Battery Inverter Energy System (IES) Requirements

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Contents

Document control

Endorsement approvals

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Record of revisions

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0	16th June 2017	Nigel Wilmot	Initial Version
1	1st August 2017	Nigel Wilmot	Updated terminology and minor corrections

1 Introduction

Western Power supports customer choice to introduce home energy systems such as solar and battery technology to complement their existing electricity supply.

Most home energy systems still rely on the network to provide key services such as frequency stability, surge current for motor and appliance starting and fault current to operate circuit breakers. The Western Power network also provides a backup energy source if a home energy system is exhausted or does not meet a customer's full energy needs.

Western Power aims to provide leadership in setting the standards/rules to ensure customers can connect their home energy systems in a safe manner that:

- is technically feasible
- satisfies customers' energy needs
- ensures we can utilise the network as an energy trading platform
- maintains the essential role of the grid in the community
- does not impact cost or service levels for other network customers

These Battery Inverter Energy System (IES) requirements will be used to update requirements and guidance for energy storage systems published in the Network Integration Guideline for Inverter Embedded Generation. This document provides interim guidance to assist industry and customers to design suitable energy storage systems for integration with the Western Power network until the Network Integration Guideline is updated.
Electric vehicle requirements and charging regimes are not covered by this document. However, any electric vehicle to grid systems would be considered in a similar way as a Battery IES. Please use the inquiry form on the Western Power website to initiate request for requirements.

2 IES requirements

All IES[1] shall comply with current AS/NZS 4777 series of standards and the requirements of Western Power. This includes complying with requirements for:

- Voltage balance
- Voltage rise
- Power quality (including harmonics, flicker and voltage fluctuations)
- Connection capacity/rating.

In addition to the above requirements IES with energy storage systems are required to have the following functionality to integrate with the Western Power network. The key areas include:

- Export limiting (used for energy self-sufficiency also known as self-consumption)
- Site generation capacity
- Voltage response requirements
- Time-based requirements
- Frequency response requirements

2.1 Export control

The export control mode is used to limit the export through the customer point of supply (PoS) to the grid. Export control is used to manage generation from the PV IES that exceeds the site load to prioritise charging batteries (i.e. store energy). This stored energy is then used to reduce peak load at a later time up to the site generation capacity. The export control mode may be used to meet customer specifications for managing energy use and/or energy storage. The requirements for export control are:

- Requirements of AS/NZS 4777.1:2016 clause 3.4.8 apply to any export limiting schemes
- Western Power does not specify export limits for PV IES.
- Export limits for 3 phase supply arrangements with battery IES may apply (see Table 1)
- Retailers' requirements where applicable need to be met

To enable energy trading in the future export capability from IES to the grid will be required. How this will work is still being developed. Western Power generally permits export from all generation to the grid.

In application of these requirements if an export limit is required by customer or retailer then any change in IES operation based on a voltage response or time based operation does not override the export limit.

2.2 Site Generation Capacity

The site generation capacity depends on the connection arrangement for customers and aligns with typical limits stated in the Network Integration Guideline for Inverter Embedded Generation. The site generation capacity is used to determine the generation limit applicable to each site. The following Table 1 provides various configurations of IES and the typical generation limits for each Battery IES configuration and supply arrangement. The requirements for the generation limit are:

(a) The generation limit is the allowed maximum concurrent output level to the AC installation from all inverter energy systems on site.
(b) The generation limit and the combined effect of operation of the IES shall not exceed the hosting capacity of the point of supply.
(c) All requirements and limits shall apply at the Point of supply. (Voltage Management, Unbalance, Power quality, voltage fluctuation and step changes etc.)
(d) The total inverter capacity on site may exceed the generation limit.

[1] IES is the same definition as in AS/NZS 4777.1:2016. Inverter Embedded Generation includes all the IES at a single point of supply. Use of the term IES in this document may refer to a single IES or multiple IES connected to the same Western Power point of supply. Any requirements are applied to all IES at a point of supply.

In all modes of operation of the IES the site generation capacity is not to be exceeded.

2.3 Voltage response

The required voltage response is dependent on the energy storage level and required mode (e.g. fully charged status battery can discharge and generate but won't be able to charge to act as a load). The voltage response requirements are:

- For voltages under 220 V,
  - reduce charging of BESS
  - increase generation from BESS,
  - Volt-watt mode enabled for charging through the grid-connect port of the Inverter AS/NZS4777.2 cl 6.4.3, V_2 = 220 V (required)
- For voltages over 250 V,
  - increase charging of BESS or,
  - reduce generation from BESS and PV ,
  - Volt-watt mode for generation AS/NZS4777.2 cl 6.3.2.2 V_3 = 250 V (required)
- Figure 1 Shows the alignment of modes of operation for IES and Battery IES with voltage range on Western Power network

A response to a voltage condition is a higher priority than time based operation. The response to the lower voltage requirements for most customers will only occur at time of maximum demand across a network. The response to higher voltage requirements will occur more often where networks have excess generation. Where a customer has implemented export limits to or charge limits from the grid in their BESS these voltage response requirements shall not override those customer limits, however, the Volt-watt modes still apply under those conditions.

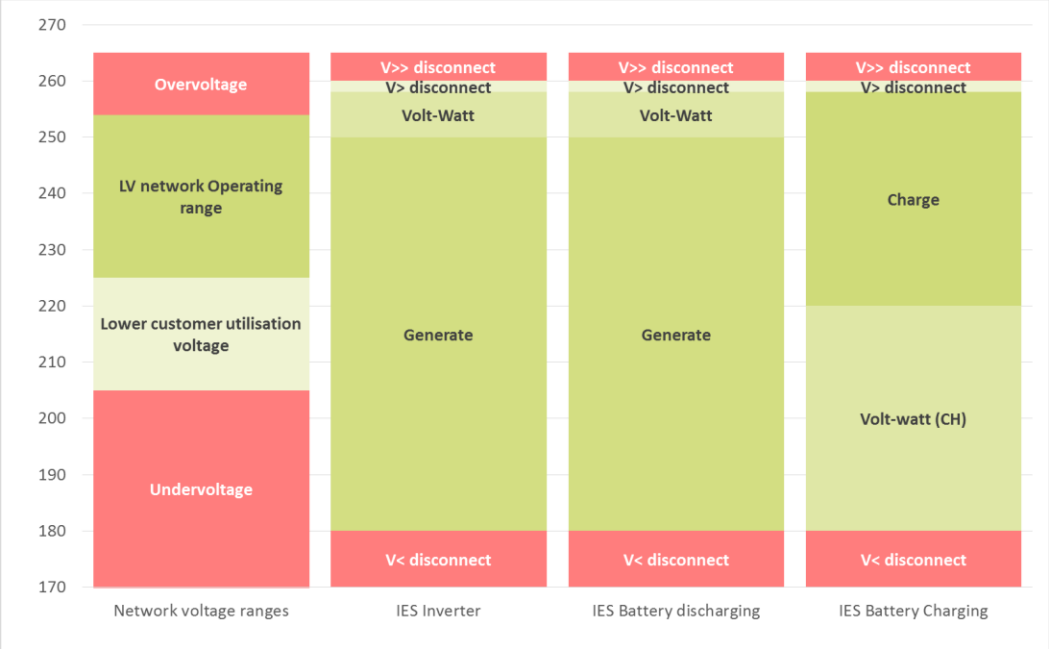


Figure 1 Voltage requirements for different modes of operation of IES with Batteries[2]

2.4 Time based operation

The time based operation has been determined based on typical residential load patterns and is provided so that battery IES can be managed in coordination with typical grid operation. The following time bands are provided to determine the operational behaviour of battery IES on the grid:

[2] Volt-watt(CH) is the Volt-watt response mode for charging energy storage as required by AS/NZS 4777.1:2016 clause 6.4.3. Other IES modes are also as defined in AS/NZS4777.1:2016 (V>>, V>, V< and Volt-watt)

- Between 6 am to 10 am is a minor peak load period and before excess solar generation is available. Avoid charging during this time if battery charge level is greater than 50%.
- Peak PV generation in residential networks 10 am to 2 pm, during this time charging of battery or net generation reduction is required as shown in Figure 2.
- Between 2 pm and 4 pm is transition between excess solar and peak load. This may vary during year and may change with each customer.
- Peak load time in residential networks is approximately 4 pm to 9 pm during this time discharging batteries or net-load reduction is required as shown in Figure 2.
- Between 9 pm and 6 am battery can operate up to the site generation capacity or required charge rate.

The customer may choose operational modes and time to align with Time of Use (TOU) tariffs provided by retailers. The customer may also change operation due to amount of storage available or load being supplied from grid (e.g. may delay discharging to later in the afternoon to manage own peak after returning from work after 5 pm).

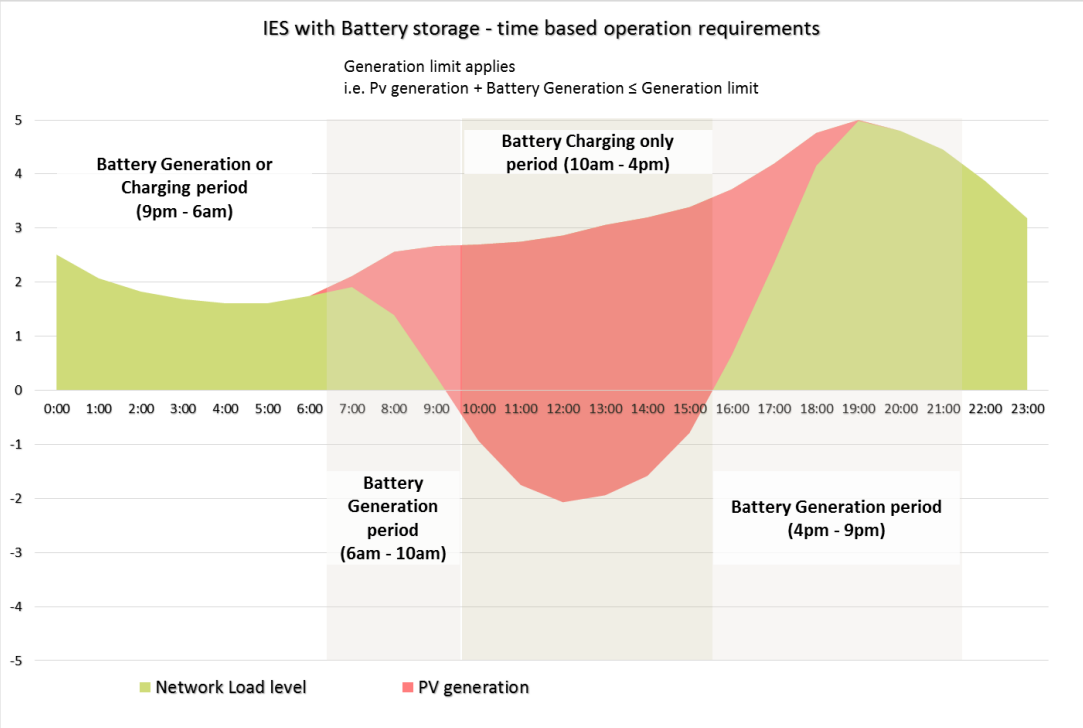


Figure 2 Example load and generation profile with time based operation of Battery IES

2.5 Frequency response

All battery IES is required to meet the requirements of AS/NZS 4777.2:2015 clause 7.5.3.2 “Response to a decrease in grid frequency”.

2.6 Load limiting

2.6.1 General

Where a battery inverter energy system is used there is a potential to increase the load beyond the capacity of the point of supply. To manage this issue it is important for the customer or their electrical consultant to understand what Western Power supply arrangement the customer has and the corresponding capacity of that supply. Likewise, the customer must not cause their electrical installation to be overloaded in any combination of IES operation.

In all cases the supply arrangement at the time of the Battery IES installation must be in accordance with current WA Electrical Requirements (WAER) and the WA Distribution Connection Manual (WADCM). This relates specifically to the Service Protection Device (SPD) and metering arrangements. Legacy connection arrangements not found in the current WADCM will be required to be upgraded to current standard.

2.6.2 Standard supplies

The following capacities apply for Western Power standard supply arrangements:

- Single phase standard supplies 63A
- Three phase standard supplies 32A
- Rural standard supplies 32A
- Consumer mains cable maximum size is 35 mm^2

The customer main switch must be a circuit breaker rated to the lesser value of supply capacity or requirement of AS/NZS 3000 for cable protection for all installation that have a battery IES.

2.6.3 Greater than standard supply arrangements with direct connected metering

Installations that have supply arrangements greater than a standard supply and still with direct connected metering may have supply capacities up to 100 A.
The site main switch shall be a circuit breaker rated to the lesser value of supply capacity or requirement of AS/NZS 3000 for cable protection.

2.6.4 CT metered sites

Installations that have CT metering arrangements the SPD shall be a suitably rated circuit breaker according to the requirements of the WAER and the WA Distribution Connection Manual. Further to the requirements of the WAER, the SPD shall:

- have a continuous current rating to the agreed Maximum Demand for the customer's point of supply, unless otherwise approved by the Western Power
- have a rated short circuit breaking capacity of at least 25kA

These supply arrangements with CT metering that have a settable SPD must be set to the agreed Maximum Demand for the site.

2.6.5 Multiple and distributed mastered metered sites

Installations that have multiple and distributed master metering arrangements shall comply with requirements of WADCM.
This includes a SPD and further to the requirements of the WAER, the SPD shall:

- have a continuous current rating to the agreed Maximum Demand for the customer's point of supply, unless otherwise approved by the Western Power
- have a rated short circuit breaking capacity of at least 25kA

The customer switch and isolation device associated with a meter shall be a circuit breaker rated to the requirement of AS/NZS 3000 for cable protection. Where a settable circuit breaker is used then this must be set to the agreed Maximum demand of the customer within the shared electrical installation.

2.7 Future further control

Western Power are aware that BESS connected to the grid is still a developing area for customers and industry. In developing these requirements other potential control and operational modes were considered and may be implemented in future requirements. These include use of ramp rates and demand response modes as defined in AS/NZS 4777.2:2015 as well as various external control methods being developed by various independent organisations. Various trials are being performed across Australia, with Western Power continuing to monitor the progress of these and may incorporate beneficial developments in the future.

3 Managing voltage imbalance with three phase customers and energy storage

Note: This section is only for customers on three phase supply arrangements.

Customers with three phase standard supply arrangements shall balance load and generation across all phases such that it does not cause voltage imbalance across the customer supply phases or on the connected network. For three phase standard supply customers PV IES is allowed no more than 2.5 kVA[3] unbalance across the supply phases.

PV IES across the network generates at the same time without any diversity in the generation, this leads to potential voltage unbalance in LV networks and results in voltage compliance issues for the customers sharing the LV network. Unlike PV, load operates in a diverse (or scattered) way and rarely does the load operate all at once. Energy storage with PV used for increased self-consumption of excess PV generation shall maintain balance across all three phases. Energy storage IES larger than 5 kVA shall be balanced across all supply phases.

For three phase standard supply customers energy storage IES shall be no more than 5 kVA of unbalance across the supply phases. The energy storage IES 5kVA or less can be connected to a single phase on a three phase supply arrangement if the following is achieved:

(a) The voltage rise on the service lead shall not exceed 1% on any one phase with any possible load or generation condition.

(b) Battery IES shall be on same phase as the load it is intended to supply[4], and;

(c) AC Coupled IES (refer Figure 3a);

  (i) Battery IES shall be connected on the same phase as the largest PV component of an IES;

  (ii) Site generation capacity shall be maintained across the three phases and on the battery IES phase it shall never exceed 5 kVA, and;

  (iii) Single phase PV IES and single phase battery IES shall be export limited to 2.5 kVA on the phase it is connected to;

(d) DC coupled energy sources (refer Figure 3b);

  (i) Single phase IES shall be rated at no more than 5 kVA, and;

  (ii) Single phase energy sources and battery storage are DC coupled and the IES shall be export limited to 2.5 kVA on the phase it is connected to.

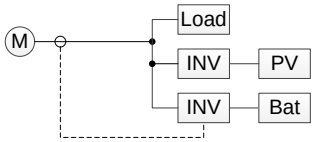
For IES that exceeds a total installed capacity of 15 kVA of inverters the additional phase balance requirements of AS/NZS 4777.1 clause 3.4.4.2 apply. (This is based on the sum of all Inverters that are connected to a single Western Power PoS).

Energy storage DC coupled with PV IES >5 kVA, has the same grid-connection requirements of the PV IES for balance across all three phase supply arrangements.

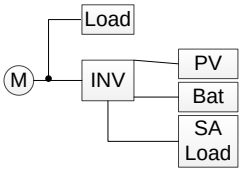
For Battery IES with ac coupled PV not on the grid connected port of the battery IES (refer Figure 3c) the balance requirements are assessed on a case by case basis.

[3] Exception: Where a single inverter is installed on a three phase supply arrangement it can be rated no more than 3 kVA.

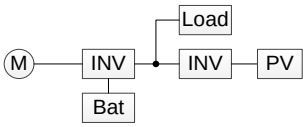
[4] This is to minimise the effect on the grid of having the battery on a phase with no load and indirectly offsetting energy to loads on other phases through net metering



(3a) AC Coupled IES



(3b) DC coupled energy sources



(3c) Battery IES with ac coupled PV not on the grid connected port

Figure 3 Example IES configuration AC and DC coupled

Balancing requirements for non-PV inverter energy systems integrated with battery storage systems are considered on case by case basis.

4 Inverter Energy System (IES) configurations including Batteries and PV

The terminology used by industry in relation to battery storage systems includes terms AC coupled and DC coupled. Sometimes AC coupled systems are referred to as AC batteries. The term coupled refers to where the battery is connected into an IES. DC coupled refers to energy sources that are connected onto a DC bus (or terminations) of an inverter. Whereas, AC coupled refers to connection of energy sources on the AC electrical installation using inverters to control operation of the storage and interaction with other energy sources. Below is listed general descriptions using this terminology for IES that include battery storage:

- Multiple IES with PV IES and AC coupled battery IES
- Single IES with PV and DC coupled battery
- Single IES with battery only (i.e. no other energy source than the grid)
- Multiple IES with PV IES and AC coupled battery IES with stand-alone functionality
- Single IES with battery inverter including stand-alone functionality, AC coupled PV inverter on stand-alone port of battery inverter.
- Single IES with DC coupled battery and PV, with stand-alone functionality

Stand-alone functionality refers to the inverters ability to supply load independent of the grid supply being present. Most cases it is used to provide backup supply to part of the home load. In some circumstances it can be used to provide an alternative supply to entire home load.
Table 1 provides guidance for acceptable arrangements and differences between configurations.

Table 1 Guidance for Standard Supply connection arrangement for energy storage system integration

Generic system type	Site generation capacity	Export limit	3 phase balance arrangements
All systems (AS/NZS 4777 IES)	• Site connection dependent • Western Power determined	• Customer IES operational preferences • Retailer requirement where applicable • As per 4777.1:2016	All IES over 3 kVA to be balanced to ≤2.5 kVA imbalance.
IES with PV Inverter and AC coupled battery inverter [5]	• 1phase = 5kVA • 3 phase = 8 kVA and 5 kVA on the battery IES phase • or as approved	–	PV imbalance ≤ 2.5kVA, BESS Imbalance ≤ 5kVA
IES with PV Inverter and DC coupled Battery	• PV IES approved site generation capacity	1ph BESS & PV on 3ph PoS ≤ 2.5 kVA per phase	Imbalance ≤ 5 kVA
IES with battery only	• 1phase = 5 kVA • 3 phase = 8 kVA or as approved	1ph BESS on 3ph PoS ≤ 2.5 kVA per phase Exporting is unlikely until energy trading is available	BESS, imbalance ≤ 5kVA
IES with load backup functionality	• 1phase = 5kVA • 3 phase = 8 kVA • or as approved	1ph BESS on 3ph PoS ≤ 2.5 kVA per phase	PV imbalance ≤ 2.5kVA, BESS, Imbalance ≤ 5kVA
IES with stand-alone supply capability	Each application assessed by Engineer	• Site connection dependent • Western Power determined	Imbalance to/from grid ≤ 2.5 kVA

[5] For an AC coupled battery where a PV system is installed the battery shall be installed on a phase with PV. Where the PV IES has an imbalance, the battery shall be installed on the phase with the highest PV inverter capacity to maximise the charging from PV.

5 Installation requirements

The Battery IES installation shall comply with all applicable regulations, rules and standards including:

- AS/NZS 3000, AS 3008
- AS/NZS 4777 series
- AS/NZS 5033
- AS/NZS 3010
- The Western Power's Technical Rules
- WAER and WA DCM.

> Note: Standards Australia is developing a new standard called "Electrical installations – Safety of battery systems for use with power conversion equipment" (AS/NZS 5139). This proposed new standard will set out the general installation and safety requirements for BESS connected to or integrated with an IES. In the interim, Energy*Safety* has prepared guidance to alert electrical contractors and electricians to the safety issues associated with BESS. The guiding principle is one of careful design and specification of equipment for each specific installation to achieve the highest practicable standard of "safety in design". The guide can be found on the Energy*Safety* website at *http*://www.commerce.wa.gov.au/sites/default/files/atoms/files/bess_guideline.pdf.

6 Glossary

BESS: Battery Energy Storage System

Electric vehicle to grid systems: Electric vehicles that are only capable of charging from the grid are considered only as a load. An electric vehicle that is capable of generating and exporting energy into the connected premise or the grid is an EV to grid system. These system will be considered as an IES and need to comply with appropriate requirements.

Inverter Embedded Generator: The collection of all IES connected via a single point of supply to the Western Power grid.

Inverter Energy System (IES): an installation of inverters and energy sources to an electrical installation according to AS/NZS 4777 series of standards. Each IES will be connected to an Inverter Supply main switch. There may be multiple IES in a single electrical installation connected to the Western Power grid. Reference to IES in this document means either a single IES or multiple IES in the one electrical installation connected to the Western Power grid.

Lower customer utilisation range: Voltage drop allowed within a customer electrical installation in AS 60038

LV network operating range: Electricity Act 1945 voltage range regulation (±6%)

Multiple IES: Where there is more than one IES installation within a customer electrical installation on a single Western Power point of supply. They may be connected to the site main switchboard or sub switchboards.

PoS: Point of Supply as per WA Distribution Connection Manual definition

V>, V>>, V< disconnect: passive anti-islanding limit values from AS/NZS 4777.2:2016

SPD: Service Protection Device as required in WA Electrical requirements.

Volt-Watt, Volt-watt(CH): power quality response modes in AS/NZS4777.2:2016. Volt-watt(CH) indicates the voltage response required for charging the batteries when the voltage is low on the network.

7 Bibliography

Australian Standards

- AS/NZS 3000 “Wiring Rules”
- AS/NZS 60038 “Standard Voltages”
- AS/NZS 4777 series “Grid connection of Energy Systems via Inverters”

Western Power documents

- WA Distribution Connection Manual
- Network integration Guideline for inverter embedded generation

WA government documents

- WA Electrical Requirements
- Battery Energy Storage Systems: A guided for electrical contractors