose is improbable).
- An assurance that the DER will disconnect within 2 seconds if there is an islanding event, and within the auto-reclose dead time if applicable.

The report must also include a justification of how the DER connection meets each eligibility requirement for a minimal grid protection assessment.

An example of a minimal grid protection assessment is included in Appendix B.

2.1.3 Transpower assistance

Evaluating the eligibility criteria requires knowledge of Transpower equipment and requirements. If you do not have access to Transpower systems to be able to evaluate this for yourself, you may contact Transpower to request assistance with determining:

- Adequacy of main and backup protection on Transpower assets.
- Risk of an out-of-sync auto-reclose.
- Auto-reclose dead time.

2.2 Standard grid protection assessment

Standard grid protection assessments are required for DERs that may have an impact on grid protection.

These assessments must be completed by an Engineering Consultant who is on the Transpower protection panel.

Standard grid protection assessments should follow TP.AP 01.02, with minor changes to account for the requirements outlined below.

2.2.1 Zone of influence

Determine the zone of influence by undertaking short-circuit studies on the existing grid, and for the grid with the new DER connected.

The zone of influence should be expanded until:

- The change in maximum bus fault levels with the DER connected is less than 5%.
- The change in branch fault currents with the DER connected is less than 10%. This is assessed by placing a fault on each bus and checking the fault contributions on each incoming branch connected to that bus.

Short-circuit studies should consider the range of normal grid configurations (including equipment outages), loading, and generator dispatch. Consult Transpower about any specific grid configurations that may also need to be considered for your assessment (e.g., system splits).

The short-circuit studies as part of this section should consider all fault types (three-phase, two-phase, two-phase to earth and phase-to-earth), but do not need to consider fault resistance. The PowerFactory "Complete" method should be used for the short-circuit studies.

2.2.2 Main protection

All Transpower assets must have adequate main protection that meets the performance requirements of TP.GP 01.06.

Bus zone differential, transformer differential and line differential schemes are typically expected to provide adequate main protection irrespective of new DER connections.

Accelerated and blocking distance schemes will require careful evaluation of their operation, particularly with respect to possible weak infeed situations or issues with distance and directional performance near inverter-based resources. Refer also to Section 2.2.5 below.

Buses that are not equipped with bus zone protection, and lines that are not equipped with signalling, are unlikely to meet the requirements of TP.GP 01.06 regardless of the DER connection. In such cases, the DER connection must not make the existing issues any worse.

Anti-islanding other than undervoltage is not considered acceptable for protection against short-circuit faults.

2.2.3 Backup protection

All Transpower assets must have adequate backup protection that meets the performance requirements of TP.GP 01.06.

Backup protection does not need to be assessed in detail for fault locations where, after all grid infeeds have cleared, the following conditions are met:

- The remaining generation connected to a fault is less than 33% of the minimum load still electrically connected to the faulted equipment.
- The DER has interface protection that includes an undervoltage element set with a pickup voltage of not less than 0.70 pu (as measured at point of connection in the distribution network), and a time delay of not more than 2.7 seconds.

DERs that meet the interface protection requirements of AS/NZS 4777.1, and the anti-islanding and cease power generation requirements of AS/NZS 4777.2 are considered to meet the requirements for interface protection.

In such cases, the DER is unlikely to be able to sustain the island and is expected to be disconnected by its undervoltage element.

Anti-islanding other than undervoltage is not considered acceptable for protection against short-circuit faults.

2.2.4 Coordination checks

2.2.4.1 Overcurrent elements

Any branches where the maximum fault current in either direction increases by more than 10% after the DER connection should have coordination of any overcurrent elements re-evaluated.

Overcurrent elements that may be affected by infeed ratio changes should be re-evaluated if the infeed ratio for faults at the infeed point changes by more than 10%.

2.2.4.2 Distance elements

Distance or impedance elements should be re-evaluated if the infeed ratio for faults at the remote-end bus changes by more than 5%.

2.2.4.3 Voltage elements

Voltage elements should be re-evaluated if the maximum fault level at the measuring bus changes by more than 5%.

This applies only to voltage elements that are expected to take some action during a fault, such as those used in voltage-controlled overcurrent elements or undervoltage elements.

2.2.5 Inverter-based resources

The fault contribution characteristics of inverter-based resources can cause maloperation of traditional protection elements.

Transpower requires assessment and mitigations for all distance and directional elements that may see fault currents where the inverter-sourced component is more than 15% of the non-inverter sourced component. The percentage of inverter-sourced current is determined by comparing the fault currents with and without the inverter-based generation contributing fault current[1].

Note that if there is other inverter-based generation in the area, this must also be included in the 15% allowance.

[1] i.e., $\frac{I_{IBR}-I_f}{I_f} > 0.15$ will require mitigation, where I_f is the fault current without any IBR contributions, and I_{IBR} is the fault current with the IBR contributions.

2.2.6 Auto-reclosing

Assurance is needed that the DER will not be affected by an out-of-sync auto-reclose. You can demonstrate this in one of four ways:

- There are no existing or planned auto-reclose schemes.
- The auto-reclose scheme is equipped with dead line / sync-check.
- An out-of-sync auto-reclose is improbable due to diversity of connections to the bulk grid (see requirements in TP.GP 01.07 for allowing plain auto-reclose schemes).
- Provide an assurance that the DER will not be affected by an out-of-sync auto-reclose.

2.2.7 Anti-islanding

The DER must be equipped with interface protection that will disconnect the DER within 2 seconds if there is an islanding event. Transpower does not necessarily require detailed assessments of anti-islanding schemes to be submitted as part of the grid protection assessment (e.g., RMS/EMT studies), but we do require an assurance that anti-islanding will operate.

Anti-islanding must disconnect the DER within the auto-reclosing dead time, with a margin of at least 0.5 seconds.

Within any prospective island, there must be some protection that will disconnect the DER if a fault were to occur. This applies even if the prospective island is only temporary (e.g., until anti-islanding operates).

2.2.8 Report content

The Executive Summary of the grid protection assessment report must include explicit statements for each of the following:

- All Transpower assets within the zone of influence have adequate main and backup protection.
- Connection of the DER does not adversely affect protection operation within the zone of influence.
- EIPC requirements are met for protection coordination and design/final clearing times within the zone of influence.
- The DER will not be affected by out-of-sync auto-reclosing (or that an out-of-sync auto-reclose is improbable).
- The DER is equipped with anti-islanding that will disconnect the DER within auto-reclose dead time.

If there are exceptions, these should be individually listed along with any mitigation actions. If an exception cannot be fully mitigated, this must be explicitly stated.

The body of the report should provide evidence to demonstrate the validity of each statement.

2.2.9 Grid protection coordination statement

Once the grid protection assessment report is approved by Transpower, a grid protection coordination statement must also be submitted with the following assurances:

- An assurance that protection is coordinated across the grid interface.
- An assurance that adequate main and backup protection is provided for nearby grid faults (listing the specific locations where main or backup protection is provided by the Customer or DER for faults on Transpower assets).
    - At a minimum, this must include backup protection for the bus at the Transpower connection point.
- An assurance that the DER will not be affected by an out-of-sync auto-reclose (or that an out-of-sync auto-reclose is improbable).
- An assurance that the DER will disconnect within 2 seconds if there is an islanding event, and within the auto-reclose dead time if applicable.

Note that these assurances are to be provided by the Customer, not the Engineering Consultant.

An example of a grid protection coordination statement is included in Appendix A.

Appendix A
Grid protection coordination statement example

Grid protection coordination statement:

The Disco Energy distribution company confirms that:

- Protection is coordinated across the grid interface at the ERE 33 kV GXP.
- Backup protection is provided by the DER for nearby grid faults, including:
  - ERE 33 kV bus phase and earth faults
  - ERE 110 kV bus phase faults
  - ERE-SOM-1 110 kV line phase faults
  - ERE-SOM-2 110 kV line phase faults
- The DER is equipped with anti-islanding that will disconnect the DER within 2 seconds if there is an islanding event, which is within the auto-reclose dead time of 3 seconds.

The Running River hydropower station cannot withstand an out-of-sync auto-reclose, however all incoming circuits with auto-reclosing are equipped with appropriate sync-check facilities so an out-of-sync auto-reclose is improbable.

Appendix B
Minimal grid protection assessment example

Project overview:

The Blue Sky solar farm project will connect into the Transpower ERE 33 kV GXP via the Disco Energy distribution network. It will normally connect via ERE Feeder 2242, but may also connect via ERE Feeder 2112.

Grid protection coordination statement:

We confirm that:

- Protection is coordinated across the grid interface at the ERE 33 kV GXP.
- Backup protection is provided for nearby grid faults, including:
    - ERE 33 kV bus phase and earth faults
- The DER will not be affected by an out-of-sync auto-reclose.
- The DER is equipped with anti-islanding that will disconnect the DER within 2 seconds if there is an islanding event. This is within the auto-reclose dead time of 3 seconds.

Justification for minimal grid protection study:

DER rating

The DER rating is 3 MW, and is inverter-based.

Change in fault levels

The DER fault current contribution is limited to 1.8 pu, which is 94A at 33 kV. Per the Transpower Forecast Fault Level Report 2024, the maximum three-phase fault level at the ERE 33 kV bus is 10.4 kA. Therefore, the change in fault level is less than 5%.

Adequate main protection

Transpower assets have main protection that is not dependent on DER fault contribution to isolate a fault:

- Bus zone protection on the ERE 33 kV bus
- Differential protection on the ERE-T1 and T2 transformers
- Bus zone protection on the ERE 110 kV bus
- Line differential protection on all incoming 110 kV circuits

Adequate backup protection

The total generation at ERE, including the new solar farm, is 7 MW. This is less than one third of the minimum load at ERE (23 MW), and so the DER interface protection can be relied upon to disconnect the DER for faults on the ERE-T1 and T2 transformers, the ERE 110 kV bus and outgoing 110 kV circuits.

As part of protection studies completed for the distribution company connection (see attached), we confirmed that there is adequate backup protection for faults on the ERE 33 kV bus:

- Under-voltage protection on the HV side of the solar farm step-up transformer will disconnect the DER within 2.7 seconds for phase faults.
- Residual voltage protection on the HV side of the solar farm step-up transformer will disconnect the DER within 2.7 seconds for earth faults.

Therefore, adequate backup protection is provided for all Transpower assets.

Out-of-sync reclosing

The solar farm will not be affected by an out-of-sync auto-reclose.

Interface protection

The DER uses inverters that comply with AS/NZS 4777.2:2020, and has interface protection in accordance with AS/NZS 4777.1:2024.

Appendix C
Frequently asked questions

What is considered a "major modification" to existing secondary assets? (Section 1.2)

Minor modifications can include:

- Level changes (pickups and time delays) for existing protection elements.
- Minor logic changes within protection relays (e.g., enabling or disabling elements, or adding blocking functions).
- CT ratio changes.

If numerous minor changes are proposed, or where changes are complex (for example, the addition of a new Special Protection Scheme), the works may still be considered a major modification. If there is uncertainty, Transpower should be consulted.

Who can complete a minimal grid protection assessment? (Section 2.1)

Within reason, the Customer can choose who they would like to complete the assessment. The person(s) chosen must be competent to do the work, and we have provided an offer of Transpower assistance on some sections to make the assessment more accessible.

If adequate main or backup protection must be demonstrated for faults beyond the immediate LV bus by carrying out a protection study (e.g., faults on the HV transmission network), Transpower generally prefers that the studies are completed by an Engineering Consultant who is on the Transpower protection panel.

Do inverters that cease generation meet the requirement to disconnect? (Section 2.1.1)

Yes, cease generation is acceptable provided the DER will fully disconnect if the grid is not restored by auto-reclosing.

What is meant by "will fully isolate a fault on that equipment (including DER fault contribution) based on the grid contribution alone"? (Section 2.1.1)

Protection schemes such as bus differential or line differential usually trip circuit breakers on all sides of the protected asset. This will disconnect both the grid contribution and the DER contribution to the fault. These protections will operate solely on current contributed by the grid, and do not depend on the DER fault contribution to operate.

An overcurrent element on a transformer incomer providing backup for LV bus faults may only trip the transformer incomer, removing the grid contribution to the fault. This does not remove the DER contribution via other feeders connected to the bus.

How should the "minimum load still electrically connected" be determined? (Section 2.1.1)

Assume that protection that relies only on grid contribution has operated and opened associated circuit breakers, leaving the DER connected to the faulted equipment. You should

include any load that is still electrically connected to the faulted equipment in your calculation of the minimum load.

As a general rule, use the lowest load recorded over the past year, unless there is a specific reason why this would not be suitable for your site.

Please note that, at this time, Transpower does not consider the timing of generation when assessing the minimum load. For example, even though solar only generates during the day, you should still use the lowest overnight load for your assessment. If this approach changes in the future, we will update the guide accordingly.

Transpower typically only has visibility of nett load (total load less any DER contribution) at a GXP. If there is other generation in the area, this can give an overly conservative estimate of minimum load. You may use load data provided by the Customer if this is more accurate.

What should be considered as the "base" when evaluating changes in short-circuit currents to determine the zone of influence? (Section 2.2.1)

The latest version of the applicable Transpower PowerFactory model should be used, with network variations activated for all Committed Projects that are expected to be commissioned prior to your DER.

For the "base" network configuration, include all DERs within your local distribution network that have already been included in a standard grid protection assessment.

For the "changed" network configuration, include all the DERs from the "base" case, and then add any additional DERs in your local distribution network that have not yet been included in a standard grid protection assessment.

Both the "base" and "changed" network setups should be adjusted as needed to reflect the range of grid configurations, load levels, and generation dispatch scenarios being considered in your short-circuit studies.

What mitigations are acceptable if inverter-sourced current exceeds 15% of non-inverter sourced current? (Section 2.2.5)

The mitigations that Transpower will accept is evolving, and can be highly site-specific. Therefore, we recommend discussing options with Transpower, as applying mitigations can add significant lead-time to your project, particularly if it means new equipment must be installed.

Is loss-of-earth protection acceptable for short-circuit protection?

No, loss-of-earth protection is not acceptable as short-circuit protection. Transpower does not permit the use of status-based schemes for this purpose. Instead, loss-of-earth protection is considered as part of anti-islanding.

How much assessment is required to determine whether protection is adequate on Transpower-owned assets?

When assessing whether protection on Transpower-owned assets is sufficient, you can generally assume that protection is adequately designed and set for the existing grid configuration. If it's clear that adding your new DER will not make the protection perform any worse, you do not need to carry out detailed calculations.

For example:

- If a low-impedance bus zone scheme is set to operate reliably for minimum bus fault levels in the existing grid, and your new DER will only increase these fault levels, no further calculation is needed to confirm the bus zone scheme's minimum operating current is adequate.
- If a distance element is set to work reliably for faults on its associated transmission line and remote-end bus, and always has a strong grid source behind it (for any credible outage scenario), then a DER addition that changes the fault level by less than 5% is not significant. In this case, you do not need to recalculate the distance element's reach.

Using this practical approach, you can often complete minimal grid protection assessments without needing detailed calculations. However, if there's any uncertainty about whether the protection remains adequate, you must provide detailed calculations to confirm.