Network Integration Guideline

Inverter Embedded Generation

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1 Introduction

This Network Integration Guideline provides guidance for completing applications to connect AS/NZS 4777[1]-compliant Inverter Embedded Generator (IEG) systems to the Western Power network.

It details critical requirements and limitations in relation to applying for IEG connections, assisting applicants in:

- identifying the customer's network connection arrangement
- determining maximum IEG on the current connection arrangement
- understanding what types of systems can be connected (PV, energy storage, other energy sources)
- identifying the correct application process for the specific requirement.

Notes: As most applications are completed by customer-appointed agents, this document assumes the reader has an electrical trade background and is familiar with the technical concepts and subject matter within.

This Guideline does not replace or supersede other rules, documents or standards relevant to this subject.

What this Guideline does not address

- The connection of commercial- or industrial-scale IEG systems (such as solar farms and wind farms), or any other form of generation requiring dedicated distribution HV feeders or transmission connected generation.
- Larger embedded distribution networks and premises with multiple points of supply requiring custom designs.
- It is not a "how-to" reference for system design or for compliance to relevant standards.

1 *AS/NZS 4777: Grid Connection of Energy Systems via Inverters* (published jointly by SAI Global Limited under licence from Standards Australia Limited and Standards New Zealand).

1.1 Technical impact considerations

Properly installed and deployed IEG systems benefit both customers and Western Power. By reducing customers' energy consumption from the network, local generation contributes to reduced network load, as well as supporting voltage levels.

As the operator of the SWIS, Western Power is required to comply with a broad range of obligations relating to safety and reliability. Prior to connecting any IEG system to the network, Western Power must assess the requirements of all relevant regulations and standards, as well as its potential to impact:

- the quality of supply to all customers on the local Low Voltage (LV) network
- correct operation of the IEG
- the customer's Point of Supply (including installed service apparatus)
- performance of the broader network and its assets.

Western Power must also consider the indirect, cumulative impacts of multiple IEG systems operating within the same local network, in terms of:

- effectiveness of network protection
- frequency stability
- voltage stability.

To expedite Western Power's assessment, the application process directs applicants (on behalf of their customers) to:

- confirm that the proposed equipment and installation practices comply with all applicable requirements
- supply technical data pertaining to the customer's connection and the proposed system
- assess the expected performance of the proposed system at the customer's premises (or electrical installation).

Note: This information must be provided on behalf of the customer by a suitably-qualified electrical contractor or electrical engineer.

1.2 Document structure

Section 1	Introduction (this section)
Section 2	Overview - Inverter Embedded Generation systems
Section 3	Customer connections
Section 4	Standard supply arrangement
Section 5	Greater than standard supply arrangement on a shared LV feeder
Section 6	Dedicated LV feeder, contiguous switchboard, > 200 A sole-use
Section 7	High Voltage (> 1 kV) connections
Appendix A	Application assessment process
Appendix B	Transformer reference data
Appendix C	Connection configurations - energy storage systems

Appendix D Alternative IEG sources
Appendix E Definitions of terms

2 Overview - Inverter Embedded Generation systems

Historically, embedded generation systems have typically consisted of large plant installed at major load sites, requiring specialist technical support.

Today, the majority of embedded generation systems being installed on the Western Power network are Inverter Embedded Generators (IEGs), comprising two main elements:

1. An energy source such as an array of photovoltaic cells, or (less commonly) wind turbines and energy storage systems.
2. An inverter that interfaces between the DC energy source and the customer's AC electrical installation.

Inverter performance must comply with both the AS/NZS 4777 series of standards and the relevant requirements of the Technical Rules. The differing characteristics of each type of generation (e.g. intermittency of supply or ability to supply rapidly changing load) must be considered in assessing potential technical impacts and compliance with the relevant requirements.

While the majority of connections to date have been small residential systems, larger commercial and industrial systems are increasingly common. These have greater potential to impact the network and the Point of Supply and require more rigorous assessment than small systems.

2.1 Export-limited systems

Export-limited systems limit the flow of power from the IEG into the network to a preset level, reducing the risk of non-compliant voltages and overloading of the consumer mains and service cables.

It is typically used in self-consumption systems to prioritise the offsetting of load and charging the energy storage. Export capacity limits are configured within the inverter's control settings and set by the contractor installing the system

A common misconception is that limiting export will permit the installation of a larger system to offset onsite load. In reality, however, the disconnection of an IEG system can cause site load to become reliant on the network. This can cause step changes in voltage on both the network and the customer's Point of Supply, which can affect other customers' quality of supply. As the size of such voltage fluctuations increases with the capacity of the IEG system, it is essential to assess the potential impacts on the shared LV network based on the full capacity of the proposed system, rather than on export limits.

The intended application of the IEG system is a key factor in evaluating the benefits of export limiting. In general, it is only appropriate when:

- the installation includes energy storage or
- export from the customer's Point of Supply is not permitted (or required).

2.2 Photovoltaic IEG[2]

Photovoltaic[3] (PV) IEG is the most common type currently being installed, generating energy from ambient sunlight. As well as reducing network energy consumption, PV systems can be configured to export excess energy to the distribution network for consumption by other customers.

By its nature, all PV systems in a given geographical area are affected similarly by changes in local conditions. This lack of diversity can result in cumulative impacts with potential to affect supply to all customers connected through that local network.

PV provides maximum output during the middle of the day, with little or no generation during the period of peak demand (usually from 4:00 PM to 8:00 PM). As the increased output from this generation coincides with lower demand, PV integration must be managed carefully to avoid nuisance tripping, power quality issues and additional stress on the network. Changes to the Australian Standard for these systems will help manage these impacts (see Section 2.4 for additional details).

2.3 Energy storage systems using inverters

IEG incorporating energy storage enables customers to store excess energy for deferred consumption.

Note: These systems are subject to the same connection processes and considerations as other IEG configurations and must be approved by Western Power before installation commences, regardless of the intended application.

While the underlying technology is not new, customer interest in energy storage systems will increase substantially as they become more viable (technically and economically).

Energy storage systems are typically deployed in one of the following configuration types:

1. **Self-consumption** systems store excess energy to meet demand at times when the embedded generation is insufficient or unavailable. This minimises the amount of energy supplied by network.
2. **Load backup** (or "Uninterruptible Power Supply") systems supply partial or critical loads in the event of a network outage.
3. **Alternative supply** (or "Stand-alone arrangement") systems supply an entire site, regardless of network connection availability. While these may be designed to operate in parallel with the network to supply load, they are unlikely to export energy to the network. This configuration offers greater flexibility for customers seeking to minimise their network dependence.

Appendix C presents a number of high-level energy storage configurations.

Note: "Multiple mode inverter" is a new term (introduced by AS/NZS 4777.2:2015) that refers to inverters with multiple energy sources or multiple modes of operation. Typically, all inverters with energy storage capability are classed as multiple mode inverters. The terms "hybrid" and "UPS" are also used in reference to inverters offering storage functionality.

[2] See Appendix D for a brief description of alternative IEG sources.

[3] The alternative terms "PV" and "solar" are interchangeable with "photovoltaic".

2.4 Inverter energy system requirements

2.4.1 General

All IEG systems connected to the network must comply with the AS/NZS 4777 series of standards relating to the LV network connection of inverter energy systems.[4]

Originally published in 2005, this series has been reviewed recently, in accordance with Standards Australia processes. This review resulted in the publication of a new Part 2 document, while a new Part 1 still being progressed. When complete, the new version of AS/NZS 4777 will be applicable to larger system installations (up to 200 kVA).

Table 1 lists applicable inverter energy system standards, together with their validity dates.

Table 1: Standard series AS/NZ4777 Grid connection of energy systems via inverters

Part	Part name	Version	Comment
AS4777.1	Installation requirements	2005	Current Note: this expected to be superseded 3 months after publication of AS/NZS 4777.1 revision (late 2016).
AS4777.2	Inverter requirements	2005	To be superseded by AS/NZS 4777.2:2015 (9 October 2016). Limited to system capacities of 10 kVA (single-phase) or 30 kVA (three-phase).
AS4777.3	Grid protection	2005	To be superseded by AS/NZS 4777.2:2015 (9 October 2016). Limited to system capacities of 10 kVA (single-phase) or 30 kVA (three-phase).
AS/NZS4777.1	Installation requirements	Draft	Draft (expected publication: mid-2016).
AS/NZS4777.2	Inverter requirements	2015	Published 9 October 2015, with 12 month transition from 2005 version. Note: inverters larger than 30 kVA are required to comply with requirements in the standard.

2.4.2 Transitional requirements for AS/NZS 4777.2:2015

- The new Part 2 of the standard (AS/NZS 4777.2:2015) removes the previous version's capacity limits for inverters and supersedes Parts 2 and 3 of the 2005 series (AS/NZS 4777.2:2005 and AS/NZS 4777.3:2005).
- A one-year transition period (ending 9 October 2016) has been granted, after which compliance with the new standard will be mandatory for all new inverters.
- The Clean Energy Council's (CEC) approved product list for inverters[5] is used to verify compliance with the standards applicable to grid-connected inverters.

[4] Separate standards apply to the generation source (e.g. PV); these are beyond the scope of this Guideline.
[5] https://www.solaraccreditation.com.au/products/inverters/approved-inverters.html

2.4.2.1 Inverters compliant with 2005 version

This section summarises the preliminary transition requirements that must be considered before connecting IEG to the Western Power network.

Inverters compliant with the superseded 2005 version have adjustable set-points. For new and retrofit installations, Western Power requires these set-points to be changed to align to its requirements and those of AS/NZS 4777.2:2015. The required settings are listed in Table 2.

Table 2: Required settings - inverters compliant with AS/NZS 4777.3:2005

AS 4777.3:2005 clause 5.3	Range	Required setting
Under-voltage, V_{min}	200 - 230 V	200 V
Over-voltage, V_{max}	230 - 270 V	265 V
Under-frequency, F_{min}	45 - 50 Hz	47 Hz
Over-frequency, F_{max}	50 - 55 Hz	51.5 Hz

The 2005 version of the standard does not cover inverters with capacity exceeding 30 kVA. The 2015 version should be implemented as soon as possible where relevant.

2.4.2.2 Inverters compliant with 2015 versions

Table 3 lists Western Power's requirements for the use of additional inverter functionality and values for set-points required for inverters, in accordance with AS/NZS 4777.2:2015. (For inverters with capacity exceeding 30 kVA, these requirements must be implemented by 9 May 2016 and will be assessed as part of the application process.[6])

The functions have configurable set-points that must be aligned to Western Power's required setting. Any requirement appearing in the standard that is not listed below must be applied as specified by the standard.

Table 3: Required settings - inverters compliant with AS/NZS 4777.2:2015

Clause	Comment	Default setting	Western Power requirement	Implementation date (> 30 kVA)
6.2	Inverter demand response modes	DRM 0 Disconnect - required. DRM 1 to DRM 8 - optional.	*DRM 0 implemented as required by Western Power* (i.e. Western Power may not require the use of inter-trip functionality for every IEG). DRM 1 to DRM 8 - not required.	9 October 2016
6.3	**Power quality response modes**			
6.3.2.2	Volt-watt response mode	Default - enabled. Tables 9 & 10 - default values.	Required by all inverters. Enabled for all inverters. Tables 9 & 10 - default values.	9 May 2016
6.3.2.3	Volt-var response mode	Default - disabled.	Disabled.	9 October 2016
6.3.2.4	Voltage balance mode	Default - disabled.	Disabled for standard supplies. Optional for customers with supplies > 100 A.	9 October 2016
6.3.3	Fixed power factor mode and reactive power mode	Default - disabled.	Disabled for standard supplies (unless enabled due to power quality issues). As directed by Western Power for supplies > 100 A.	9 October 2016

[6] For information about the application process, refer to http://www.westernpower.com.au/residential-customers-solar-pv-system-connections.html.

Clause	Comment	Default setting	Western Power requirement	Implementation date (> 30 kVA)
6.3.4	Power factor curve -Cos Φ (P)	Default - disabled.	Disabled for standard supplies. As directed by Western Power for supplies > 100 A.	9 October 2016
6.3.5 (6.3.5.3.2 & 6.3.5.3.3)	Power rate limit Note: This will be applied to reconnection (i.e. ramp up/soft start).	Required. Default ramp time W_{Gra}=16.67% T_n=6 minutes	Required. W_{Gra} or W_{Gra}+ = 16.67% Tn+=6 minutes W_{Gra}-=50% T_n-=2 minutes	9 May 2016
Protective functions for connection to electrical installations and the grid				
7.3	Active anti-islanding protection	Either test methods of Appendix F or IEC 62116.	Test method to IEC 62116 is required.	20 January 2016
7.5.2	Sustained operation for voltage variations	Required. Default setting $V_{nom-max}$ = 255 V	Required. Default setting $V_{nom-max}$ = 258 V	9 May 2016
7.5.3	Sustained operation for frequency variations (generation operation).	Required. Default setting F_{stop}=52 Hz	Required. Default setting F_{stop}=51.5 Hz	9 May 2016
7.6	Disconnection by external signal.	Required.	Required. Note: while this capability is a requirement for inverters, this function is generally only implemented for larger systems (> 200 kVA) where an inter-trip is required.	9 October 2016
Additional requirements for multiple mode inverters				
6.3.5.3.4	Changes in energy source operation. Note: For multiple mode inverters (i.e. with energy storage) will also apply for changes in energy source operation.	Default - disabled.	Enabled. For changes in energy generation and consumption through grid-interactive port.	9 October 2016
6.4.3	Volt watt response mode for charging of energy storage	Required.	Required. Table 9 and Table 12 - default values.	9 October 2016
7.5.3	Sustained operation for frequency variations (charging operations)	Required. Default setting F_{stop}-CH=49 Hz	Required. Default setting F_{stop}-CH=49 Hz	9 October 2016

3 Customer connections

3.1 General

A customer's electrical installation is connected to the Western Power electricity distribution network at the Point of Supply. Electrical load capacity provided to a customer is typically sized according to an allocated amount based on diversity factors, which means the load capacity supplied is less than the customer's maximum demand.

In some cases where the customer has a sole-use substation the maximum load demand is used to size the network equipment and service apparatus. The existing requirements for connections to the network are available in the West Australian Distribution Connections Manual (WADCM).[7] For developments where many lots are connected the requirements are available in the Underground Distribution Schemes Manual (UDSM).[8]

The type and age of the distribution network, related network equipment and service apparatus to which the proposed IEG is to be connected will have a direct impact on the maximum available capacity of the Point of Supply. This is due to differing industry/network standards and work practices applied and used over time for design, installation and connection of customer electrical installations and Western Power's distribution network.

For instance many residential areas with overhead distribution network constructed in the 1970's were designed for a load capacity per Point of Supply of 2.5 kVA, whereas more recent underground distribution networks have a design load capacity of 4.7 kVA.

Typically, commercial and industrial areas have increased load capacity as compared to residential developments given that the commercial and industrial capacity is based on lot sizes or a calculated load/maximum demand requested by the customer.

A general observation of the distribution network may be sufficient to identify the type of supply arrangement for an individual connection. When considering the addition of an Inverter Embedded Generator (IEG) an evaluation of the supply arrangement and connection (PoS) capacity is required before designing the IEG system.

The ability of a customer's connection to the network to accommodate the IEG is dependent on multiple factors which need to be assessed by a qualified electrical contractor or electrical engineer, based on:

- customer's electrical installation capacity
- characteristics of site
- intended uses of the IEG system
- the supply arrangement.

Following this assessment, Western Power will assess the network's capacity to host the proposed IEG.[9]

In general, however, the maximum possible IEG capacity is limited to either the size of the customer's electrical installation (wiring) or the capacity of the supply arrangement or the network hosting limits whichever has the lowest rating.

7 http://www.westernpower.com.au/documents/WA_Distribution_Connections_Manual.pdf

8 http://www.westernpower.com.au/land-developers-designers-guidelines-and-manuals.html#UDS

9 See Appendix A for an overview of this process.

3.2 Capacity considerations

The capacity of a connection to the Western Power network to supply load differs from its capacity to host embedded generation. This is a consequence of the difference in behaviours of embedded generation (typically PV) and load.

To satisfy customer load requirements across the network, generation has traditionally been situated in central locations from where it is distributed via the high voltage transmission network to the high voltage distribution network and finally to the customer typically at low voltage.

The design of the network must balance capacity and cost.

When supplying load, energy flows in one direction and the network benefits from the diversity in customers' loads. However when hosting embedded generation the flow of energy reverses. PV IEG systems generate most when direct sunlight is available, thus all PV in a geographical area will generate at the same time reducing the level of diversity factor upon which the network was designed.

PV generation does not have the same diversity as load. To avoid overloading the network, when all embedded generation systems are generating, the capacity of IEG that each customer connects to the network must be limited.

In addition to the generation hosting capacity required for each connection, many other facets of an network require investigation to enable the network to successfully incorporate IEG. These include, but are not limited to:

- effectiveness of network protection
- network-wide frequency stability
- network voltage stability
- network current carrying capacity (continuous and fault).

Some of these factors may result in a requirement to redesign or deploy additional network equipment, both of which may require additional time to complete.

The maximum generation capacity is limited to the electrical capacity of the customer's Point of Supply (PoS) for residential customers or the discrete non-diversified capacity allocation for commercial and industrial customers. These capacities are subject to compliance with all other technical requirements set out in this document.

The collective IEG capacity on a local LV network cannot exceed the operational capacity of the network equipment and service apparatus. The general guideline used for the assessment of generation connected to a shared LV distribution network is 30% of the network asset capacity. When 30% of the network asset capacity is exceeded, a detailed evaluation is required to confirm additional IEG will not adversely impact the network or other customers.

3.3 Application and assessment processes

Western Power is responsible for approving the connection of new IEG systems to the Western Power Network. A system can only be connected once all of the applicable connection eligibility criteria have been met. To ensure power quality, reliability of supply and prevent a network capacity overload, Western Power must be advised of, and approve the connection of, all IEG systems.

Customers must exercise caution prior to purchasing generation systems by ensuring that the existing or intended supply arrangement to their premises has the ability to service and the required capacity to accommodate the system size of the IEG or if it is a new connection that there is in fact a network connection available to service their proposed new installation and IEG.

Prospective customers and their agents should not automatically assume that a connection which satisfies their expectations[10] is available, until confirmation has been provided from Western Power. Customers should be wary of purchasing an IEG prior to this confirmation.

After the IEG system is designed and the correct application process has been followed Western Power will perform appropriate checks which may include a technical review to assess the proposed embedded generator system for compatibility with the customer Point of supply (PoS) and with the upstream Western Power network

Should a customer's total generation capacity exceed that of the existing supply arrangement, then the additional electrical capacity requirement may call for the network to be modified to facilitate the generation. The costs associated with providing that additional capacity will be charged to the customer.

Therefore it is essential that the type and capacity of the network supply be determined before choosing an IEG system and initiating the application process.

If an application for additional generation results in the network limits being exceeded, the Customer may:

- retract the application as presented, thereby choosing not to connect a generation system
- consider a downsized generation system that ensures network performance limits are maintained or
- request, at their cost, an upgrade of their connection and effected portion of the network to accommodate the installation of the desired generation system that ensures network performance is not jeopardised.

3.4 Types of supply

Depending on the size of load to be supplied or capacity of generation to be connected there are different connection arrangements to the Western Power distribution network. These connections may be split into two groups according to the voltage level at which they are made:

- Low Voltage (LV) distribution network
- High voltage (HV) distribution network

The most common customer connection type is a connection to the LV distribution network, with electricity supplied at a nominal voltage of 240 V.

[10] It should not be assumed that a three-phase supply is readily available at all new or existing developments. In some instances the network to a subdivision or lot may only be single-phase.(WADCM Reference)

3.4.1 Connections to the LV distribution network

The LV distribution network is generally provided as a four-wire system at 240 V (single-phase) or 415 V (three-phase). In some country, rural/semi-rural and metropolitan fringe areas, only a single-phase system may be available at 240 V.

LV distribution connections are typically used to supply residential, commercial and industrial installations where the load or generation PoS is typically less than 500 metres (cable route length) from the distribution transformer.

Connection to the LV network can be categorised into three general supply arrangements:

4. Standard Supply Arrangement
5. LV-connected, greater than standard supply arrangement on shared feeders
6. Dedicated LV feeders, contiguous connections and large (≥ 250 A) sole-use supply arrangements.

Note: Single-phase 480 V supply arrangements are not considered to be Standard Supply and new connections are not allowed to use this arrangement. Sometimes these are referred to as either two-phase or split-phase connections.

3.4.2 Connections to the HV distribution network

The distribution high voltage network is generally provided as a three wire system at pressures of 6.6 kV, 11 kV, 22 kV, or 33 kV.

It should be noted that distribution networks operating at 6.6 kV and 11 kV are used in some regional areas but are semi-redundant in the Perth and Fremantle CBDs, with only a few limited applications still remaining.

22 kV is the current standard HV distribution network within the South West Interconnected System and is also used in some regional towns.

33 kV is the current standard high voltage distribution network for less densely populated country areas.

See Section 7 for further information on connections to the HV distribution network.

3.5 Identification of the connection

The identification of the supply arrangement and Point of Supply (PoS) is ascertained from the electrical infrastructure in the area of the customer's premise. The identification and assessment must be performed by a qualified electrical contractor or engineer. The predominant connection type and size may differ between areas such as residential, commercial or industrial.

For residential customer premises the default connection provided is a *standard supply*. For illustrative purposes some typical LV supply arrangements for small customers are shown in Figures 1 to 4.

Customers consuming more than 50 MWh per year (an average of 137 kWh per day) are contestable. Contestable customers may choose their retailer and will most likely have applied for a specific connection size which will be larger than a standard supply.

Most non-contestable customers will be connected via a standard supply, unless records indicate a larger supply.

3.5.1 Connection identification process checklist

3.5.1.1 Step 1: Identify the type of customer premises

Western Power categorises premises as:

- Standalone residential premises (including townhouses) are typically supplied through a Standard Supply arrangement.
- Small commercial premises are also typically supplied with Standard Supply.
- Medium, Large Commercial and Industrial premises will generally have connections larger than standard supply in a variety of arrangements. An example in older overhead areas is four bare overhead conductors terminating onto the Point of Supply, as shown in Figure 2.
- Underground connections are typically made within a uni-pillar, as shown in Figure 4. Small supermarkets or car service centres are examples of medium commercial. Large commercial installations include shopping malls or office buildings which normally use dedicated LV feeders or HV connections.
- Semi-rural and rural locations, such as farms or acreage properties, are typically supplied with rural standard supply.
- Private distribution systems (networks) can include apartment buildings, retirement villages, private estates and strata residential or commercial units on a single lot. Western Power can only assess the connection (PoS) of the private network to the SWIS. Western Power has no jurisdiction to assess connections within private networks. As such the IEG in the private network will be assessed based on the collective IEG capacity within the private network. Private supply arrangements are determined by the developer and need to comply with relevant Australian Standards. Although Western Power is unable to provide definitive information on such supply arrangements, it may be possible to obtain information from the relevant private network owner, body corporate, or strata company. IEG applications within private networks must be submitted to Western Power through the appropriate network owner.

In addition to identifying the type of premise, the location of the premise either in the metropolitan area, a small town or rural setting will also affect the characteristics of the supply arrangement.

In each of the above premise types it is possible to have a larger than Standard Supply. This can be achieved through an upgraded connection provided by Western Power at the customer's request and cost. Table 4 summarises of possible connection types for each category of customer premises.

Table 4: Possible connection types for various premises

Premise	Standard supply	Larger than standard supply on shared LV feeder	Dedicated LV feeder, contiguous supply and large (≥ 250 A) sole-use	HV connection
Residential metro	✓	Possible	✗	✗
Residential rural	✓	Possible	✗	✗
Small commercial	✓	✓	✗	✗
Large commercial	✗	✗	✓	✓
Industrial	✗	✓	✓	✓
Embedded networks	✗	✓	✓	✓

3.5.1.2 Step 2: Check network type

Overhead networks

Overhead networks are evident from distribution network poles and wires located in the road reserve along the street. An overhead LV customer connection consists of a service cable from the Western Power pole to the customer's mains connection box (MCB), located on the building or private pole. The size of Western Power's overhead service cable for a standard supply is typically 6 mm^2 for single- and three-phase supply arrangements. The Point of Supply for the overhead connection is contained within the MCB.

Details for larger overhead supply arrangements must be assessed individually however as a guide the size of the customer's boundary fuses may provide and initial indication of cable size and capacity.

A customer may also request an underground connection in an overhead distribution area. In such cases and subject to satisfaction of specific connection criteria a ground mounted pillar, connected to the overhead distribution network via a 25 mm^2 service cable can be installed inside the customer's property boundary.

This configuration is known as a pole-to-pillar connection and should be treated in the same way as a normal underground connection.

Pole-to-pillar connections have the benefits associated with an underground supply arrangement, but the connection capacity is limited to that of an overhead network. Pole-to-pillar connections are only available for residential premises and provide only a standard supply.

Figure 1: Single-phase overhead residential supply showing Point of Attachment and Point of Supply

Figure 2: Larger than standard supply - overhead three-phase (bare)

Underground networks

Underground networks can be identified by the absence of poles and wires in the street and the presence of green ground-mounted dome-shaped pillars on a corner of every second residential lot. An underground connection is made inside the pillar, which is typically located in close proximity and inside the customer's property boundary. The Point of Supply for an underground connection is within the pillar.

Mini pillars (320 mm diameter) are the most common type used in residential areas and typically provide standard supply. Mini pillars are not used in commercial or industrial areas.

Note: Pillars may only be accessed and opened by authorised personnel.

Figure 3: Mini pillar

Universal pillars (commonly referred to as uni pillars) have the same appearance as mini pillars but they are slightly bigger at 480 mm diameter. In residential areas, uni pillars are used for switching point in the LV network but can also provide standard supplies to residential premises. Commercial and industrial premises are commonly supplied with a dedicated uni pillar to provide a larger than standard supply on a shared LV feeder.

Figure 4: Uni pillar

Table 5: Typical supply arrangements based on connection types for various network topologies

Western Power equipment		Customer supply arrangement			
Network type	Connection made at / via	Standard supply	Larger than standard supply on shared LV feeder	Dedicated LV feeder, contiguous supply and large (≥ 250 A) sole-use	HV connection
Overhead	Insulated service cable from pole	✓	✓	✗	✗
Overhead	Bare conductors from pole	✗	✓	✓	✓
Overhead	Pole-to-pillar	✓	✗	✗	✗
Underground	Mini pillar	✓	✓	✗	✗
Underground	Uni pillar	✓	✓	✓	✗
Underground	Customer main switch board contiguous to Western Power transformer	✗	✗	✓	✗
Underground	Sole-use, Western Power-owned distribution transformer	✗	✗	✓	✗
Underground	Western Power metering transformer and customer-owned power transformer	✗	✗	✗	✓

Note: These connection types include current and legacy configurations for customer supply arrangements. All new connections and modification to existing connections will be designed and installed to the current standards.

3.5.1.3 Step 3: Identify the meter location

The meter location is important as it identifies the customer end of the consumer mains cable and is a critical reference point for determining the length and size of consumer mains and number of phases supplied. This information is essential for the voltage rise calculations required for IEG system compliance.[11]

[11] All meter locations are outlined in Section 11 of the WADCM.

3.5.1.4 Step 4: Identify metering type and number of phases supplied

The metering type is also important, as it indicates whether it is likely to be a Standard supply or a larger supply.

The number of phases in the supply arrangement may be identified at the meter. These can be single-, two- or three-phase supplies. Existing meters may include older style mechanical meters - These are unable to measure bi-directional current flow and as such are not suitable for embedded generation connections and will require replacement to enable the connection of IEG.

Meter types include (but are not limited to):

- Single-phase direct metered - two wires (Active and Neutral) from the service cable terminating onto the meter. Single-phase meters do not have terminations points available for more conductors.
- Single-phase 480 V direct metered - uses three-phase electronic meters, however only two Actives and one Neutral conductor terminate at the meter, leaving the two terminals for the third active conductor vacant.
- Single-phase 480 V direct metered - uses single-phase / three-wire mechanical meters with two Actives and one Neutral conductor terminate at the meter.
- Three-phase direct metered - four wires (three Actives and one Neutral) are provided via the service cable, terminating at a three-phase meter.
- Three-phase CT metered - the meter is not connected in series with the supply (as is the case with direct metering). Current transformers are used between the meter and the supply. This is commonly used in commercial and industrial installations when the installation is connected at low voltage for loads ranging from 100 A to 2,625 A per phase.
- HV metered - used when customers own their transformer(s) and associated HV switchgear.

Regardless of the number of phases present, a standard supply is always direct-metered, i.e. the consumer mains terminate directly onto the meter through the Service Protection Device (SPD). See the WADCM Section 11 for standard supply meter arrangements.

Table 6 lists metering types (described above) and the supply arrangements that can be used with each type of meter.

Table 6: Possible metering types for each supply arrangement

Metering type	Phase arrangement	Standard supply	Larger than standard supply on shared LV feeder	Dedicated LV feeder, contiguous supply and large (≥ 250 A) sole-use	HV connection
Direct metered[12]	1Ø	✓	×	×	×
Direct metered	1Ø 480 V, split-phase	×	×	×	×
Direct metered	3Ø	✓	✓ (up to 100 A)	×	×
CT metered - inside distribution board	3Ø	×	✓	✓	×
HV metered - Western Power metering	3Ø	×	×	×	✓

[12] A 480 V connection is not a standard supply arrangement. It consists of a 480 V supply, made up of a neutral conductor and two actives referenced at +240 V and -240 V, respectively. A 480 V supply capacity is generally equivalent to that of Standard Supply arrangements.

Metering type	Phase arrangement	Standard supply	Larger than standard supply on shared LV feeder	Dedicated LV feeder, contiguous supply and large (≥ 250 A) sole-use	HV connection
transformer					

4 Standard supply arrangement

4.1 General

Customers who have a standard supply are limited to the maximum generation limits, as shown in Table 7. These limits are the maximum permitted and based on evaluation of the typical characteristics of a standard supply and a shared LV network.

The application and approval processes for connection of IEG will evaluate the Point of Supply. In some cases, connection of an IEG of lower capacity will be approved; in others, an upgraded supply or different supply arrangement will be required.

Customers with a standard supply arrangement are on a shared network. These networks are designed based on the customer load demand to meet steady state voltage compliance, power quality and supply total customer demand.

It must be assumed that, the customer IEG system is not always available, therefore to maintain power quality and compliant voltage levels, the maximum load is considered when designing or assessing the network capacity. This ensures the network capacity is not exceeded should the customer's generation system be removed from service for any reason. Thus even though the Point of Supply may allow sufficient capacity, other limits linked to power quality and network performance requirements, may be exceeded by the proposed generation system. Tables 7 to 10 list the evaluation characteristics applicable to standard supply arrangements. Although certain evaluation characteristics may allow larger IEG systems, the evaluation characteristic resulting in the smallest IEG capacity will be the limiting characteristic.

Table 7: Standard supply arrangement - service apparatus connection limits

Connection phases	WADCM ref	Maximum IEG capacity	Notes
Single-phase	15.12.1	5 kVA	Subject to Technical Rules compliance check and site-specific constraints.
Three-phase	15.12.1	15 kVA	Subject to Technical Rules compliance check and site-specific constraints.

4.2 IEG limits

Table 8 lists the maximum IEG capacity for phase arrangements and summarises the key technical limits for evaluation of a Point of Supply's IEG capacity.

Table 8: IEG capacity evaluation limits at Point of Supply

Evaluation characteristic	Single-phase	Three-phase	Explanation
Maximum limit	5 kVA	15 kVA (balanced)	Limit defined in WADCM. This maximum limit considers specifications of current underground network design standards for residential subdivisions. It also considers the need to maintain balanced voltages and loads on the networks.
Maximum imbalance for 415 V three-phase connection	-	2.5 kVA between any phases	Technical Rules 3.7.2 (a). Note: for single-phase inverters, no more than 3 kVA can be installed on a three-phase supply arrangement. Larger capacities must be balanced to minimise impact on the local LV network.
Customer electrical installation current rating	Rated full load current of IEG shall not exceed the capacity of the upstream electrical installation.		The safety and protection of the electrical installation. Refer WADCM 15.7.1.
Voltage rise (evaluated at full export capacity of the system)			
Customer electrical installation (from IEG terminals to PoS)	2%	2%	WADCM 15.16.8.1. Industry best practise is 1%.
Service cable	1%	1%	Technical Rules 3.7.2 (c). WADCM 15.12.3.
Shared LV feeder	2%	2%	Technical Rules 3.6.8 (c). This evaluation includes aggregation of all IEG on the same feeder. Typically, it is checked in small sparse networks or where IEG penetration is high.

Table 9 summarises maximum IEG capacities for the most common transformer capacities used for standard supply arrangements.

Table 9: Typical IEG capacity by transformer size

Transformer capacity	Single-phase	Three-phase	Explanations
5 kVA (sole-use)	3 kVA	N/A	This assumes the customer's service cable is directly connected to the transformer. Typically customers connected to 5 kVA transformers have legacy customer supply arrangement limiting the size of IEG capacity to 3 kVA to avoid IEG causing power quality and voltage rise issues for the customer. This may cause inverters to disconnect affecting performance of IEG system.
10 kVA	5 kVA - Sole-use 3 kVA - Shared (up to 4 customers)	N/A	These transformers are used only for standard supply arrangements and are single-phase supply (see Table 8). Multiple customer connections share the transformer capacity for load and generation. 3 kVA is based on typical behaviour of load and generation, including some diversity.
25 kVA	5 kVA - Shared up to 6 customers	5 kVA	Note: Sole-use customers with 25 kVA transformers are not considered to be standard supply arrangements and are subject to the provisions described in Section 5.
63 kVA	5 kVA	5 kVA	Three-phase customers are limited due to the small transformer capacity, which is shared with other customers.
> 63 kVA	5 kVA	8 kVA	Typical IEG capacity for three-phase standard supply customers is limited, due to the 30% allocation of the shared asset.

Note: The connection may be further limited if the number of customers exceeds those listed above.

Appendix B contains reference data for the most common types of distribution network transformers.

4.2.1 Hosting capacity

The general hosting guideline used for the assessment of all generation connected to a shared LV distribution network, is the lesser of 30% of:

- transformer capacity
- LV feeder capacity.

When 30% is exceeded further evaluation is performed to confirm additional IEG does not negatively impact the network or other customers. If the impact of the proposed IEG exceeds any limits, the capacity of the IEG systems allowed to connect may be limited or alternatively the customer, at their cost, may apply for a suitable network upgrade.

4.3 Single-phase 480 V or split-phase connections

A single-phase 480 V or split-phase supply arrangement has been used for customer supplies in rural and remote areas supplied by a single-phase HV distribution network. This type of supply arrangement provided for customer equipment that required more power than available in single-phase 240 V arrangements. Typically used for some electric pumps and electric motors used for various farm equipment.

The need for this type of supply arrangement is no longer deemed relevant given the advances in motor starting technology.

Where a customer has a 480 V supply arrangement and wishes to connect an IEG, it is preferred that a customer change to single-phase and apply for single-phase IEG.[13] Where this is not practical, the following applies:

- For split-phase customers requesting ≤ 1.5 kVA of inverter capacity, a single inverter may be used.
- For systems larger than 1.5 kVA, two inverters of equal size must be used, balanced across the two phases.

Total IEG capacity for 480 V connections shall be < 10 kVA, subject to hosting capacity and voltage rise checks.

Table 10 summarises evaluation parameters applicable to single-phase 480 V or split-phase supply arrangements. Although some parameters may allow for larger IEG, the parameter which results in the lowest IEG capacity is the limiting parameter.

Table 10: Evaluation of IEG capacity at Point of Supply based on 480 V supply arrangements

Evaluation parameter	Single-phase 480 V or Split-phase	Explanation
Maximum limit	1.5 kVA single-phase	Where only one single-phase inverter is used (see below: maximum limits based on transformer size).
Maximum imbalance	2.5 kVA	Technical Rules 3.7.2 (a).
Customer Electrical installation current rating	Rated full load current of IEG shall not exceed the capacity of the upstream electrical installation	The safety and protection of the electrical installation. WADCM 15.7.1.
Voltage rise	These supply arrangements are more likely to be sensitive to voltage imbalance and voltage rise issues.	
Customer Electrical installation (from IEG terminals to PoS)	2%	WADCM 15.12.3. WADCM 15.16.8.1. Industry best practise is 1%.
Service cable	1%	Technical Rules 3.7.2 (c). WADCM 15.12.3.
Shared LV feeder	Not applicable	These supply arrangements should only be for use sole-use situations, so no LV feeders are used.
5 kVA sole-use transformer (480 V / split-phase)	3 kVA (i.e. two 1.5 kVA inverters)	Balanced across the split-phase's two 240 V supplies
10 kVA sole-use transformer (480 V / split-phase)	6 kVA (i.e. two 3 kVA inverters)	Balanced across the split-phase's two 240 V supplies
25 kVA sole-use transformer (480 V / split-phase)	10 kVA (i.e. two 5 kVA inverters)	Balanced across the split-phase's two 240 V supplies

13 See Western Power's website for information on upgrading residential and commercial connections.

Evaluation parameter	Single-phase 480 V or Split-phase	Explanation
> 25 kVA	Not applicable	

5 LV-connected, greater than standard supply arrangement on shared feeders

5.1 General

When the supply arrangement is identified as having a capacity larger than a standard supply on a shared LV feeder the following section applies to the connection of IEG at the customer's Point of Supply.

Supply arrangements larger than standard supply are always[14] provided as a three-phase arrangement, with service apparatus and network equipment in accordance with DSM 1-03.

Generally, a technical assessment is initiated for all systems greater than 5 kVA to assess the direct impacts on the customer's Point of Supply and the distribution network. The maximum IEG capacity for these larger PoS is determined by the impact of the IEG on the steady state voltage and power quality on the shared LV feeder for all customers. When the total collective IEG capacity of all customers on the feeder exceeds 30% of the shared feeder capacity then a more detailed technical assessment is required to consider the aggregated impacts.

Typically, an underground feeder's maximum load capacity is 315 A (approximately 220 kVA) based on current design standards. On a shared LV feeder the largest supply to a single customer is 250 A.[15] A 250 A supply is an approximate load capacity of 180 kVA and typically, the other assessment criteria (voltage rise, step changes, etc.) limit the total IEG capacity to less than this. Also the collective impacts from all IEG on the feeder to all customer connections on that shared feeder or transformer become significant.

Supplies exceeding 250 A typically require a substation to be installed on the customer's property[16] and a dedicated LV feeder with contiguous supply arrangement to be used; the same requirement applies to IEG exceeding 250 A (or 180 kVA).

5.2 IEG limits

Table 11: Evaluation limits for IEG based on supply arrangement

Evaluation characteristic	Three-phase	Explanation
Customer electrical installation current rating	Rated full load current of IEG shall not exceed the capacity of the upstream electrical installation	The safety and protection of the electrical installation. WADCM Section 15.7.1.
Voltage rise (evaluated at full export capacity of the system)		
Customer electrical installation (from IEG terminals to PoS)	2%	WADCM Section 15.16.8.1. Industry best practise is 1%.
Service cable	1%	Technical Rules 3.7.2 (c). WADCM 15.12.3.
Shared LV feeder	2%	Technical Rules 3.6.8 (c). This evaluation includes aggregation of all IEG on the same feeder.

14 With the exception of rural areas where only a single-phase network is available

15 See DSM-1-03 (sheet 2 of 2).

16 WADCM Section 14.1.

Table 12: Example of IEG capacity limits based on supply arrangement

Example LV Customer Connection	Ref	Network type	Typical IEG capacity	Example LV Customer Connection)
80 A Overhead (maximum of 58 kVA)	Legacy standard	Overhead 16 mm^2 service cable to 80 A MCB	18 kVA (approx. 30% of load allocation)	District
100 A supply Uni Pillar LU11 (maximum of 72 kVA)	DSM[17]1-03	Shared underground LV street circuit Note: 100 A to 250 A	22 kVA (approx. 30% of load allocation)	District
200 A supply Uni Pillar LU11 (maximum of 144 kVA)	DSM1-03	Shared underground LV street circuit Note:100 A to 250 A	44 kVA (approx. 30% of load allocation)	District

5.2.1 Hosting capacity

The general guideline used for the assessment of generation connected to large customers on a shared LV distribution network is the lesser of 30% of:

- transformer capacity
- LV feeder capacity
- Point of Supply capacity.

When 30% of the network asset capacity is exceeded a further evaluation is required to confirm the proposed IEG does not negatively impact the network or other customers. If the impact of the proposed IEG exceeds any limits, the capacity of the IEG systems allowed to connect may be limited or alternatively the customer, at their cost, may apply for a suitable network upgrade.

The most common district transformer in the overhead network has a rating of 200 kVA (largest used is 315 kVA) which limits the connection capacity available to large customers and also the maximum aggregated IEG size on a shared overhead feeder. Available capacity for a customer's IEG system would be proportionate to the share of transformer capacity available to the customer.

5.2.2 Additional guidance for IEG exceeding 30 kVA

IEG systems on a shared LV feeder may not exceed 150 kVA (200 A) in capacity. As a minimum, any system exceeding this threshold must have a dedicated LV feeder; however a sole-use distribution substation may be required, depending on the proposed IEG capacity. See Section 0 for information on the requirements for connections of this type.

For IEG systems up to 150 kVA that meet the requirements listed Table 3, a single external protection relay is required as close as practical to the Point of Supply.

No Neutral Voltage Displacement (NVD) protection is required for IEG systems up to 150 kVA on a LV Point of Supply. IEG systems larger than 150 kVA need to implement an NVD protection scheme. NVD protection is a form of earth fault protection use to detect HV distribution systems earth faults and is used to prevent embedded generation from generating when a fault is present on the HV distribution network.

[17] http://www.westernpower.com.au/land-developers-designers-distribution-substation-manual.html

6 Dedicated LV feeders, contiguous supply arrangements and large (≥ 250 A) sole-use supply arrangements

6.1 General

When the supply arrangement is identified as being a dedicated LV feeder, a customer switchboard contiguous to a Western Power distribution substation or a sole-use distribution substation, the following section applies to the connection of IEG at the customer's Point of Supply.

Typically, an underground feeder's maximum load capacity is 315 A (or approximately 220 kVA), based on current design standards. A dedicated LV feeder is the minimum supply arrangement for a supply greater than 200 A.

Supplies greater than 250 A typically require the installation of a substation on the customer's property and a contiguous customer switchboard. Various large LV supply arrangements can be found in the Western Power DSM Section 1 and DSM-1-04 through DSM-1-09, with the relevant substation equipment in the DSM Section 3.

Substations may either be district (shared by many customers) or sole-use.

District substations are shared by other customers in the area. Therefore, the hosting capacity of the transformer available to that customer shall be taken into account when designing the IEG system. The maximum IEG capacity for these large dedicated PoS is determined by both the PoS capacity and any impact of the IEG on the steady state voltage and power quality of the shared transformer for all customers supplied by that transformer. When the total collective IEG capacity of all customers supplied from that transformer exceeds 30% of the transformer capacity, a more detailed technical assessment is required to consider the aggregated impacts.

Sole-use transformers are not sized using a diversity factor because they supply only a single customer. Therefore the transformer is sized to meet the maximum demand of the customer. As such customers supplied via a sole-use transformer may consider IEG systems up to the rating of the transformer, provided all other technical requirements for the IEG system are satisfied.

Supply arrangements larger than 4 MVA are required to be connected to the HV distribution network, although HV connected supply arrangements for supplies less than 1 MVA is also available.

6.2 IEG limits

In general, LV-connected customers on dedicated connections to a District transformer potentially can have exporting capability to the rating of the PoS, provided full compliance with the Technical Rules requirements is maintained for voltage and quality of supply at the PoS.

Each case is assessed at application stage for compliance. Table 13 provides some indication as to various dedicated customer supply arrangements, their max capacity as well as typical IEG capacity.

Table 13: Dedicated supply arrangements and capacities

Example LV Customer Connection	Ref	Network type	Typical IEG capacity	Substation Customer is Connected to
200 A Supply Uni pillar (LU11) or Wall box (LU35) (Maximum of 144 kVA)	(DSM1-04)	Dedicated LV underground street circuit	100 kVA	District
250 A Supply Wall box (LU35) (Maximum of 180 kVA)	(DSM1-04)	Dedicated LV underground street circuit	120 kVA	District
315 A Supply Uni pillar (LU11) (Maximum of 227 kVA)	(DSM1-04)	Dedicated LV underground street circuit	150 kVA	District
Supplies larger than 315 A up to up to 2500 A via LV Kiosk	(DSM1-05) (DSM1-06)	Customer M.D.B Contiguous with District substation with Dedicated LV circuit to customer	> 70 kVA	District (on or adjacent to customer property)
Sole-use substation and LV kiosk on customer's premises. Transformers from 25 kVA to 2 x2 MVA in groups of two 1 MVA transformers each.	(DSM1-07) (DSM1-08) (DSM1-09)	Sole-use substation with customer M.D.B Contiguous to substation. No street feeds supplied form substation.	Up to the rating of the transformer or transformer group provided all other technical requirements are met.	Sole-use substation / transformer

6.2.1.1 Hosting limits

The general guideline used for the assessment of generation connected to large customers with dedicated supply arrangements from a shared transformer is the lesser of 30% of the:

- transformer capacity
- Point of Supply capacity.

When 30% of the network asset capacity is exceeded, further evaluation is required to confirm additional IEG does not negatively impact other customers on the shared transformer. If the impact of the proposed IEG exceeds limits the capacity of the IEG systems allowed to connect may be limited or alternatively the customer, at their cost may apply for a suitable network upgrade.

6.2.2 Additional guidance for IEG exceeding 30 kVA

Depending on the size of the proposed IEG system, a sole-use substation may be required if the proposed IEG cannot comply with all technical requirements for voltage rise and power quality on a shared transformer.

For IEG systems up to 150 kVA that meet the requirements listed in Table 3, a single external protection relay is required as close as practical to Point of Supply.

No Neutral Voltage Displacement (NVD) protection is required for IEG systems up to 150 kVA on a LV Point of Supply. IEG systems larger than 150 kVA need to implement an NVD protection scheme. NVD protection is a form of earth fault protection use to detect HV distribution systems earth faults and is used to prevent embedded generation from generating when a fault is present on the HV distribution network.

7 HV (>1 kV) connections

7.1 General and IEG limits

A customer installation with a HV supply arrangement requires a determination of the actual connection capacity provided to the customer. The maximum IEG capacity that can be connected is determined by various factors including;

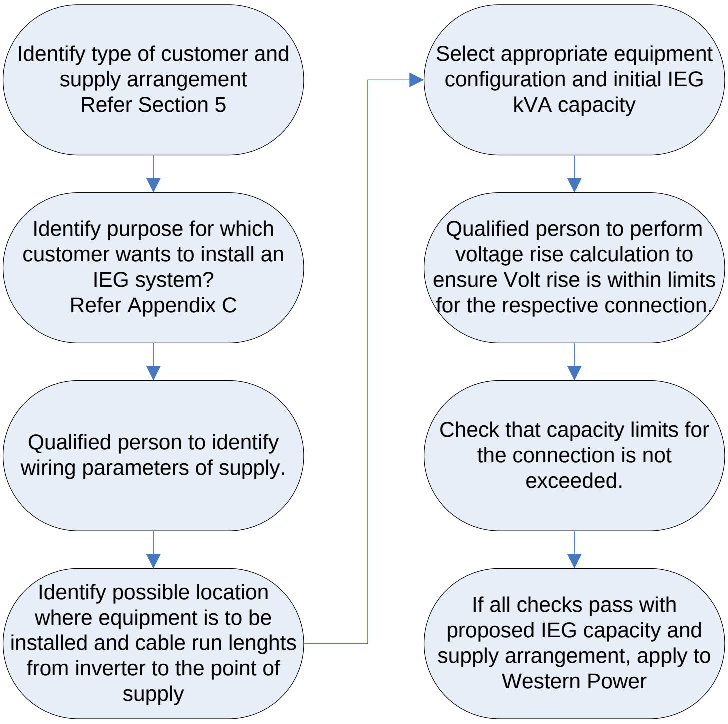
- the LV electrical installation to which the IEG will be connected
- rating of customer-owned transformer/s
- HV connection capacity
- compliance with relevant regulations and rules.

Generally, Western Power has no information of customer installation ratings and will assess the requirements for connection of the IEG at the Point of Supply which is at HV.

Appendix A Application assessment process

The information in this appendix is general in nature and should not be relied upon as a substitute for independent research and professional advice. Figure 5 provides basic high level steps for the suitably qualified electrical contractor or electrical engineer for assessing a customer's Point of Supply for a particular IEG system. These steps are not exhaustive and individual projects may require additional checks.

Figure 5: Basic assessment steps for an IEG connection



Western Power's website contains additional information on the application assessment process.

Appendix B Transformer reference data

This appendix lists key characteristics of the most common types of distribution transformers in the Western Power network.

Western Power advises against making any assumptions in relation to any transformer's available capacity for the connection of generation based on this information.

Table 14: Ground-mounted transformers

Stock number	Nameplate rating (kVA)	Secondary voltage (V)	Phases
XA2163	160	440	3
XA2177	160	440	3
XA2183	160	440	3
XA2164	160	440	3
XA2178	160	440	3
XA2184	160	440	3
XA2215	160	440	3
XA2165	315	440	3
XA2171	315	440	3
XA2185	315	440	3
XA2166	315	440	3
XA2172	315	440	3
XA2186	315	440	3
XA2201	315	440	3
XA2202	315	440	3
XA2167	500	440	3
XA2173	500	440	3
XA2187	500	440	3
XA2168	500	440	3
XA2174	500	440	3
XA2188	500	440	3
XA2203	500	440	3
XA2204	500	440	3
XA2169	630	440	3
XA2175	630	440	3
XA2189	630	440	3
XA2170	630	440	3
XA2176	630	440	3
XA2190	630	440	3
XA2217	630	440	3
XA2218	630	440	3
XA2220	750	440	3
XA2221	750	440	3
XA2225	750	440	3
XA2226	750	440	3
XA2191	1000	440	3

Stock number	Nameplate rating (kVA)	Secondary voltage (V)	Phases
XA2192	1000	440	3
XA2205	1000	440	3
XA2207	63	440	3
XA2200	63	440	3
XA2206	63	440	3
XA2136	25	500 / 250	1
XA2137	25	500 / 250	1
XA2138	25	500 / 250	1
XA2210	50	500 / 250	1
XA2211	50	500 / 250	1
XA2209	50	500 / 250	1
XA2208	50	500 / 250	1
XA2259 - (IPS)	630	440	3
XA2260 - (IPS)	630	440	3

Table 15: Pole-top transformers

Stock number	Nameplate rating (kVA)	Secondary voltage (V)	Phases
XT0008	25	440	3
XT0030	25	440	3
XT0035	25	440	3
XT0143	63	440	3
XT0140	63	440	3
XT0141	63	440	3
XT0127	100	440	3
XT0032	100	440	3
XT0038	100	440	3
XT0010	200	440	3
XT0033	200	440	3
XT0039	200	440	3
XT0184	315	440	3
XT0182	315	440	3
XT0181	315	440	3
XT0007	10	500 / 250	1
XT0018	10	500 / 250	1
XT0022	10	500 / 250	1
XT0026	10	500 / 250	1
XT0020	25	500 / 250	1
XT0024	25	500 / 250	1
XT0029	25	500 / 250	1
XT0040	25	500 / 250	1
XT0194	10	500 / 250	1
XT0197	25	500 / 250	1

Appendix C Connection configurations - energy storage systems

Energy storage systems may be installed for a variety of purposes, including:

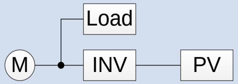
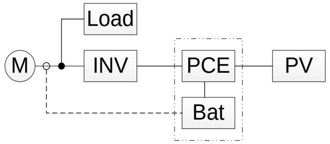
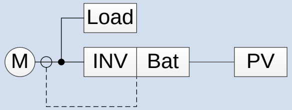
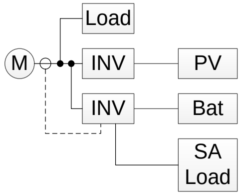
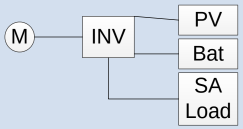
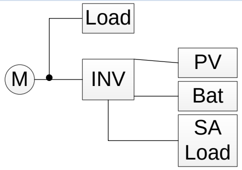
- supplying energy to the customers load or exporting to the network at times when no generation is available
- self-consumption with excess export
- self-consumption with zero export
- backup power for partial site load or critical loads
- off-grid or stand-alone operation.

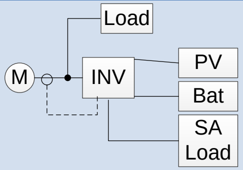
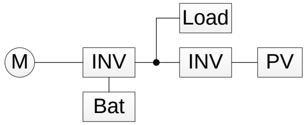
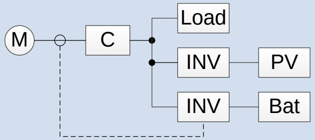
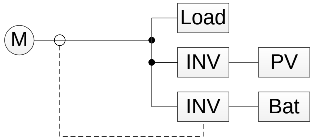
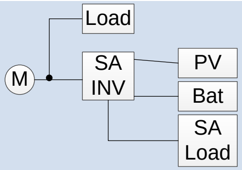
Table 16 lists the different applications for which energy storage may be installed, referenced against recommended configurations from Table 17. (Table 17 includes additional detail on each configuration and what each allows the customer to achieve.)

Table 16: Various purposes for installing energy storage

Purpose for installing IEG	Description	Suitable topologies (ref: Table 17)
Export	Typically consist of only PV array and inverter. The inverter will output as much energy as available from the PV array up to the rating of the inverter. The energy will first supply the customer's load and the balance if any will be exported to the network. This configuration could also be used for other energy sources. Export power from other energy source or an energy storage system is also possible.	1
Self-consumption with excess export	Typically includes PV array and a form of energy storage. Energy produced from the PV array is first used to supply the customer's load and remaining energy is then stored in the storage device and once full the excess energy, if any, is then exported onto the network. The storage device is typically not charged from the network nor discharged onto the network.	2 3 4 5 10
Self-consumption with no export	Same as for Self-consumption with excess export, however the system is set up so that when the storage device is full, the system is throttled so as not to export energy onto the network.	2 3 4 5 6 7 8 10 11
Backup power for only partial site load or critical loads.	A stand-alone inverter or one with a stand-alone port is used to supply power to limited customer loads from a storage device when the Network is off. This may be used as a UPS for critical loads. Prioritises the charging of storage and supply of customer load before exporting to the network.	4 6 7
Off-grid operation. Alternative supply to entire site, allowing entire site to operate independent from the network.	This allows the entire site to be supplied from a storage device even when disconnected from the network. These systems typically do not export any excess power to the network once the storage is full.	8 9 11

Table 17: Various configurations for energy storage systems and their possible uses

ID	Configuration	IEG System	Network Energy	Export	Export control	Self-consumption	Stand-alone load support
1		Standard PV installation	All excess energy to network	Export excess generation	✗		✗
2		Standard PV with additional storage (note- can be retrofitted to any standard system)	Excess PV energy charges battery for time shifting load. Some export after battery charged.	Minimise export of excess energy Preference to charge battery to time shift use	✓ Uses external measurement	✓	✗
3		PV Inverter with battery port or integrated battery	Excess PV energy charges battery for time shifting load. Some export after battery charged	Minimise export of energy. Preference to charge battery to time shift use	✓ Uses external measurement	✓	✗
4		Standard PV with additional Battery inverter system	Load and battery charging priority over network export	Minimise export of energy Provide stand-alone power to essential loads	✓ Uses external measurement	✓	✓
5		PV & Battery inverter system	Load and battery charging priority over network export	Minimise export of energy Provide stand-alone power to site loads	✓ Internal to inverter	✓	✓ Inverter system provide Alternative supply to Load
6		PV & Battery inverter system	SA Load and battery charging priority over other loads and network export	Minimise export of energy Provides stand-alone power to essential loads	✓ Internal to inverter Typically allows excess PV to be exported only	✗ Can provide some self-consumption but mostly configured for load backup	✓ Inverter system provide Alternative supply to partial site Load

ID	Configuration	IEG System	Network Energy	Export	Export control	Self-consumption	Stand-alone load support
7		PV & Battery inverter system	Load, SA Load and battery charging priority over network export	Minimise export of energy Provides stand-alone power to essential loads	✓ External to inverter		✓ Inverter system provide Alternative supply to partial site Load
8		Battery inverter with PV and Load	Load and battery charging priority over network export	Minimise export of energy Provide stand-alone power to all loads	✓ Internal to inverter	✓	✓ Inverter system provide Alternative supply to Load
9		Standard PV system with additional Battery system with external Alternative supply	Load and battery charging priority over network export	Minimise export of energy Provide stand-alone power to all loads	✓ Uses external measurement	✓	✓ This is an Alternative supply arrangement which allows complete site to disconnect from network
10		Standard PV system with additional Battery system	Load and battery charging priority over network export	Minimise export of energy	✓ Uses external measurement	✓	✗
11		Stand-alone inverter system with no network integration	Network used as charging source only and is not bi-directional	None	N/A		✓ This is an Alternative supply arrangement which allows complete site to disconnect from network

Legend

(M)	**Meter**
Load	Normal site load
INV	Inverter system
Bat	Battery or other energy storage
SA Load	Stand-alone load (for uninterrupted supply in case of network failure)
PCE	Power conditioning equipment (e.g. DC to DC controller for PV Array battery charging)
	power flow measurement system
C	changeover switching arrangement
SA INV	Stand-alone inverter
PV	PV array or other energy source

Notes:

- **The stand-alone load consists of electrical appliances and customer equipment that is powered by the inverter in a stand-alone mode after the network supply is removed. It is sometimes referred to as UPS load, critical or emergency load. Typically the load is supplied through a port on the inverter either from the inverter energy source or from the network source when network supply is available.**
- **Port is terminology that refers to an electrical connection for either input or output of an electrical signal or power on an inverter. Typical ports name on these inverters include: -grid-connect, stand-alone, battery, PV.**
- **Alternative supply is where the load is capable of being supplied from an alternative source when the normal supply is removed. The term alternative supply is used to align with the use in AS/NZS 3000**
- **Typically export control is used to maximise the self-consumption and avoid export to the network. The type of tariff the customer chooses will determine the ability of the system to export energy**
- **Meter refers to the utility meter installed for the installation energy consumption and generation.**

Appendix D Alternative IEG sources

Wind turbines are available and have been installed as IEG systems connected to the Western Power network. They are not commonly used due to the need for a constant wind resource and it also involves complex site evaluation, preparation and installation. The mechanical nature of generation requires higher level of maintenance and on-going servicing compared to PV systems. In some cases it can require significant structures and may require additional approvals from local councils.

Hydroelectric systems traditionally require running water courses and typically require a dam. Energy storage may also be done in the form of pumped hydro systems which require two reservoirs at different elevations. Although these natural resources are rare in Western Australia their connection to the network using a correctly designed IEG interface is possible.

Fuel cells are electrochemical energy conversion devices that convert alternative fuels (including hydrogen and oxygen) into electricity, heat, and water. Fuel cells may be considered similar to an energy storage systems and have been trialled in Western Australia and connected to the Western Power network previously. The technology is more suited to larger scale generation, typically exceeding 100 kVA.

Geothermal power stations use heat from the earth's core, a couple of kilometres or more below the earth's surface, to produce steam to drive a conventional steam generator. Geothermal systems require significant infrastructure to implement but can in concept be interfaced to the network using IEG technology.

Wave energy systems generate electricity by converting ocean swell (wave) energy into electricity. One type uses a buoyancy unit, fixed to a pump on the ocean floor, follows the vertical movements of the waves to drive a pump which drives an electrical generator. Wave energy systems of this type have been successfully trialled in Western Australia and connected to the SWIS via inverters. There is other wave energy systems type being trialled around the world.

Micro-turbines fuelled by natural gas can be an attractive bi-generation system for applications in which both electricity and heat generation is required. The gas-fired turbine drives a high frequency electricity generator which can be effectively interfaced to the network via inverter technology.

Bio-gas (primarily methane) is a by-product of the fermentation of organic matter in the absence of oxygen. While it is commonly harvested from landfill sites, bio-gas may also be produced in sealed reactor vessels. As methane is flammable, it can power electric generators which typically use conventional generation techniques to interface to the network. However, they may also be interfaced with the network via inverter technology to create an IEG system.

Appendix E Definitions of terms

Term	Definition
After Diversity Maximum Demand (ADMD)	The calculated maximum demand for a proposed load with a suitable diversity factor applied to forecast the likely continuous power demand.
Alternative supply	A system capable of providing an alternative electricity supply to the normal electricity supply.
Contestable	Customers permitted to choose their retailer because they consume more than 50 MWh per year (an average of 137 kWh per day).
CT	Current transformer.
Distribution HV	Distribution High Voltage - voltage levels used on the Western Power distribution network (6.6 kV, 11 kV, 22 kV and 33 kV)
District substation / District transformer	A District substation is a distribution substation with LV connections to the street mains. In most cases, it is limited to 2 MVA and is available to customers who will not cause interference problems to other customers connected to the same LV network.
Embedded generator	An embedded generator is any form of generator which is connected to (or embedded in) an electrical distribution network.
Private network	A distribution network that is supplied through a connection to Western Power's distribution network, rather than through a connection to the transmission network.
Inverter Embedded Generator (IEG)	An embedded generator that connects to the Western Power network via an inverter.
IEG penetration	Total inverter capacity (kVA) / (Transformer rating kVA).
Inverter	An electronic device that changes an energy source's electrical output to a 50 Hz alternating current (AC) compatible with network requirements.
Island / Islanded network	A part of the network or a customer's installation that remains energised and operating when the main supply from the network has been switched off.
kVA	kilo Volt Ampere - the unit used for apparent power in an electrical circuit is "Volt Ampere". For inverters and connections, it is used to indicate the apparent power transfer capability of the connection or inverter.
HV	Voltages exceeding 1000 V AC.
LV	Low Voltage - voltages above 50 V AC but below 1000 V AC. Typically used to refer to a 240 V or 415 V supply.
OH	Overhead.
Point of Attachment (PoA)	The point at which aerial conductors of an overhead service cable or aerial consumer mains are terminated (secured) on the customer's structure.
Point of Supply (PoS)	The junction of the consumer mains with the conductors of the distribution system.
PV	Photovoltaic (or "solar") cells
Service apparatus	Any works, apparatus or system capable of being or intended to be used for conveying, measuring or controlling electricity supplied from a Network Operator's distribution system to the Point of Supply, inclusive of Network Operator-owned metering equipment.
Service cable	An overhead line operating at below 1000 V, generally located between the network's overhead line and an electrical installation's Point of Supply.
SPD	Service Protection Device.
Stand-alone	The ability of an inverter to supply load without a healthy network voltage being available, creating an islanded network.
Standard supply	240 V single-phase (+/- 6%) or 415 V three-phase (+/- 6%), limited to: ● 63 A single-phase (Perth metropolitan and SWIS major regional centres); or ● 32 A single-phase (rural areas); or ● 32 A per phase for multi-phase (SWIS); ● Maximum size of consumer mains cable shall not exceed 35 mm^2.
Supply arrangement	The type and configuration of a customer's connection to the Western Power network.

SWIS	South West Interconnected System.
Technical Rules	The detailed technical requirements (approved by the Economic Regulation Authority) to be met by Western Power on the transmission and distribution networks and by customers connecting facilities to these networks.
UPS	Uninterruptable Power Supply.
UDS	Underground Distribution Scheme Manual (published by Western Power).
WADCM	West Australian Distribution Connections Manual (published by Western Power).