ELECTRIC POWER CORPORATION

Grid Code – technical requirements for connection of generation plant to the EPC Grid

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Version information

Version	Date Issued	Notes
1.0	13 September 2018	FINAL initial version – applies to Independent Power Producers only (Part 1) – approved for release by the EPC Board
2.x	various	Various development drafts of second version
3.0	1 April 2019	FINAL second version – applies to Independent Power Producers (Part 1) and to consumer self-suppliers (Part 2) – approved for release by the EPC Board

Grid Code Contents

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1 Introduction and application of the Grid Code

1.1 Policy context

This document is the Electric Power Corporation (EPC) Grid Code, prepared by EPC in accordance with the Electricity Network Services License under which EPC operates.

The Grid Code gives effect to policies published by the Office of the Regulator (OoTR) that relate to providing access to the Grid to connect approved generation plant owned by eligible third parties. In general, independent power producers (IPPs) may apply to EPC to connect least cost renewable energy (RE) generation plant to the Grid that fulfils a capacity need outlined in EPC's current *Power System Expansion Plan (PSEP)*.

Additionally, to meet identified PSEP capacity needs in a timely manner, EPC may also request proposals from eligible IPPs through a formal tender process.

Third party *applicants* that may seek to connect generation plant to the Grid are:

- community IPPs
- commercial IPPs
- consumer self-suppliers.

These third party entities are further defined in section 2.

The Grid Code applies to all generation plant intended to be electrically connected to the Grid. This includes generation plant connected within a consumer's electrical installation that is, in turn, connected to the Grid. Rooftop solar PV installations are connected in this way.

Larger-scale generation plant, such as the diesel backup generation plant installed at some businesses, eg hotels and resorts, also require EPC's approval to connect if they operate while electrically connected to the Grid, even if they only electrically connect to the Grid for short periods of time (eg, during start-up and shutdown).

The Grid Code specifies, for applicants seeking to connect generation plant to the Grid:

- general information about the Grid
- requirements and processes for obtaining EPC approval to connect generation plant to the Grid
- requirements for operating Grid-connected generation plant.

1.2 Application of the Grid Code to different installation classes

The Grid Code is divided into two Parts, reflecting the different complexities and requirements for connecting plant requested by different classes of connection applicants:

- IPP generation plant (typically larger-scale); and
- consumer self-supplier generation plant (typically smaller-scale).

Table 1 provides the eligibility criteria for each connection class.

Table 1 – Application of the Grid Code to generation plant classes

Connection Class	Indicative Capacity	Typical generation plant (example only)	Connection voltage	Grid Code
Large (IPP)	> 100 kW – a maximum capacity limit may apply – must fulfil an identified RE capacity need, as set out in the current PSEP	IPP owned: (a) inverter & transformer-connected solar PV & battery array; or (b) transformer-connected hydro or wind synchronous generator	22 kV distribution feeder 33 kV transmission tie	Part 1
Business (consumer self-supplier)	< 100 kW	Consumer self-supplier owned inverter-connected rooftop solar PV for a business	240/415 V low voltage (LV) feeder	Part 2
Residential (consumer self-supplier)	< 5 kW per phase (ie up to 15 kW max. for 3-phase)	Consumer self-supplier owned inverter-connected rooftop solar PV for a private residence	240/415 V low voltage (LV) feeder	Part 2

1.2.1 Part 1 of the Grid Code is for IPP-owned RE generation plant

Part 1—

- applies to IPP-owned generation plant intended to be connected through a step-up transformer to an EPC 22 kV distribution feeder or a 33 kV transmission tie. Typical generation plant in this class will range in capacity from 100 kW up to several MW. The key determinants are that:
  - the IPP generation plant is Grid connected to either EPC's 22 kV distribution network, or 33 kV transmission network, through a dedicated step-up transformer;
  - the IPP generation plant is intended to fill an identified generation capacity need in accordance with EPC's current Power System Expansion Plan (PSEP);

  - the IPP sells generated electricity to EPC, in accordance with the terms and conditions negotiated by the parties and recorded in a valid Power Purchase Agreement (PPA); and
  - the IPP and EPC will also enter into an Interconnection Agreement;
- by its nature, must cover a range of renewable generation technologies and broad and generic subject matter intended for the widest application. Accordingly, some sections of Part 1 may not be relevant to every IPP generation plant connection and the Grid Code must be read in conjunction with all other relevant documentation. This includes all agreements between EPC and the IPP related to connection and operation of IPP generation plant, in particular, the PPA that will need to be entered into by the IPP and EPC
- also applies to EPC-owned grid-connected RE generation plant.

1.2.2 Part 2 of the Grid Code is for consumer self-supplier RE generation plant

Part 2—

- applies to consumer self-supplier generation plant intended to be connected through an inverter to an EPC low voltage (ie 240 V 1-phase or 415 V 3-phase) feeder. Generation plant in this category includes:
  - residential (including small business) rooftop solar PV generation plant with a capacity of up 5 kW per phase (ie, up to 15 kW for a 3-phase installation); and
  - business rooftop solar PV generation plant with a capacity of up 100 kW
- includes an eligibility criterion that requires that the maximum permissible generation plant capacity is limited to the lesser of:
  - the capacity required to provide the consumer with self-supplied renewable electricity up to the amount of its own annual energy consumption; or
  - 100 kW.

2 Defined terms

The terms and definitions in Table 2 are used throughout the Grid Code.

Table 2 – Defined terms

Term	Definition
Connection Agreement	the agreement entered into by EPC and a consumer self-supplier, which specifies: • the rights and obligations of the parties related to the connection of the consumer's generation plant to EPC's Grid; and • the sale to EPC of any excess electricity generated by the consumer self-supplier's generation plant that may flow into the Grid
consumer self-supplier	an EPC electricity consumer who also generates electricity within their electrical installation, located at their own premises, *for the sole purpose of generating part of their own electricity demand*. At times when the level of the consumer self-supplier's electricity generation exceeds their own demand, excess electricity may flow into the Grid and be sold to EPC
DoC	Declaration of Conformity (to a specified technical standard)
electrical installation	the electrical fittings used to convey electricity within a consumer's premises
electrically connected	in relation to electrical assets, means the state of being physically connected to the Grid and electrically livened, so that electricity may flow between the connected assets
EPC	the Electric Power Corporation, established in accordance with the Electric Power Corporation Act 1980
generation or generation plant	any device capable of injecting electricity into the Grid, or into an electrical installation that is electrically connected to the Grid. This includes: • traditional generation plant (eg from a synchronous machine powered by a hydro turbine) • non-traditional generation plant and other energy sources (eg from an inverter-connected solar PV array that may optionally include a battery storage system)
Grid	the electrical networks owned and operated by EPC on the Samoan islands of Upolu, Savai'i and Manono
Grid Code	the current published version of this document, as amended by EPC from time to time, and available on request to EPC at the address for enquiries on the cover sheet

Term	Definition
IPP	Independent Power Producer – any owner/operator of Grid-connected generation plant, the output of which is intended to be sold to EPC. IPPs fall into one of two subgroups: • commercial IPPs – a for-profit organisation that is in the business of designing, constructing, owning and operating generation plant *for the sole purpose of generating electricity and selling that electricity to EPC* • community IPPs – a not-for-profit organisation or community group that owns and operates generation plant *for the sole purpose of generating electricity and selling that electricity to EPC*
OoTR	the Office of the Regulator
Point of Connection	the physical point on the Grid at which an IPP's generation plant assets are – or are intended to be – electrically connected to Grid assets, and at which point electricity may flow between the generation plant and the Grid
PPA	power purchase agreement – the master agreement negotiated and entered into by EPC and an IPP, which specifies the rights and obligations of the parties related to the connection of the IPP's plant to the Grid and the sale and purchase of electricity generated by the IPP's Grid-connected generation plant
PSEP	Power System Expansion Plan
RE	renewable energy
solar PV	solar photovoltaic
Electrical terms and units of measure	
A	amperes (amps) – the standard measurement of electrical current and, for AC systems, is expressed as an RMS value
AC	alternating current
DC	direct current
Hz	hertz – the standard measurement of electrical frequency in an AC system
LV	standard low voltage
RMS	root mean square
s	seconds
UFLS	under-frequency load shedding
V (kV)	volts (kilovolts) – the standard measurement of electrical voltage and, for AC systems, is expressed as an RMS value

3 Referenced standards

3.1 Introduction

In general, the external standards applicable to the Grid are selected Australian and New Zealand standards (AS/NZS). Australian and New Zealand standards are, in turn, based on relevant international standards and thereby provide access to reputable and widely-adopted source references.

The referenced AS/NZS standards are available for purchase at https://www.standards.org.au and https://www.standards.govt.nz.

Each referenced standard may refer to other standards and documents as normative (ie mandatory) or informative (ie for information and guidance only) references.

If a standard provides separate requirements for Australia and New Zealand, the Australian provisions apply, unless otherwise noted.

Connection applicants (or their specialist service providers) are responsible for procuring all relevant standards.

3.2 General standards

The following standards apply to all connections:

- AS/NZS 3000:2018 — Electrical installations – known as the Australian/New Zealand Wiring Rules
- AS/NZS 3100:2017 — Approval and test specification – General requirements for electrical equipment
- AS/NZS TR IEC 61000.3.6 — Electromagnetic compatibility (EMC) - Part 3.6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems
- AS 2067:2016 — Substations and high voltage installations exceeding 1 kV AC

3.3 Standards for inverters

The following standards apply to connections that include a DC/AC power inverter:

- AS/NZS 4777.1:2016 — Grid connection of Energy Systems via Inverters – Part 1: Installation requirements
- AS/NZS 4777.2:2015 — Grid connection of Energy Systems via Inverters – Part 2: Inverter requirements

3.4 Standards for solar photovoltaic arrays

The following standards apply to connections of photovoltaic arrays:

- AS/NZS 5033:2014 — Installation and safety requirements for photovoltaic (PV) arrays

4 General information about the Grid

4.1 Geographical coverage of the Grid

The Grid provides generation plant connections and electricity supply to consumers on Samoa's two main islands, Upolu and Savai'i, and on the small island of Manono, connected to Upolu by undersea cable. While EPC has electricity supply equipment on Apolima, this island has no *Grid-connected* electricity supply equipment.

The areas serviced by the Grid are shown in Figure 1 and Figure 2.

Figure 1 – EPC Grid on Upolu & Manono

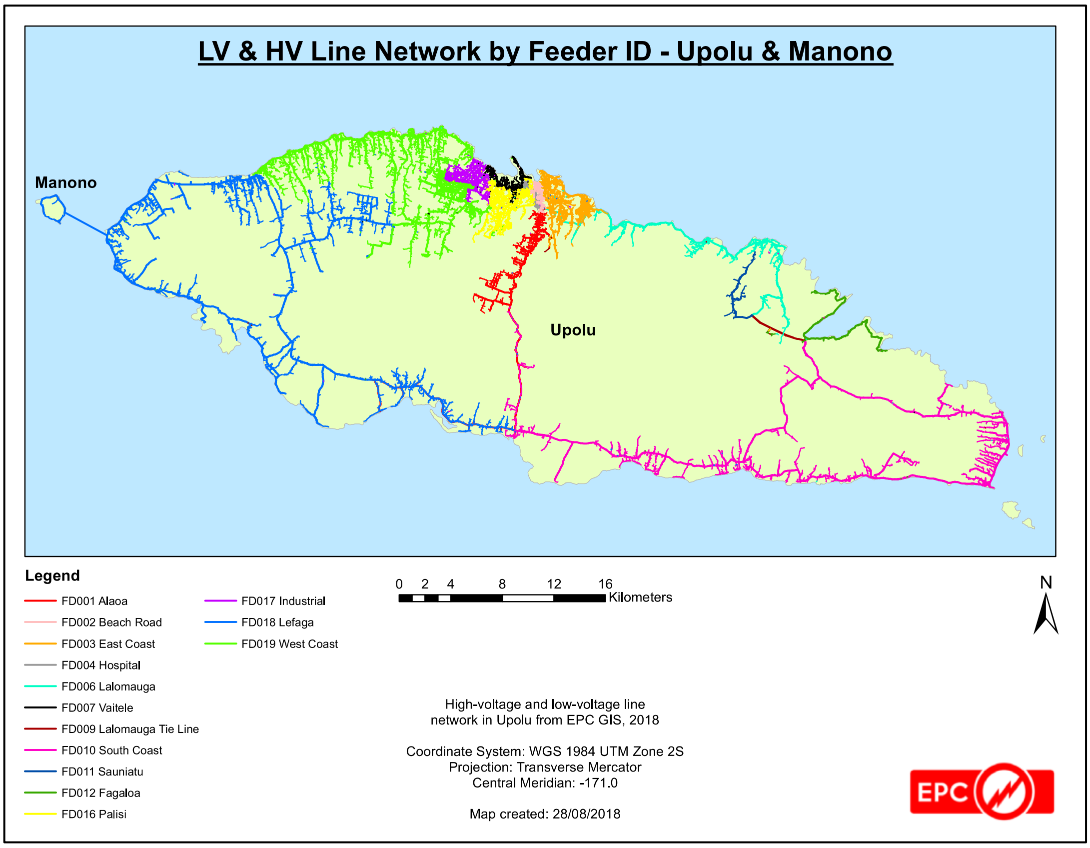
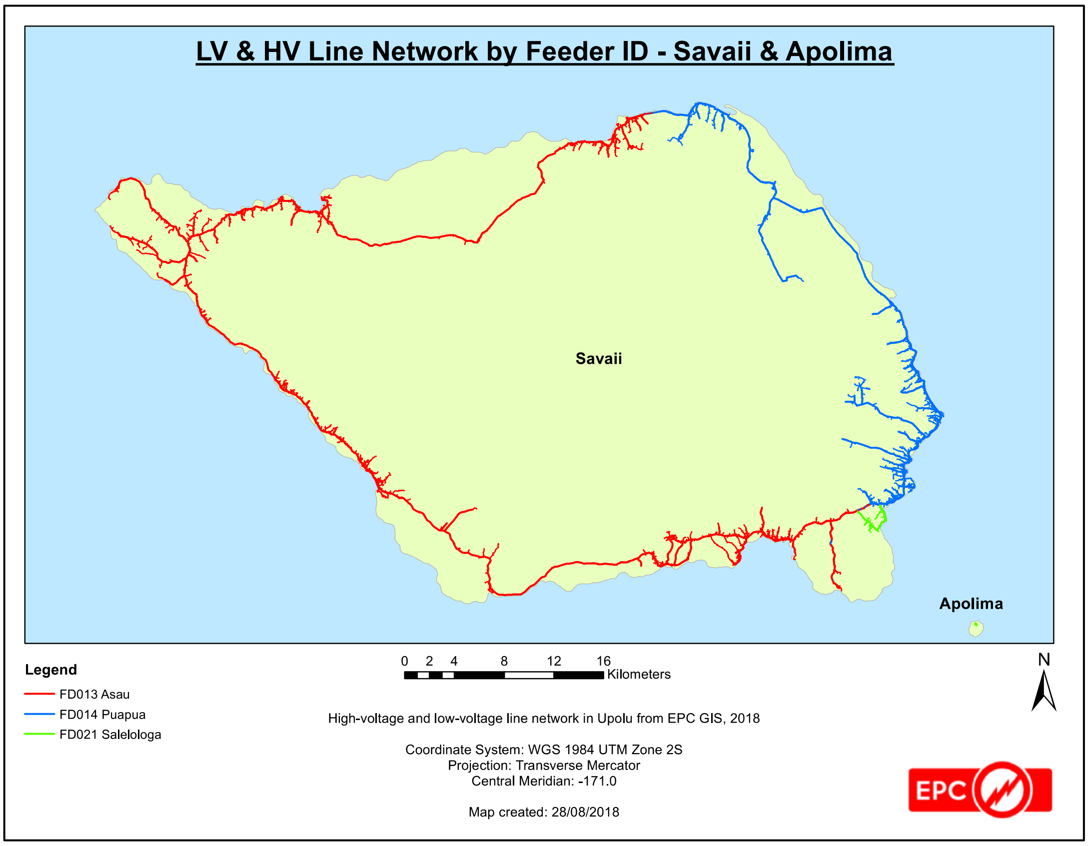


Figure 2 – EPC Grid on Savai'i



4.2 Grid construction

Transmission, distribution and LV networks are predominantly of overhead construction, using wooden or concrete poles. Distribution transformers are predominantly pole mounted. Poles may carry circuits with multiple voltages on their various cross arms.

High voltage underground cables are used for some transmission tie circuits, in some urban areas and within substations.

Transmission ties are mostly single circuit except for the double circuit tie between Fiaga and Fuluasou.

4.3 Grid electrical configuration

4.3.1 Standard construction voltages used

The Grid adopts the following standard AC voltages, measured between phases:

- Transmission ties – 33 kV and 22 kV
- Distribution feeders – 22 kV
- LV supply feeders – 415 V between phases and 240 V between phase and neutral.

All transmission ties provide direct circuits between regional substations, except:

- the Lalomauga – Tanugamanono tie/feeder (FD006 in Figure 1), which also serves as a distribution feeder using 33/0.415 kV distribution transformers
- the Lalomauga – Taelefaga tie/feeder (TL001), which also serves as a distribution feeder using 22/0.415 V distribution transformers.

Generation plant that employs synchronous machines usually incorporates a suitable intermediate voltage internally, eg 6.6 or 11 kV, and increases that voltage to transmission or distribution voltage through a step-up transformer.

4.3.2 Target operating voltage range

When the Grid is operating normally, EPC seeks to maintain the following nominal Grid voltages, measured between phases:

- for transmission ties and busses, the nominal Grid voltage is 33 kV ± 10%
- for distribution feeders and busses, the nominal Grid voltage is 22 kV ± 10%
- for LV feeders, the nominal supply voltage is 415 V ± 10% between phases (or 240 V ± 10% between phase and neutral).

The output of generation plant that operates at any other AC voltage is transformed to the appropriate Grid voltage through a suitably rated 2 or 3-winding step-up power transformer. Step up transformer ratings are selected to provide sufficient capacity to allow the generating plant to operate within its expected generation profile, in all expected ambient conditions, at up to the maximum export apparent power level.

The standard step-up transformer phasing configuration for generation plant is YNd11.

Generation plant that operates at any DC voltage – eg solar PV and battery energy storage systems – is electrically connected to the Grid through a suitably rated DC/AC power inverter.

4.3.3 Target operating frequency

The Grid operates within a normal frequency band of 50 Hz ± 1% (ie ± 0.5 Hz).

Automatic frequency keeping equipment acts to maintain the Grid frequency at or near 50 Hz.

To avoid a system collapse in the event a large block of generation trips offline, under-frequency load shedding (UFLS) acts to quickly and automatically trip selected armed feeders. Feeders armed for UFLS trip in a time-graded pre-set sequence if the local Grid frequency does not recover and remains below 48.5 Hz.

Generation plant is normally set to trip on over-frequency protection if the frequency rises above 52 Hz.

4.3.4 Power quality and harmonic limits

Power quality disturbance limits apply at each Point of Connection and include the following potential disturbances:

- voltage fluctuations:
  - rapid voltage changes
  - voltage flicker
- high-frequency currents and voltages:
  - harmonics
  - inter-harmonics
  - disturbances greater than 2 kHz
- unbalanced currents and voltages:
  - deviation in magnitude between the three phases
  - deviation in angle separation from 120° between the three phases.

Voltage and current waveform distortion must not exceed the limits stated in AS/NZS TR IEC 61000.3.6. Additionally, requirements for generation plant connected to the Grid through inverters are provided in AS/NZS 4777.2:2015.

In general, power quality concerns may be raised by EPC, or by the IPP, at any time during the operational lifetime of the generation plant. If power quality-related issues arise, EPC undertakes appropriate investigations, including taking measurements using power quality recording devices connected at suitable locations, seeks to determine the cause of the disturbance and initiate appropriate remedial action.

PART 1 — CONNECTION OF IPP GENERATION PLANT

5 Requirements for Grid-connected generation plant – IPPs

5.1 General requirements

Section 7 details the process by which IPP generation plant may be approved for connection to the Grid.

IPP generation plant connects to the Grid at a Point of Connection. The Point of Connection is the point at which IPP assets electrically connect to Grid assets, allowing electricity to flow between the generation plant and the Grid. The location of the Point of Connection must be agreed between EPC and the IPP.

A Point of Connection is typically located at the point that the cable from the IPP generation plant is connected to Grid network assets through a circuit breaker, air-break switch, solid disconnecting links or fuses.

All connection design and operational details must be agreed with EPC prior to connecting the IPP generation plant to the Grid. Before an electrical connection is made, all relevant details must be agreed and recorded in the PPA, properly executed by the IPP and EPC.

When generation plant connection assets are in place and ready for livening, EPC field staff (or EPC warranted contractors) will arrange for, and carry out, all electrical testing, connection and livening activities.

All generation plant that is available for service must be capable of electrically synchronising to the Grid and operating normally when the Grid is operating within its nominal electrical parameters (see section 5.2). Synchronising to the Grid – and disconnecting from it – must be undertaken by the IPP in accordance with dispatch instructions issued by the NCC Grid operator (see section 6.4) and all relevant terms included in the PPA, if any.

5.2 Generation plant performance requirements during normal operations

Subject to the scheduling and dispatch requirements included in sections 6.3 and 6.4, generation plant must be capable of operating normally and continuously when the Grid voltage and frequency are within their respective nominal ranges, measured at the relevant Point of Connection.

5.2.1 Active and reactive power capability

Generation plant active and reactive power capability and capacity limits are highly plant/technology-specific. A specific generation plant's capability and capacity limits are normally shown on a generation power capability diagram.

Examples of these diagrams are shown in Figure 3 and Figure 4.

Figure 3 – Typical generation capability diagram for inverter-connected plant

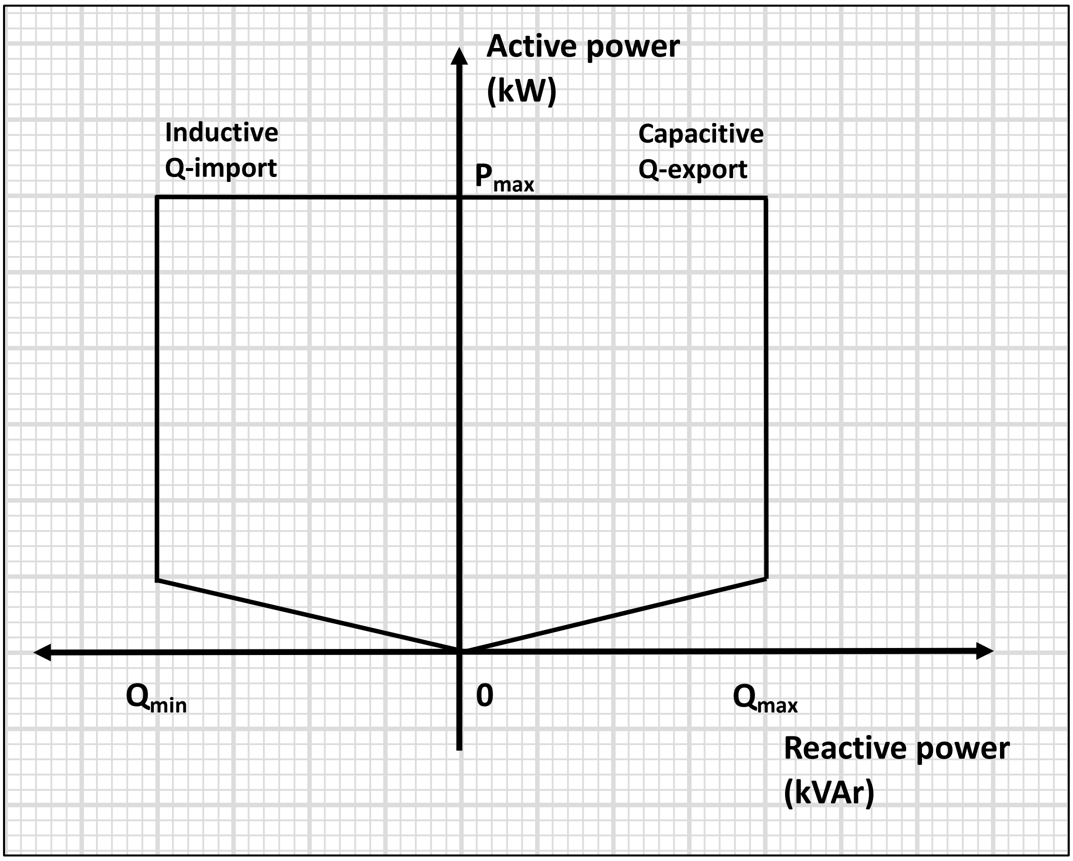
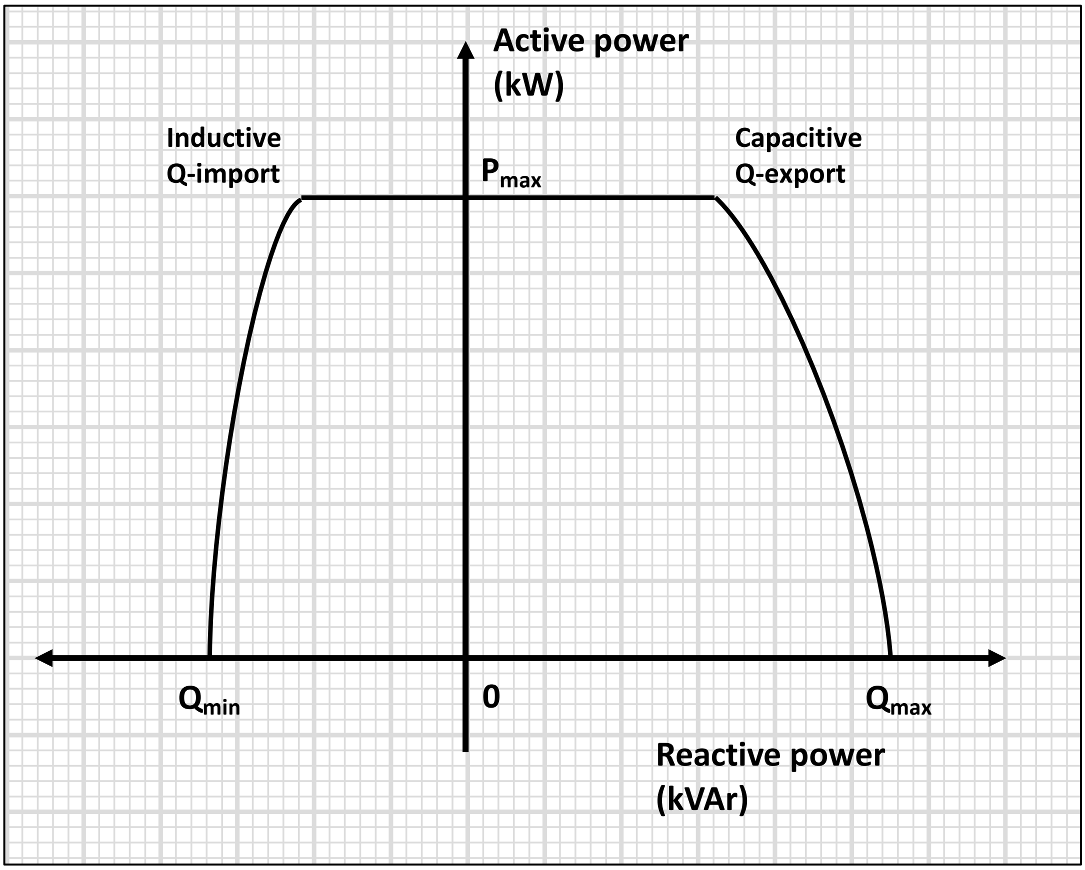


Figure 4 – Typical generator capability diagram for a hydro generator



IPPs seeking to connect generation plant to the Grid must provide full details of the proposed plant's operating capability. This includes any capability the generation plant may have to contribute to:

- Grid frequency keeping and/or
- operational or standby reserve capacity that is capable of contributing to maintain Grid stability.

5.2.2 Voltage support mode

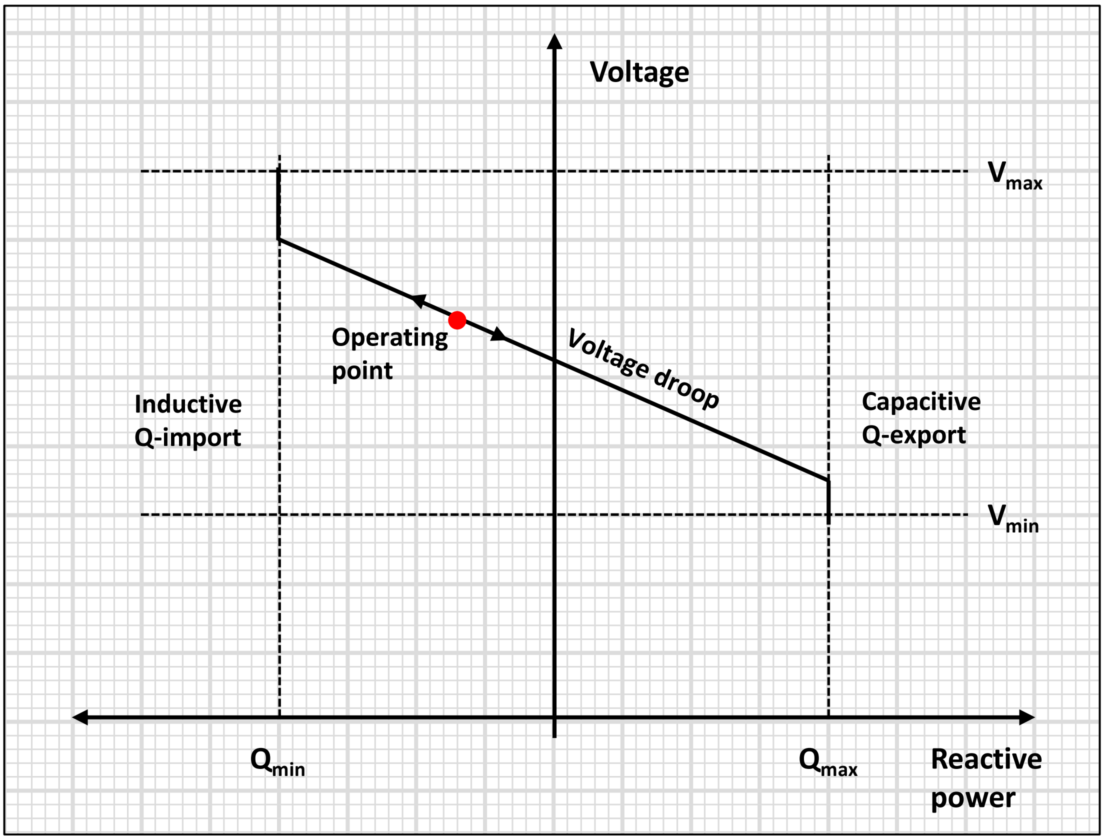
Generation plant must be capable of providing local voltage support, within limits to be agreed with EPC, to maintain the local transmission or distribution voltage at or near a target voltage under normal conditions, such voltage target and range to be defined by EPC. Limits and settings will normally depend on:

- the location of the Point of Connection within the Grid
- the voltage regulating capability of the generation plant.

When the generation plant is operating, EPC may issue reactive power dispatch instructions to the generation plant to achieve a specific target voltage. The generation plant must be capable of accepting and promptly implementing such dispatch instructions at all times while operational.

Figure 5 shows an example of active voltage control provided by generation plant.

Figure 5 – Voltage support mode



The limits V_{min}, V_{max}, Q_{min} and Q_{max} are specific to individual generation plants and must be agreed between EPC and the IPP, and appropriate detail included in the PPA.

Reactive power control is required for all generation technologies, for both AC and DC technologies, including for storage battery technologies.

5.3 Generation plant performance requirements during abnormal operating conditions

Operational generation plant must be capable of remaining synchronised with the Grid, and operate at or near pre-fault levels, during short-duration voltage and frequency transients caused by other generation plant faults, system faults and other electrical disturbances.

5.3.1 Voltage disturbance ride-through

Generation plant must be capable of remaining connected and operational within the “no-trip zone” depicted in Figure 6. The no-trip zone applies to all 1-phase, 2-phase and 3-phase faults.

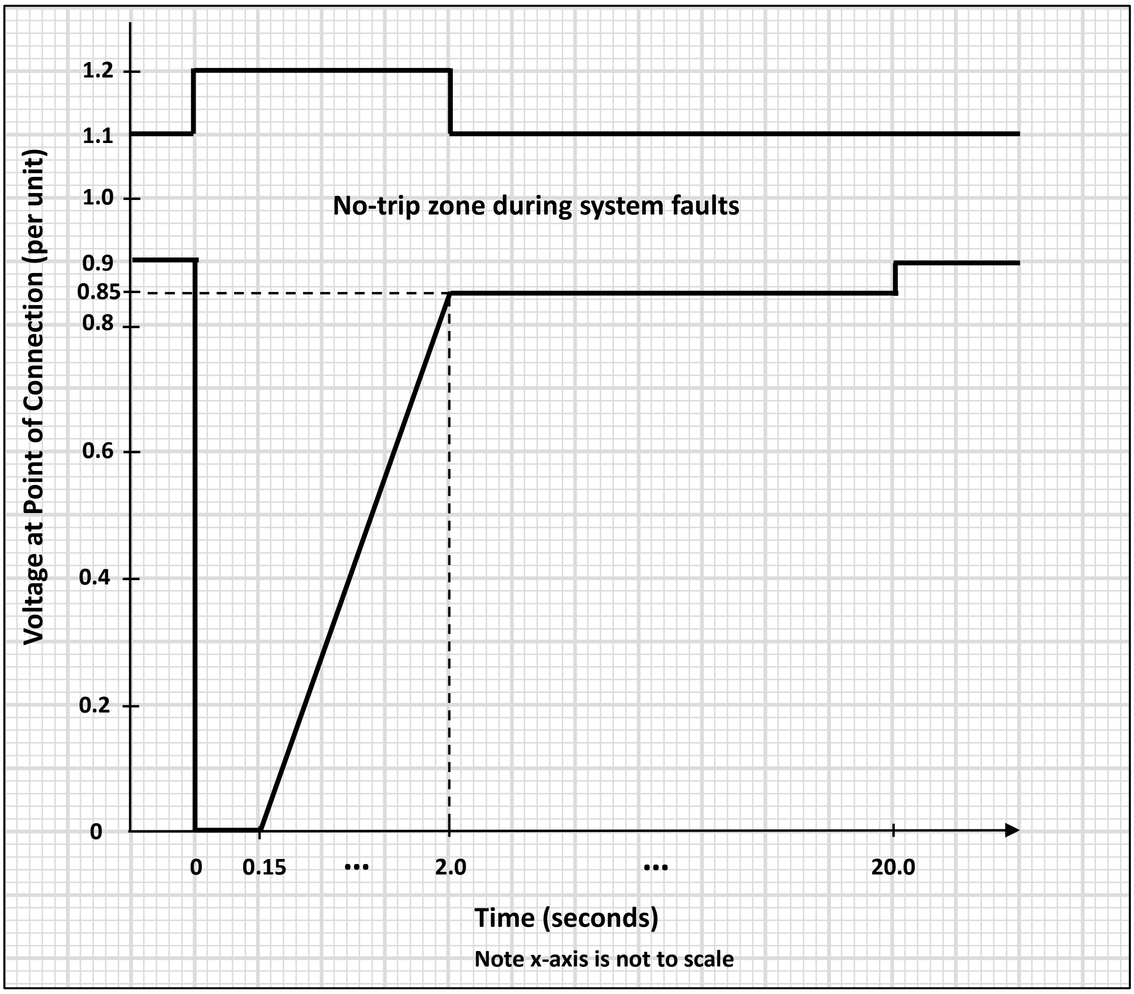
EPC will model proposed generation plant connections to provide assurance that the proposed generation plant will perform as required under short-term transient conditions.

A wider (voltage) and/or longer (time) no-trip zone may be agreed between EPC and the IPP if the proposed generation plant is capable of such performance.

Grid-supportive reactive power control is critical when operating within the no-trip zone during the initial fault onset and the fault recovery periods.

Pre-fault active power output should be maintained throughout the fault onset and recovery phases, within the maximum capability of the generation plant.

Figure 6 – Voltage ride-through no trip zone



5.3.2 Frequency disturbance ride-through

Generation plant must be capable of remaining connected and operational while the Grid frequency at the Point of Connection is:

- within the range of 47.0 to 52.0 Hz
- subject to a rate of change of frequency not exceeding 1 Hz per second.

A lower minimum frequency and/or a higher maximum frequency ramp rate may be agreed between EPC and the IPP, if the generation plant is capable of such performance. For example, it is likely to be advantageous from the perspective of maintaining Grid stability that generation plant is capable of remaining connected and operating at frequencies as low as 45 Hz.

5.4 Grid and generation plant protection requirements

5.4.1 General protection design requirements

At the generation plant design stage, before an IPP finalises key generation plant design parameters, the IPP must provide to EPC a comprehensive digital model of its proposed generation plant, and the proposed connection configuration, in DigSILENT PowerFactory^{TM} format.

Coordination with EPC protection systems must be discussed with the EPC protection engineer at the design stage, and approved by EPC.

The IPP must ensure that its generation plant is specified and equipped with the necessary protection functions, such that the plant is protected against damage potentially caused by faults and disturbances arising in the Grid.

Generation plant protection systems must be designed to coordinate with (ie, maintain correct discrimination with) existing Grid protection systems. The objective is to ensure that faults on the generation equipment are detected accurately and rapidly (eg, by use of unit protection schemes such as differential current) and rapidly cleared locally before Grid protection systems operate in backup time. Note that backup protection activations will generally lead to a wider Grid disruption.

5.4.2 Design network fault levels

The design 3-phase and 1-phase to earth Grid fault levels are location-dependent and will be provided for a specific point of connection location by EPC, upon request by the IPP.

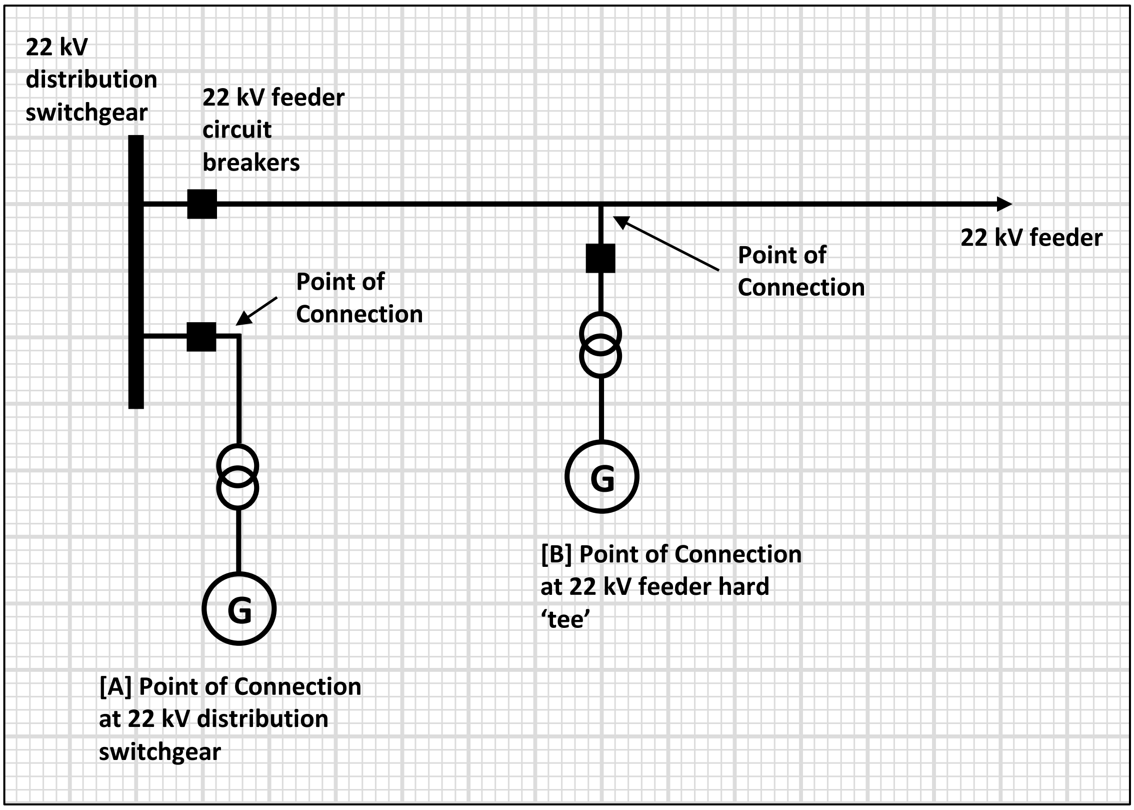
5.4.3 Overcurrent and earth fault protection

Figure 7 shows two common Grid connection configuration options– note: 22 kV distribution options are shown, but the principles also apply to connections to 33 kV transmission ties.

For IPP generation plant connections to EPC transmission or distribution voltage switchgear, EPC will install a suitable switchgear panel that includes all necessary Grid protection elements. All cost contributions and points of demarcation must be agreed with the IPP and relevant terms included in the PPA.

For IPP generation plant connections to a transmission tie or distribution feeder via a hard “tee” configuration, the circuit breaker at the point of connection must include overcurrent and earth fault protection elements at a minimum, designed and set to EPC’s requirements. Note that while a 22 kV circuit breaker is shown in Figure 7, the circuit breaker may instead be located on the generation plant side of the step-up transformer, in which case a suitable load-break or air-break switch and/or fuses may be installed on the 22 kV side.

Figure 7 – Generation plant connection configuration options



5.4.4 Over-voltage and under-voltage protection

Over- and under-voltage protection must be installed to isolate the generation plant from excessively high or low Grid voltages. Settings are to be coordinated with EPC and details included in the PPA.

5.4.5 Generation plant earthing

Each generation plant must be solidly and effectively earthed through a suitably designed earth grid. In general, the resistance between the plant earth grid and a remote earth reference must not exceed 1 Ω, however, specific detail must be agreed with EPC when designing the plant electrical protection systems.

Step and touch potentials around the plant must not exceed levels determined using good electricity industry practice.

5.4.6 Islanding

Unless otherwise agreed between EPC and the IPP, IPP generation plant must not remain connected and operating if the feeder or switchgear to which the generation plant is connected is disconnected from the rest of the Grid (referred to as "islanded" operation). Continued operation of generation plant while islanded is a serious safety concern for EPC line staff and the public. Active and/or passive anti-islanding protection must be provided to ensure that islanded operation is not possible, unless otherwise agreed by EPC and the IPP.

For example, for a generation plant connected in a feeder hard “tee” configuration, as shown in Figure 7, option [B], the feeder is deemed to be disconnected from the Grid if the feeder circuit breaker at the supplying 22 kV distribution substation trips.

Islanded operation of IPP generation plant by design is theoretically feasible for IPP generation plant that is designed and installed with specific capabilities and the capacity to maintain frequency and voltage. All cases of intentional operation of IPP generation plant while islanded from the Grid must be discussed by EPC and the IPP (or IPPs, if more than one IPP is connected to a single feeder) and specific design, performance and operational details agreed prior to execution of the PPA.

6 Grid operations

6.1 EPC is the Grid operator

EPC carries out the Grid operator role on a 24-hour, 7-day a week basis, at the EPC National Control Centre (NCC) at Fuluasou, Upolu. A smaller backup Control Centre is staffed by EPC on a similar basis at Salelologa, Savai'i.

The Grid operator has overall operational control of the Grid in real time.

The Grid operator's primary functions include:

- scheduling and dispatch of all Grid-connected IPP generation plant
- approval of planned outages of all Grid plant, including all IPP generation plant
- monitoring of power quality and network security
- operational control of Grid switching and remote operation of switchgear that has the capability to be controlled remotely via the EPC Supervisory Control and Data Acquisition (SCADA) system
- coordination of Grid fault and restoration response activity, including stabilising the Grid frequency and voltage and re-establishing lost supply.

6.2 Generation plant must provide a SCADA interface

The Grid operator uses the EPC SCADA system to monitor the Grid and generation plant and to remotely control switchgear and generation plant that has been provided with remote control functionality.

SCADA system interface requirements are documented in the EPC controlled document *Integration Requirements for SCADA*, available from EPC upon request.

The design of an IPP generation plant must include secure housing, panel space and supply of power for an EPC-provided SCADA Remote Terminal Unit (RTU) and associated communications terminal facilities.

The IPP must provide cabling to connect the required monitored points and control points to the RTU. EPC will provide an operational communications link between the RTU at the generation plant and NCC, which may involve fibre optic cable or microwave radio links.

IPPs must ensure their SCADA equipment is completely compatible with EPC's SCADA system. Specific technical details will be discussed with the IPP prior to executing the PPA.

6.3 Generation scheduling

The operational status of the generation plant will be subject to the specific terms to be set out in the PPA. Prospective IPPs should note that the Grid operator will need to receive, consider and approve technology-relevant:

- forecasts of generation plant output level (export) on seasonal, week-ahead and day-ahead bases
- requests for planned major and routine maintenance outages, to be submitted at least 6 weeks before the requested start date of the planned outage or such shorter request period if such is forced on the IPP
- requests for urgent or short-term forced maintenance outages with as much forward notice as possible – outage requests received with less than 24-hours' notice will be treated as forced outages.

Specific scheduling process details must be agreed prior to connecting the generation plant to the Grid and included in the PPA.

6.4 Generation dispatch

The Grid operator uses an automatic control system that monitors the balance of electricity generation and demand in real time and adjusts dispatched generation plant to maintain the Grid frequency within the nominal frequency range, as specified in section 5.2. This system is referred to as the micro grid controller.

Similarly, Grid voltage is monitored at points around the Grid and controlled manually or automatically, depending on the location and the control facilities provided. For example, generation plant may be provided with an automatic voltage regulator that continuously monitors local voltage and adjusts the level of reactive power export/import accordingly. Grid transformers are generally provided with on load tap changers and, in some cases, automatic voltage regulating controls.

Dispatch responsibilities require that the Grid operator ensures an adequate level of automatic frequency keeping capacity is continuously available to regulate the Grid frequency by balancing supply and demand in real time.

The presence of significant proportions of intermittent generation plant in the generation mix, such as solar PV and wind, can make frequency keeping a particularly challenging exercise. EPC has deployed advanced battery storage dispatch functionality to mitigate the real time impacts of intermittent generation. This is continuously coordinated by the micro grid controller.

Dispatch responsibilities also require that the Grid operator provides an adequate level of reserve generation capacity that can be rapidly and automatically deployed in contingency situations, for example, in response to a sudden unplanned fault causing generation plant or a feeder to trip.

Accordingly, all generation plant, including both IPP-owned and EPC-owned plant, must promptly and accurately follow dispatch instructions issued by the Grid operator. This includes dispatch instructions issued in respect of generation plant whether communicated by the Grid operator:

- using voice communications to an onsite operator; or
- through use of SCADA remote control functionality.

In normal operating conditions, dispatch instructions issued by the Grid operator, which require an IPP's generation plant to be brought online by synchronising with the Grid, will assume that the Grid voltage and frequency at the relevant Point of Connection are within their respective nominal ranges, as specified in section 5.2.

Generation plant dispatch is highly plant/technology-specific and applicant IPPs must provide full details of the dispatch capability of their proposed generation plant to EPC. This includes any capability the generation plant may have to provide operational or standby reserve capacity that may be automatically or manually brought online at short notice.

Any capability the proposed generation plant has (or could have) to regulate its output to maintain Grid frequency in real time should be discussed with EPC prior to PPA finalisation.

Specific dispatch process details must be agreed prior to connection of the generation plant to the Grid and included in the PPA.

6.5 Emergency management

The Grid operator oversees Grid security levels and seeks, via provision of fast acting reserves, to maintain resilience to identified contingent events, such as a sudden, unplanned loss of an item of generation plant caused by a fault.

Reserves may include:

- partly-loaded hydro generation plant using short-term hydro head pond drawdown or longer-term hydro reservoir storage
- partly loaded thermal plant
- energy stored within a battery energy storage system
- potentially, other technologies that provide energy storage and a means of rapid and automatic deployment.

Nevertheless, Grid emergencies can be expected, with or without warning, at any time. Accordingly, the Grid operator may call on an IPP's generation plant to operate under emergency conditions, on a reasonable endeavours basis, until Grid operations return to normal. The Grid operator will coordinate overall Grid restoration activities and communicate clearly and regularly with the IPP throughout the event, as appropriate.

The ultimate aim in managing a Grid contingency event is to avoid a complete Grid collapse, if at all possible.

Any capability the proposed generation plant has (or could have) to “black start” (ie establish generation if the Grid at the Point of Connection is de-energised) must be discussed with EPC and agreed prior to PPA finalisation.

Specific emergency management provisions relevant to an IPP’s generation plant will be subject to any specific terms to be set out in the PPA. For example, IPPs operating intermittent generation, such as solar PV, will be subject to curtailment during periods of emergency management and must follow dispatch instructions.

7 IPP generation plant connection process

7.1 Grid connection

IPPs may apply to connect least cost RE generation plant to the Grid that fulfils a capacity need outlined in EPC's current *Power System Expansion Plan (PSEP)*.

A connection application generally requires four phases:

- initial concept (proposal)
- establishing feasibility
- approval of the design
- construction.

Each phase consists a number of actions that, in general, must be completed before moving onto the next stage.

7.1.1 Initial concept

IPPs must provide EPC with high level details of their proposed generation plant. EPC will provide guidance on the connection process, and provide a high level response that covers feasibility, connection options, Grid constraints and likely connection timeframes.

EPC will strive to treat all Grid connection applicants even-handedly, including where EPC itself proposes to connect new generation plant to the Grid.

7.1.2 Establishing feasibility

The IPP must review EPC's response and decide whether to proceed with its proposal. This process may involve more consultation with EPC before the IPP commits to more detailed studies and designs.

This stage involves developing details such as:

- generation technology
- land acquisition
- environmental impact assessment
- obtaining all statutory planning consents
- negotiating tariffs for electricity sold to EPC
- revenue metering systems
- technical Grid connection design
- drafting a PPA.

7.1.3 Approval of Design

When it is ready, the IPP must provide comprehensive details of its final design to EPC for approval.

At this stage, further discussions between EPC and the IPP will likely be required about methodology and design details prior to final approval. Approvals from other government agencies will likely also be required. These agencies include:

- Ministry of Natural Resources and Environment (MNRE)
- Ministry of Works, Transport and Infrastructure
- Fire Emergency Services Agency
- The Office of the Regulator (OoTR).

The applicant IPP is responsible for obtaining all relevant statutory approvals.

7.1.4 Construction

Construction may only commence when all necessary approvals have been granted by the respective agencies and a PPA finalised and executed by EPC and the applicant IPP. Note that each PPA requires that EPC obtains OoTR prior approval.

The IPP must provide EPC with up-to-date work schedules from project inception through to plant commissioning and update these at regular intervals.

Regular project management meetings are required throughout the construction phase in accordance with a timetable to be agreed by EPC and the IPP. Comprehensive, professional project management is required of the IPP in all construction activities and in its dealings with EPC.

7.2 Generation plant commissioning

This section outlines the plant commissioning process for all IPPs seeking a Grid connection. Commissioning comprises four phases:

- planning
- pre-commissioning
- commissioning
- post-commissioning.

Each phase consists of a number of actions that must to be completed before moving onto the next phase.

7.2.1 Planning

The planning phase starts soon after execution of the PPA, once EPC grants approval to the IPP to commence construction. EPC in its role as Grid owner will meet with the IPP to discuss key aspects of the commissioning, including highlighting any issues that may cause delays, so that the IPP is made aware of potential issues and can plan accordingly.

7.2.2 Pre-commissioning

EPC will review the information provided by the IPP to ensure compliance with all requirements. All requirements (including those of other agencies) must be satisfied before testing and commissioning may commence.

7.2.3 Commissioning

The IPP must perform the required tests and document the outcomes for EPC's information. This involves the following stages:

- IPP performs the tests – tests must follow the timetable included in the EPC-approved commissioning and test plan
- EPC to specific witness tests – EPC will witness tests as necessary
- IPP to provide test results – documented test results must be provided to EPC.

7.2.4 Post-commissioning

The IPP must provide all final test results and data to EPC. EPC reviews this information and assesses compliance.

- Post-commissioning data – the IPP provides a final updated document of the test results
- Test reports – the IPP submits a complete test report to EPC. The test report must include details of all as-built modifications or alterations, including the outcomes of all test procedures and results, including tests that did not meet the requirements.
- Non-compliance – all non-compliance outcomes must be clearly stated. Remedial procedures must be carried out to ensure that compliance is achieved.
- Assessment of non-compliance – EPC will issue a final report on non-compliance, based upon the information provided throughout the commissioning process.

The generation plant may commence commercial operation at the completion of the commissioning phase.

PART 2 — CONNECTION OF CONSUMER SELF-SUPPLIER GENERATION PLANT

8 Introduction

Some consumers may wish to install rooftop solar PV generation plant that connects within their electrical installation – ie connects "downstream" of the consumer's meter – so as to supply part of their own electricity demand. The Grid Code refers to these consumers as *consumer self-suppliers*. Part 2 of the Grid Code sets out EPC's technical and connection process requirements for consumer self-supplier renewable energy generation plant.

The vast majority of consumer self-supplier installations are expected to be inverter-connected rooftop solar PV systems; accordingly, Part 2 is written for rooftop solar PV. This does not preclude renewable energy generation connection applications for other technologies; EPC will advise of any technology-specific requirements when considering a consumer's application for connection.

A consumer considering connection of a generation technology other than rooftop solar PV should discuss their plans with EPC at an early stage. The technical and connection process requirements set out in Part 2 will provide a broad overview of connection requirements but some of the detail may need to be adapted to take account of the specific attributes of the generation technology.

Residential & small business "small-scale" generation plant

"Small-scale" means generation plant with a maximum capacity of up to 5 kW connected to a single phase consumer installation. For guidance, a rooftop solar PV installation in the range 1 – 3 kW will normally provide ample capacity to supplement the energy needs of a residence or a small business. A specialist solar PV installer will be able to advise on the specific circumstances.

Consumer electrical installations can be supplied from the Grid by 1 or 3 "phases"; each phase is a separate live wire. To maintain a reasonable power flow and voltage balance across each of the 3 phases in EPC's network, a consumer self-supplier solar PV installation with a peak electrical capacity in excess of 5 kW will require a 3-phase connection. A small-scale 3-phase connection can accommodate generation plant capacities up to 15 kW maximum.

Business & industrial "large-scale" generation plant

"Large-scale" means 3-phase connected renewable energy generation plant with a peak capacity of up to 100 kW. This should provide sufficient capacity to supplement the energy needs of larger businesses.

EPC may consider proposals for connection of consumer self-supplier generation plant capacities in excess of 100 kW but such proposals are likely to be of sufficient size and complexity that the provisions of Part 1 of the Grid Code will better suit the application. For example, a 100 kW peak capacity solar PV proposal requiring connection to the Savai'i network would represent a very significant addition in the context of that daytime Grid demand (typically in the range of 1,200 – 1,600 kW). While EPC will take a flexible approach when considering such requests, it is important to note that there are practical limits to the peak power capacities of third party generation plant that may be suited for connection to the Grid in Samoa.

Large-scale generation plant power output must be balanced across all 3 phases.

8.1 Eligibility criteria for connection under Part 2

The main difference between connecting IPP generation plant (covered in Part 1) and consumer self-supplier generation plant is that:

- IPPs exist to supply (sell) all the electricity they generate to EPC; whereas
- consumer self-suppliers supply part of their own electricity demand at their own premises first, and trade their electricity "overs" (sell to EPC) and "unders" (buy from EPC) with EPC at the prevailing, Regulator-approved tariff rates.

This means that consumer self-supplier generation plant must be specified so that in one year, the total energy expected to be generated by the consumer self-supplier's generation plant (*Qpv*) is not greater than the total energy expected to be consumed within the consumer installation (*Qload*) within a year. That is:

$$\sum_{1\,year} (Qpv - Qload) < 0$$

Assessment of connection applications against this eligibility criterion requires estimates of annual *Qpv* and annual *Qload*. When considering a connection application, EPC will assess these quantities as follows:

- *Qpv* will be assessed based on the customer self-supplier's reasonable estimate of the design annual energy production of the proposed solar PV system. In practice, *Qpv* will normally be estimated by the customer self-supplier's system design specialist, using an established methodology that takes account of the capacity, location and orientation (including shading effects) of the proposed solar PV panels. EPC will use the Global Solar Atlas solar calculator, available at http://globalsolaratlas.info/?c=-13.777067,-172.041435,11&s=-13.821411,-171.773869 (or other similar resource) to provide a check of claimed design annual energy production for a given design peak power output.
- *Qload* will be based on the most recent aggregate annual consumption, net of the energy generated by any existing onsite generation within the same period, at the premises at which the solar PV system is proposed to be installed. If a complete year of consumption records is not available (eg

in the case of a new residence), or if the most recent annual consumption record is not representative of expected future consumption for any reason, EPC will make a reasonable estimate of expected annual consumption.

If the installation is modified in future, eg if additional capacity is proposed, EPC will re-assess the annual energy quantities based on the proposed new aggregate *Qpv* and the *Qload* consumption at the time the new application is made.

8.2 General advice about connections under Part 2

Part 2 is primarily written for the information and guidance of service providers who are trained and competent to design, gain EPC approval for, install, commission and provide ongoing customer service for consumer self-supplier generation installations.

Whether electricity is supplied from the Grid or from your own generation plant, any system of electricity supply to a consumer's premises can be highly dangerous.

EPC strongly advises customers that may be considering connection of any renewable energy (RE) generation plant to obtain and follow specialist advice from a competent service provider. Please note that specialist service providers may need to be licensed to provide RE design and installation services in Samoa.

All consumer electrical wiring and fittings – and EPC Grid equipment – must be treated as being energised (live) at all times, unless definitively proven by a competent person to be otherwise.

As stated in the introduction, Part 2 provides for connection of consumer self-supplier rooftop solar PV systems only. This does not preclude applications to connect other forms of renewable generation plant, rather it reflects that rooftop solar PV is the most likely generation technology that consumer self-suppliers will seek to have connected to the EPC Grid.

Because other renewable generation technologies have unique features and technical needs, EPC strongly advises applicants considering such connections to discuss their plans directly with EPC before committing to a project or submitting a formal connection application.

8.3 Common connection configurations

The electrical wiring and fittings within a consumer's premises make up the consumer's *electrical installation*.

To assist prospective connection applicants, Part 2 firstly provides a brief overview of the main components required in consumer electrical installations:

- without solar PV – ie a normal consumer electrical installation
- with rooftop solar PV
- with rooftop solar PV and incorporating an optional storage battery.

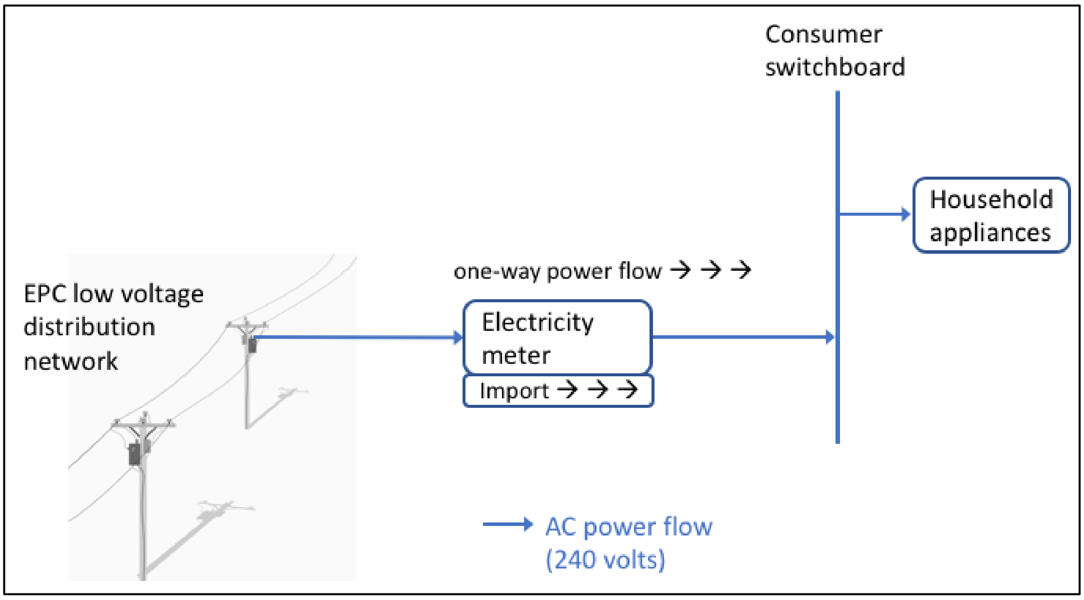
8.3.1 Consumer installations

Consumer electrical installations connect to the Grid at a Point of Connection. The amount of electricity consumed within a consumer's electrical installation is continuously measured by a metering installation, configured to measure aggregate consumption in kilowatt-hours (kWh) at the Point of Connection and record the aggregate total energy in an *import register*.

Many consumers have pre-payment meters. Pre-payment meters also measure energy import but additionally require the consumer to maintain a positive credit balance in the meter so that electricity may flow into the consumer's electrical installation.

The main components of a consumer installation are shown in Figure 8.

Figure 8 – Typical consumer installation without solar PV



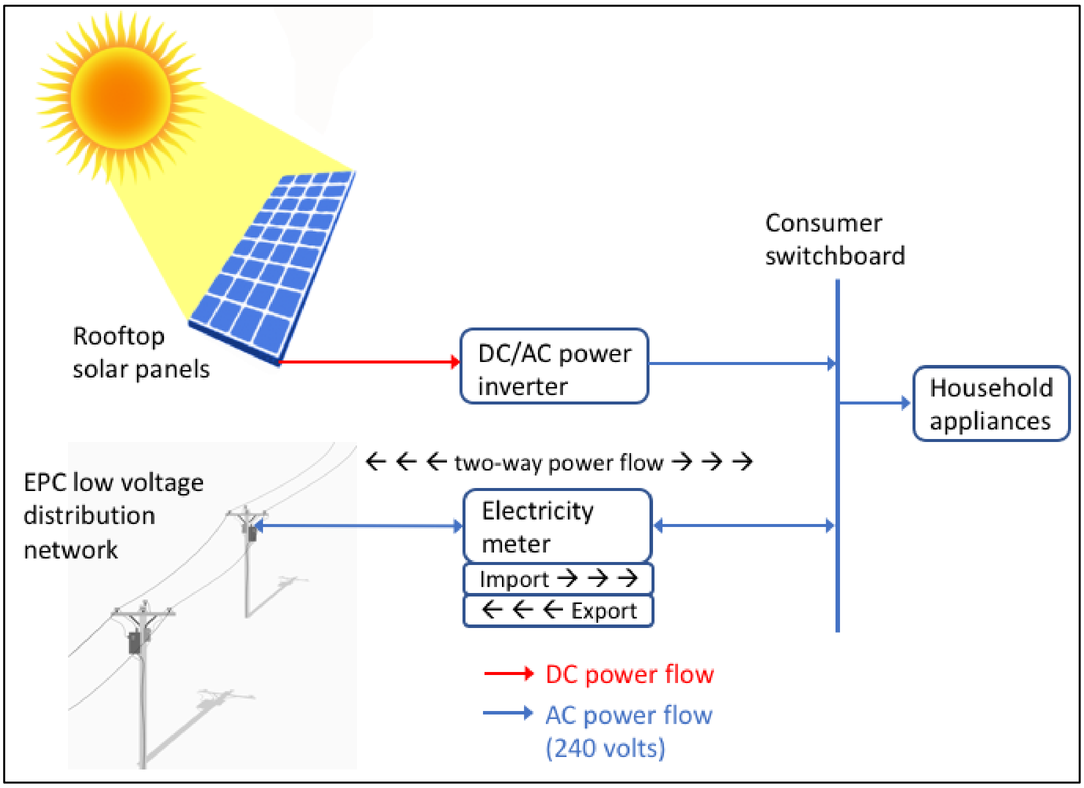
8.3.2 Consumer self-supplier installations

Rooftop solar PV systems can be installed either with or without an integrated storage battery.

Rooftop solar PV without storage battery

Figure 9 builds on Figure 8 and shows how a rooftop solar PV installation connects to the electrical installation.

Figure 9 – Typical rooftop solar PV electrical connections



A solar PV installation requires the following components:

- an array of solar PV panels that generate DC electricity from sunlight
- a power inverter that converts the DC electricity into AC electricity at Grid voltage (nominally 240 volts AC, measured between the phase and neutral wires)
- an additional meter *export register* that separately measures and records electricity exported to the Grid.

Peak solar generation occurs in sunny overhead conditions through the period either side of solar noon. However, for small-scale installations, peak household demand typically occurs in the evening, powering cooking, lighting and other household appliances. As a consequence, at most times of the day, solar PV output will not exactly match a consumer's household demand.

The benefit of remaining connected to the Grid is that a Grid connection enables consumer self-suppliers to trade their electricity "overs" and "unders" with EPC, selling excess quantities to EPC and buying shortfalls from EPC.

A metering installation with separate export and import meter registers allows separate measurement and recording of export and import quantities.

Rooftop solar PV with battery storage

As mentioned above, the maximum output from a solar PV installation usually occurs in the hours either side of noon. This may not coincide with a consumer's maximum electricity demand, which, for residential consumers, is typically in the early evening hours.

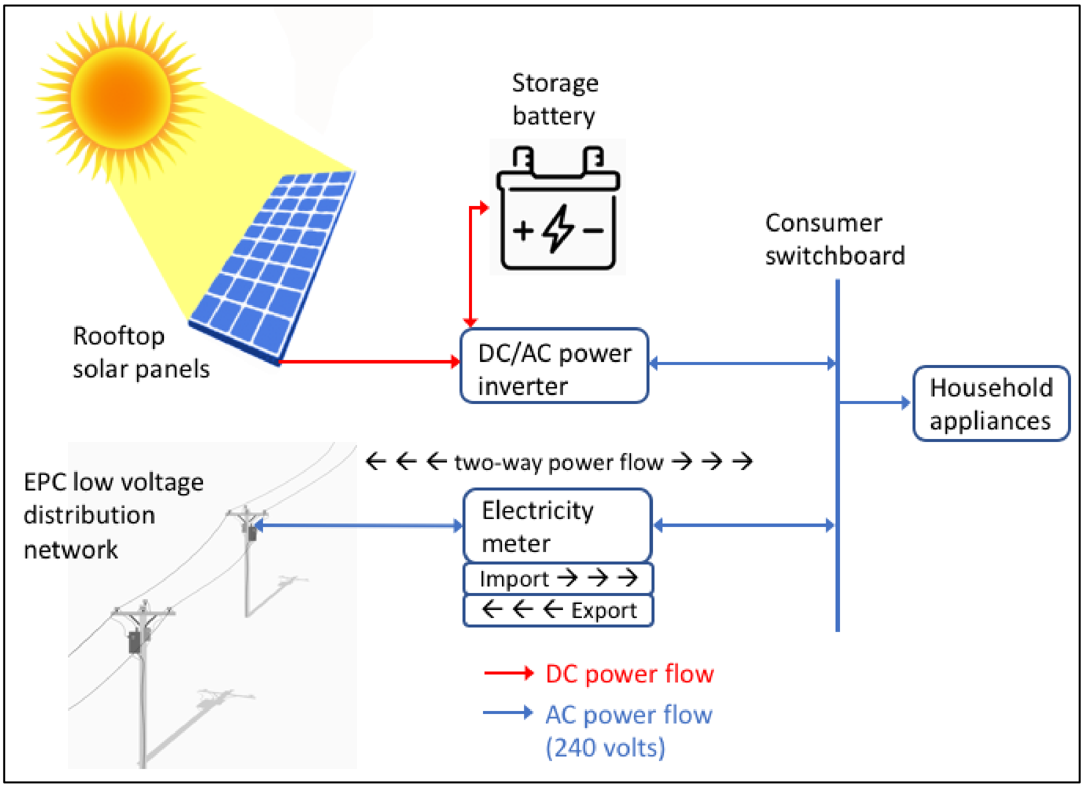
Storage batteries are increasingly integrated with small and large-scale solar PV installations to enable “time shifting” of the relatively more abundant energy generated during the day by storing electrical energy locally and releasing it in the hours of maximum consumer demand in the evening.

EPC encourages the inclusion of a properly setup storage battery of suitable capacity in consumer self-supplier solar PV installations that have a significant time mismatch between periods of maximum energy generation and periods of maximum energy consumption. This situation likely applies to most residential installations and will, in each case, require a situation-specific assessment.

Battery storage won’t completely eliminate overs and unders but it will minimise them, as compared with an installation with the same solar PV capacity and household demand but without battery storage.

Figure 10 builds on Figure 9 and shows how a storage battery connects to the electrical installation.

Figure 10 – Rooftop solar PV with an optional battery



Note: the storage battery may alternatively connect to the switchboard via its own separate DC/AC power inverter. In this case, inverter losses would be higher as compared with the configuration shown in the diagram.

9 Technical requirements for Grid connection

A rooftop solar PV system connected to a consumer's electrical installation, which is itself connected to the Grid, can affect the safety, power quality and reliable operation of Grid electricity supply for all Grid users.

For these systems, Part 2 of the Grid Code provides:

- EPC's technical requirements for Grid connection – in this section 9
- a connection application and approval process and application form – in section 10
- a Connection Agreement template – in a separate companion document.

Headline principle governing the technical requirements

In setting the technical requirements, EPC's objective is to *assess and, if appropriate, approve compliant solar PV systems intended to be electrically connected to, and operated in parallel with, the Grid.*

At all times, Grid-connected generation plant must operate *safely* and *reliably*, and contribute to maintaining *good local power quality*.

9.1 Connection Process

A consumer who wishes to install a rooftop solar PV generation system that will connect to a Grid-connected electrical installation must apply to EPC for approval to connect. Further details of the connection application and approval process are included in section 10.

All connection design and operational details must be agreed with EPC prior to connecting the consumer self-supplier generation plant to the Grid. Before an electrical connection is made, all relevant details must be agreed and recorded in a Connection Agreement. The finalised Connection Agreement must be properly executed by the applicant and by EPC.

In addition, the consumer must obtain a Generation License from the Regulator. Further details are available on the Office of the Regulator's website at: https://www.regulator.gov.ws.

When the generation plant is in place and ready for livening, EPC engineering and field staff will arrange for, and carry out, all electrical inspection, testing, connection and livening activities.

9.2 Safety and technical requirements are based on AS/NZS 4777

The standards identified in Section 3 apply to connection applications made under Part 2. In particular:

- the solar PV installation must comply with the relevant requirements of AS/NZS 4777.1, which specifies *the electrical and general safety installation requirements for inverter energy systems up to or equal to 200 kVA for the injection of electric power to an electrical installation connected to the grid at low voltage*; and
- the inverter proposed for a consumer self-supplier installation must comply with the relevant requirements of AS/NZS 4777.2, which specifies *requirements and tests for low voltage inverters for the injection of electric power through an electrical installation into the grid at low voltage*.

Compliance of a specific inverter make and model with AS/NZS 4777.2 must be demonstrated by the inverter having been issued with a Declaration of Conformity (DoC). The DoC certifies that the inverter has been type-tested and complies with all mandatory aspects of AS/NZS 4777.2, by a test laboratory that has an appropriate accreditation to undertake such testing. The process of applying for a DoC for a specific inverter model is the responsibility of the inverter manufacturer or distribution agent (eg an importer/wholesaler of solar power inverters).

EPC will maintain a register of previously approved inverter makes and models, including details of the relevant DoC (ie the make, model, date awarded, version number of the AS/NZS 4777.2 complied with, including a copy of the properly issued DoC document).

A connection application that includes an inverter model that, at the date the application is made, is not included on EPC's approved inverter register must include a copy of the DoC for that inverter model.

9.3 Overview of compliance requirements with AS/NZS 4777.2

AS/NZS 4777.2 variously includes both *mandatory* and *optional* requirements. EPC requires compliance with:

- all *mandatory* requirements of AS/NZS 4777.2; and
- some specific *optional* requirements, as described in the following sections.

Table 3 provides an overview of required compliance with AS/NZS4777.2, starting at clause 5 (General Requirements).

Table 3 – Overview of compliance requirements with AS/NZS 4777.2

AS/NZS 4777.2 clause	Topic/feature	Degree of compliance required

5	General requirements	**mandatory**, as relevant to the circumstances
6	Operational modes and multiple mode inverters	see following subclause detail—
6.2	Inverter demand response modes (DRMs)	only to the mandatory requirements of this clause, ie that DRM 0 must be supported – however, EPC does not intend at this stage to make use of DRM 0, so this mode should be disabled by default
6.3.1	Inverter power quality response modes - General	**mandatory** compliance with volt response modes, per the following subclause detail—
6.3.2.2	Volt-watt response mode	**mandatory** – see setting requirements in Grid Code section 9.6.1
6.3.2.3	Volt-var response mode	**mandatory** – see setting requirements in Grid Code section 9.6.2
6.3.2.4	Voltage balance modes	**optional –** compliance required only if the mode is available in the inverter
6.3.3	Fixed power factor mode and reactive power mode	**optional –** disabled if the mode is available in the inverter
6.3.4	Characteristic power factor curve for cos φ (P) (Power response)	**optional –** disabled if the mode is available in the inverter
6.3.5	Power rate limit	**mandatory** – see setting requirements in Grid Code section 9.5
6.4	Multiple mode inverter operation	must discuss with EPC, if relevant – eg if a battery is included in the installation and is connected to the DC side of the inverter
6.5	Security of operational settings	**mandatory**
7	Protective functions for connection to electrical installations and the grid	**mandatory**

The following sections 9.4 – 9.7 relate to the electrical power quality conditioning and protection functions performed by the inverter and expand on the overview provided in Table 3.

These functions require the secure application of appropriate settings within the inverter, which must incorporate measures that resist tampering by unauthorised persons (eg by providing digital access security measures and passwords).

> *Electrical hazard warning: Internal inverter settings affect the safe and reliable operation of the inverter and the overall performance of the solar PV generation installation.*
>
> *An inverter has **no user-accessible adjustments or settings**.*
>
> *Settings must be properly applied by the properly authorised inverter service agent/installer prior to commissioning.*
>
> *Any subsequent in-service adjustments that may be required must only be made by the properly authorised inverter service agent/installer.*

9.4 Sustained operation for frequency variations

Rationale

From time to time, the Grid will experience frequency disturbances caused by fluctuations in generation from large generation plant and changes in demand of large loads. Sometimes, generation plant and loads can suddenly and unexpectedly electrically disconnect from the Grid, eg during a fault. These supply and demand fluctuations will cause the Grid frequency to fluctuate up or down from its nominal 50 Hz level.

It is important that inverter-connected, consumer self-supplier generation plant is able to remain in stable, coordinated operation throughout frequency fluctuation events, within specific limits. This section specifies these limits.

Requirements

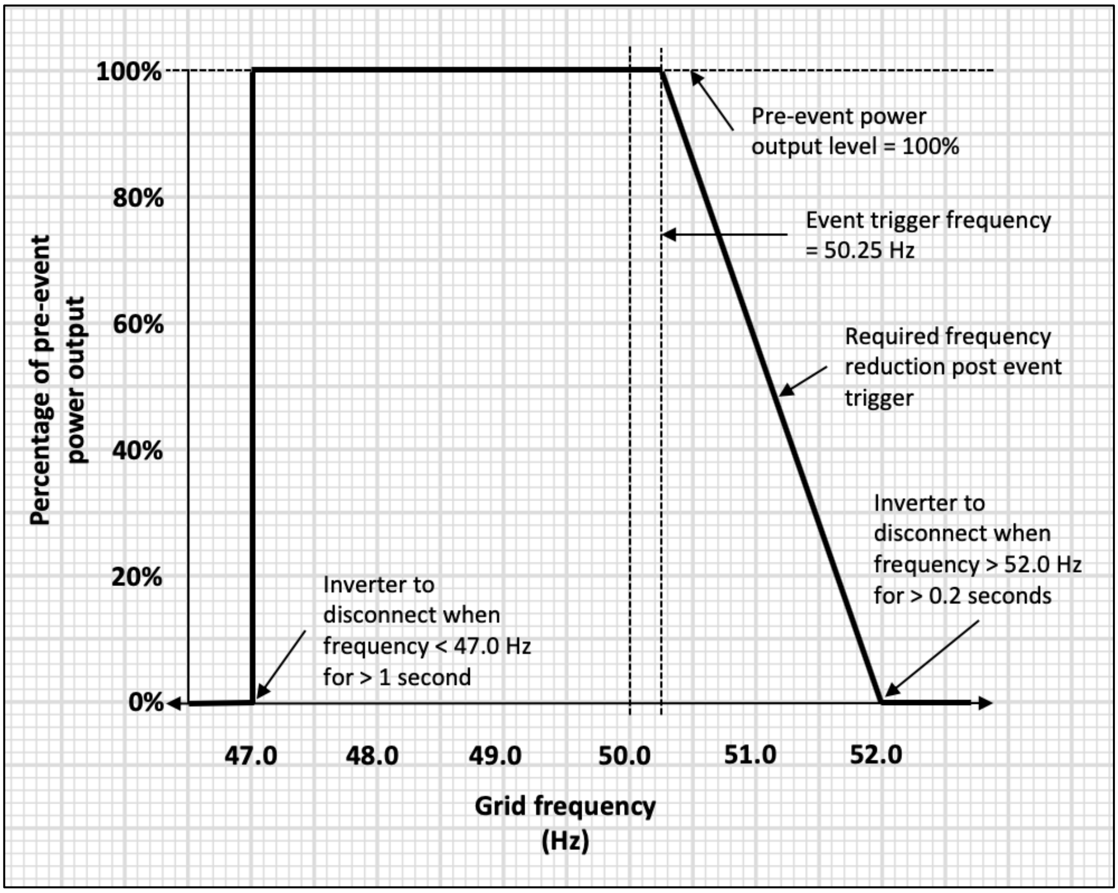
Every inverter must be capable of remaining connected while the Grid frequency remains within the range 47.0 – 52.0 Hz.

Every inverter must be capable of remaining connected and (if there is sufficient input power eg sunlight) able to operate at output power levels up to its rated capacity while the Grid frequency remains within the range 47.0 – 50.25 Hz.

For over-frequency fluctuations, if the Grid frequency exceeds 50.25 Hz (defined as an "event" – see Figure 11) and continues to rise, the inverter must linearly reduce its output power as shown in Figure 11, such that the power output reaches zero watts if the frequency reaches or exceeds 52.0 Hz and disconnects if the frequency remains above 52 Hz for at least 0.2 seconds (see also section 9.7.3).

For under-frequency fluctuations, the inverter must disconnect if the Grid frequency falls and remains below 47.0 Hz for at least 1 second (see also section 9.7.3).

Figure 11 – Inverter power output response to frequency variations



These mandatory requirements are more comprehensively described in:

- clause 7.5.3.1 of AS/NZS 4777.2 (in particular, f_{stop} = 52.0 Hz); and
- section 9.7.3.

Clause 7.5.3.1 also describes the allowable rate of restoration of inverter power output levels after the Grid frequency returns to within its normal operating range.

Compliance with the restoration rates is also mandatory.

9.5 Stable restoration following an over-frequency event

Rationale

Sudden large increases in consumer self-supplier generation output levels can be experienced in the following situation:

1. there is a large aggregate capacity of solar PV generation plant connected to the Grid (“large aggregate capacity” here means large relative to the aggregate demand supplied by the Grid);

2. solar PV generation plant is operating at high output levels in aggregate and electrically disconnects from the Grid due to a system event that causes a frequency deviation in excess of the limits specified in Figure 11;
3. the Grid subsequently returns to normal operation within the normal frequency band following fault restoration; and
4. the electrically disconnected solar PV generation plant (in item 2) attempts to reconnect to the Grid at high/full power output at the same time.

A large aggregate capacity of solar PV generation simultaneously reconnecting and (in sunny conditions) very quickly ramping to its full aggregate output level could potentially create an unstable operating situation, possibly leading to Grid over-frequency and further Grid instability.

Inverters that comply with AS/NZS 4777.2 can contribute to the rapid restoration of normal Grid operation by limiting (slowing) their rate of power output increase in the immediate post-event Grid restoration period.

Requirements

Power rate limit mode is included in AS/NZS 4777.2 and the Grid Code requires that all consumer self-supplier inverters include the "soft ramp up after connect or reconnect" power rate limit mode and have this mode enabled by default.

Power rate limit mode capability

The requirements for soft ramp up after connect or reconnect power rate limit mode are described in clauses 6.3.5.2 and 6.3.5.3.2 of AS/NZS 4777.2. Specifically:

- W_{Gra} is the ramp rate limit of inverter real power output (expressed in % of rated real power per minute);
- T_n is the nominal ramp time (in minutes); and
- $W_{Gra} = \frac{100\%}{T_n}$

Power rate limit mode default settings

Table 5 lists the *default settings* that must be applied to small and large-scale consumer self-supplier inverters connected to the EPC Grid.

Table 4 – Inverter power rate limit mode default settings

Connection class (see Table 1)	W_{Gra} (%/minute)	T_n (minutes)
Residential	100%	1
Business	33%	3

Additionally, in special circumstances, EPC may require that *alternative, installation-specific settings* are applied to individual inverters when they are initially installed. In this case, the relevant details will be recorded as special conditions in Schedule 1 in the Connection Agreement.

EPC further retains the right to require a consumer self-supplier to have different settings applied, within the inverter's design capability, at any time during the operational life of the inverter, should a future need arise. In this case, the relevant details will be recorded as special conditions in an amended Schedule 1 in the Connection Agreement.

9.6 Power quality response modes

9.6.1 Volt-watt mode

Rationale

Excessive levels of active power injected into a network can lead to excessively high local voltages.

Inverters that comply with AS/NZS 4777.2 can act to limit local over-voltages by automatically curtailing their power output if local voltages rise to extreme levels.

Requirements

Volt-watt mode is included in AS/NZS 4777.2 as an optional power quality response mode, however the Grid Code requires that all consumer self-supplier inverters have the capability to operate in volt-watt mode and that this mode is enabled by default.

The requirements for volt-watt mode are described in clause 6.3.2.2 of AS/NZS 4777.2:2015 and must be complied with in all respects, with the following specific settings to be applied as the *default settings* for inverters connected to the EPC Grid.

Additionally, in special circumstances, EPC may require that *alternative, installation-specific settings* are applied to individual inverters when they are initially installed. In this case, the relevant details will be recorded as special conditions in Schedule 1 in the Connection Agreement.

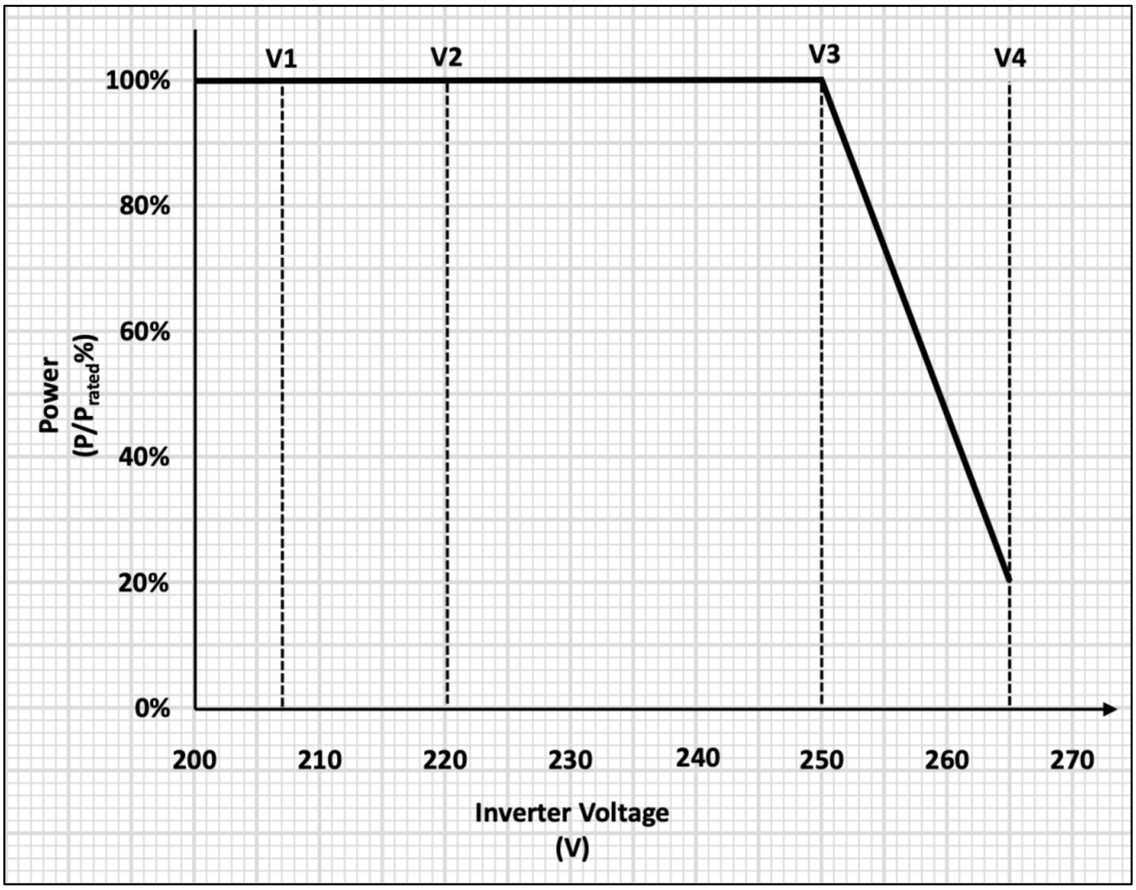
EPC further retains the right to require a consumer self-supplier to have different settings applied, within the inverter's design capability, at any time during the operational life of the inverter, should a future need arise. In this case, the relevant details will be recorded as special conditions in an amended Schedule 1 in the Connection Agreement.

Volt-watt mode capability

Every inverter must have the *capability* to curtail (ie ramp down) its power output from 100% to 0%, as a function of the voltage measured at the inverter's AC terminals.

Volt-watt mode default settings

Figure 12 – Inverter volt-watt mode default settings



Volt-watt mode must be enabled by default.

The maximum power output levels corresponding to the voltages V1 – V4 in Figure 12 must be set in the inverter's firmware settings as set out in Table 5.

Table 5 – Inverter volt-watt mode default settings

Figure 12 Reference	Voltage (volts)	Maximum apparent power output as a percentage of rated apparent power
V1	207	100%
V2	220	100%
V3	250	100%
V4	265	20%

Note that these are default settings only; EPC may require that alternative settings are applied to specific inverters in special circumstances. In this case, the relevant details will be recorded as special conditions in Schedule 1 in the Connection Agreement.

9.6.2 Volt-var mode

Rationale

In general, LV networks have no capability to actively regulate the local voltage. Generation and network equipment that is capable of regulating a LV network's voltage is installed at higher voltage levels in the network.

Voltage fluctuations in LV networks are exacerbated by connected consumer self-supplier generation plant. This usually manifests as very high local voltages that exceed the upper target voltage limit for consumer supply (which is 264 volts – see section 4.3.2).

Inverters that comply with AS/NZS 4777.2 can provide a level of local voltage regulation by continuously and automatically generating (sourcing) or consuming (sinking) reactive power. Generating reactive power will act to increase the local voltage while, conversely, consuming reactive power will decrease the local voltage.

Requirements

Volt-var mode is included in AS/NZS 4777.2 as an optional power quality response mode, however the Grid Code requires that all consumer self-supplier inverters have the capability to operate in volt-var mode and that this mode is enabled by default.

The requirements for volt-var mode are described in clause 6.3.2.3 of AS/NZS 4777.2 and must be complied with in all respects, with the following specific settings to be applied as the *default settings* for inverters connected to the EPC Grid.

EPC may require that *alternative, installation-specific settings* are applied to individual inverters when they are initially installed, in special circumstances. In this case, the relevant details will be recorded as special conditions in Schedule 1 in the Connection Agreement.

EPC further retains the right to require a consumer self-supplier to have different settings applied, within the inverter's design capability, at any time during the operational life of the inverter should a future need arise. In this case, the relevant details will be recorded as special conditions in an amended Schedule 1 in the Connection Agreement.

Volt-var mode capability

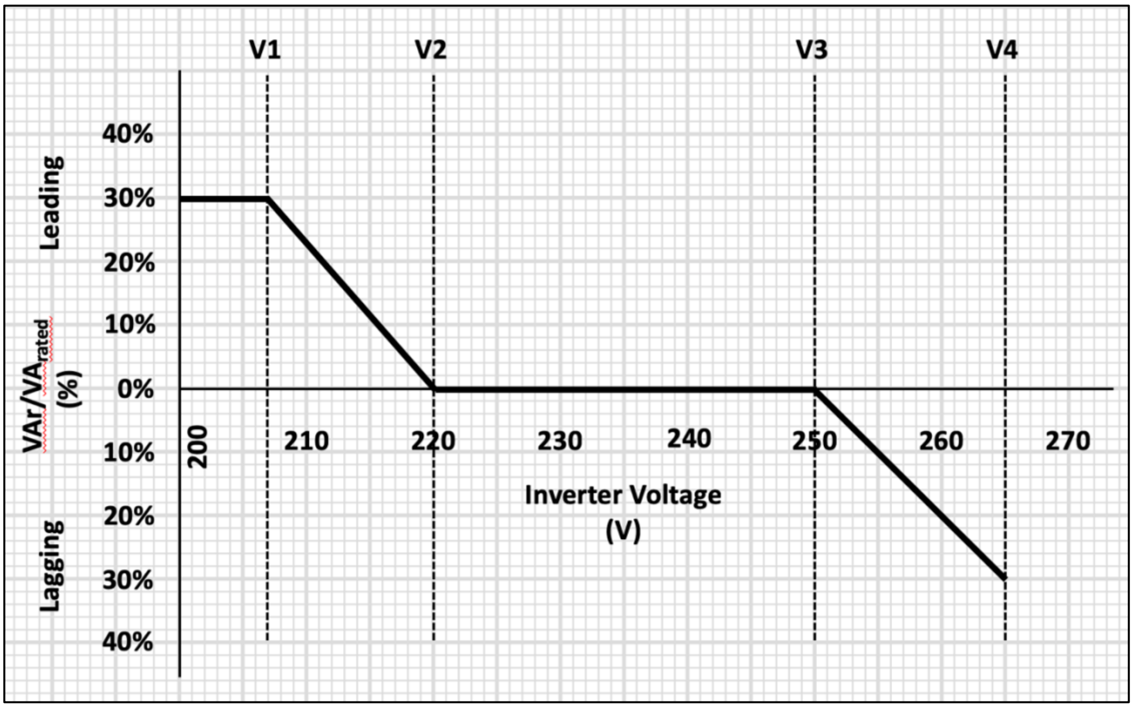
Every Inverter must have the *minimum capability* to operate at a power factor within the range:

- from 0.8 lagging (ie importing (sinking) reactive power from the Grid)
- to 0.8 leading (ie exporting (sourcing) reactive power to the Grid).

This power factor operational range represents each inverter's required *minimum power factor capability* only; the required *default power factor settings* are described next.

Volt-var mode default settings

Figure 13 – Inverter volt-var mode default settings



Volt-var mode must be enabled by default.

The inverter power factor corresponding to the voltages V1 – V4 in Figure 13 must be set within the inverter as set out in Table 6.

Table 6 – Inverter volt-var mode default settings

Figure 13 Reference	Voltage (volts)	Reactive power as a percentage of rated apparent power	Implied power factor
V1	207	30% leading	0.95 leading
V2	220	0%	1.0
V3	250	0%	1.0
V4	265	30% lagging	0.95 lagging

"Leading" means that reactive power is generated (sourced) by the inverter and exported into the consumer electrical installation.

"Lagging" means that reactive power is consumed (sunk) by the inverter and imported from the consumer electrical installation.

Note that these are default settings only; EPC may require that alternative settings are applied to specific inverters in special circumstances. In this case, the relevant details will be recorded as special conditions in Schedule 1 in the Connection Agreement.

9.7 Protection systems

The protective elements for inverter-connected consumer self-supplier generation plant involve operation of an automatic disconnection device that, when triggered, can rapidly electrically disconnect the inverter from the consumer's electrical installation – and, hence, from the Grid.

All mandatory requirements in clause 7 of AS/NZS 4777.2 are mandatory requirements of the Grid Code. The following sections provide specific detail about the settings required for inverters connected to the EPC Grid.

9.7.1 Anti-islanding protection

Consumer self-supplier generation plant must not remain connected if the LV network to which the generation plant is connected becomes disconnected from the rest of the Grid (referred to as "islanded" operation).

Continued operation of generation plant while islanded is a serious safety concern for EPC field staff and the public.

Active (clause 7.3) and passive (clause 7.4) anti-islanding protection must be provided to ensure that islanded operation is not possible.

9.7.2 Operation while isolated from the Grid

Grid-isolated operation of consumer self-supplier generation plant by design is feasible for consumer self-supplier generation plant that is designed and installed with specific capabilities to maintain frequency and voltage and to detect and isolate electrical faults.

"Grid-isolated" means that the main circuit breaker between the consumer's electrical installation and the grid is open (ie tripped) and that local power source(s) connected within the consumer's electrical installation directly supply the consumer's loads.

Such installations will typically require a means of energy storage, usually a battery energy storage system, and an inverter that is specifically designed to operate in grid-isolated mode.

Small grid sections that can supply electricity locally, whether connected to the EPC Grid or not, are sometimes referred to as "micro-grids". A specially designed inverter automatically manages connection to and disconnection from the main Grid system.

All connection applications that seek to include the capability to intentionally operate while isolated from the Grid must be discussed with EPC at the earliest opportunity. Specific design, performance and operational details must be agreed by EPC and the consumer prior to finalisation of the Connection Agreement.

In principle, the AS/NZS 4777.2 inverter requirements set out in Part 2 of the Grid Code apply to such installations, modified and extended as necessary to accommodate the specific needs of a micro-grid installation.

9.7.3 Voltage and frequency limits for passive anti-islanding protection

Clause 7.4 sets out protective function limits and settings for over- and under-voltage and for over- and under-frequency.

Table 7 is derived from Table 13 in AS/NZS 4777.2 and sets out the specific settings to be applied to all inverters connected to the Grid (ie, these are the country-specific settings referred to in the referenced standard).

Table 7 – Passive anti-islanding set-point values

Protective function	Protective function limit	Trip delay time (seconds)	Maximum disconnection time (seconds)
Under-voltage (V<)	180 V	1 s	2 s
Over-voltage 1 (V>)	260 V	1 s	2 s
Over-voltage 2 (V>>)	265 V	–	0.2 s
Under-frequency (F<)	47 Hz	1 s	2 s
Over-frequency (F>)	52 Hz	–	0.2 s

9.8 Metering installations

All electrical installations that have consumer self-supplier generation plant that operates while electrically connected to the Grid must have a metering installation that has *separate import and export registers*.

The metering installation must be configured so that it separately measures and records all active energy (ie kWh) that flows:

- **from** the Grid **to** the consumer installation in the **import register**; and
- **to** the Grid **from** the consumer installation in the **export register**.

EPC will periodically read the meter registers in line with EPC's normal meter reading arrangements. Terms and conditions related to metering and billing of consumer self-supplier generation plant are included in the Connection Agreement.

9.9 Installer requirements

All consumer self-supplier generation plant installation activities must be undertaken by suitably experienced and qualified design and installation specialists, who must follow the equipment manufacturer's installation instructions in all relevant respects. EPC strongly advises customers that may be considering investing in RE generation plant to obtain and follow specialist advice from a competent service provider. *Please note that specialist service providers may need to be licensed to provide RE design and installation services in Samoa.*

All relevant Samoan building and electrical codes and standards must be followed. Building consents may be required and must be obtained before the generation plant is commissioned.

All wiring installation, testing and electrical livening work associated with the generation plant must be undertaken by a registered electrician, in compliance with Samoan electrical safety regulations and/or other relevant legislation.

9.10 Network congestion management

Because consumer self-supplier generation plant can export energy back into EPC's Grid, the generation plant has the potential to overload parts of the Grid. An overloaded part of the Grid is said to experience "network congestion".

While this is likely not an issue at the outset, solar PV generation plant in particular has the capacity to contribute local network congestion. This is because all solar PV installations within a locality will likely connect to the same LV network and generate at their peak capacity at the same time (ie in the same weather conditions, especially in direct sunlight in the 2 or 3 hours either side of solar noon). If consumer loads are coincidently low at these times, the local LV network will experience reverse power flow, as excess consumer self-supplier generation is "pushed back upstream" into the wider Grid.

Like all traditional electricity grids, EPC's Grid is (for the most part) engineered on the assumption that electricity flows in one direction only (ie "downstream", from upstream Grid-connected generators to downstream consumers). High levels of growth of consumer self-supplier generation plant may, at some future time, create reverse power flows and congestion on some parts of the Grid.

Typically, congestion is initially experienced as excessively high local voltages, which can damage local consumers' electrical appliances as well as EPC's Grid equipment. If the level of the reverse power flow is high enough, it may exceed the rated capacity of circuits, switchgear and transformers. The requirements related to inverter voltage support and power output curtailment, set out in section 9.6, are designed to pre-empt, and where possible, remediate this particular issue.

EPC will monitor this situation as consumer self-supplier solar PV installations begin to connect to the Grid, including by installing special voltage and current monitoring equipment in targeted problem locations. EPC may need to undertake future congestion relief measures, including imposing limits on how many new or upgraded solar PV installations may be permitted within a specific locality. If this eventuates, EPC will communicate issues and remedies with the affected consumer self-suppliers and the local community.

Congestion management strategies are best determined on a case-by-case basis during the Grid connection application process. There are two main ways to manage network congestion:

- by ensuring that generation plant connection only occurs in uncongested areas, or is accompanied by an appropriate Grid upgrade; or
- by agreeing and implementing, on a case-by-case basis, the real-time operational rules that will apply to a particular consumer self-supplier installation.

The outcome will depend on the nature of the network congestion and the operational characteristics of the generation plant.

10 Consumer self-supplier connection application and approval process

10.1 Overview of the process to gain approval to connect consumer self-supplier generation

Consumer self-supplier new generation installations

Consumers that may be considering adding self-supply generation plant to their property, such as a rooftop solar PV system, should familiarise themselves with the connection application process set out in this section.

The main stages of a consumer self-supplier generation project are:

- Check feasibility and carry out conceptual design
- Apply to the relevant authority to obtain relevant building consents, as required by the relevant regulations
- Apply to EPC for a Grid connection
- Sign a Connection Agreement with EPC
- Apply to the Office of the Regulator for a Generation License
- Install the generation plant
- Notify EPC that the generation plant is ready for livening
- With EPC engineering and connections staff, inspect, test and commission the generation plant
- Consumer self-supplier training and ongoing support

Section 10.2 provides further detail of the requirements and timeframes in each of these steps. An information pack describing these processes will be made available on EPC's website.

Upgrading an existing consumer self-supplier generation installation

While not relevant at the outset, consumers that have connected consumer self-supplier generation plant that operates while electrically connected to the Grid may wish to upgrade an existing installation.

Any upgrade, eg installing additional solar panels to increase the capacity or replacing the inverter, requires a new application to EPC. EPC will review upgrade applications in accordance with all relevant sections of Part 2 of the Grid Code that are current at the time of application.

10.2 Process detail for design, approvals, installation and commissioning

The following sections outline the main process steps for connecting a consumer self-supplier generation installation to the EPC Grid.

10.2.1 Check feasibility and carry out conceptual design

Requirements	Timeframe
Consumer's considering investing in consumer self-supplier generation plant should initially consult EPC's website for the latest information regarding the process at https://www.epc.ws.	Applicant controlled – take as much time as necessary.
Consumers will need to obtain the services of a competent solar PV designer/installer (the Grid Code refers to this person as "the installer"). Please note that this person may need to be licensed to perform consumer generation plant design and installation services in Samoa. EPC will provide guidance on this aspect on request. The installer will assess the suitability of the consumer's property for a solar PV installation and provide pre-sales advice and information about the plant, including costs and benefits, and the installation process. The consumer will need to consider trade-offs between the capability and costs of available/suitable plant options.	Applicant controlled – take as much time as necessary.
If a consumer self-supplier generation plant installation looks to be suitable, and the consumer accepts the installer's product/service offer, the consumer and installer will need to enter into a commercial agreement to proceed. This will be managed/guided by the installer.	Applicant controlled – take as much time as necessary.

10.2.2 Apply for building consents

Requirements	Timeframe
EPC itself has no relevant requirements and offers no specific advice in this area. It is the applicant's (or their agent's) responsibility to determine and comply with all building/development consents and safety and other regulations that may be relevant to the intended project.	Applicant controlled – take as much time as necessary.

10.2.3 Apply to EPC for a Grid connection

Requirements	Timeframe
Acting as the consumer's agent, the installer completes and submits an application for a generation plant that will operate while connected to the EPC Grid. Once finally installed and commissioned (but not yet!), electricity may flow between the consumer's electrical installation and the Grid in either direction, depending on the balance of instantaneous generation output and the consumer's electricity demand. "Overs" and "unders" will flow to and from the Grid respectively throughout the day – see section 8.3.2 for more information about this.	Applicant controlled – take as much time as necessary.
Solar PV installations using a standards-compliant inverter should be relatively straight-forward for EPC to review. Other technologies are likely to require more specific assessment by EPC; consumers/installers are advised to contact EPC early in the process – ie before submitting a connection application – if a different generation technology, or a more complex scheme, is being considered.	Applicant controlled – take as much time as necessary.
A Connection Application Form for consumer self-supplier generation plant is available on the EPC website at https://www.epc.ws. Once submitted by the installer, EPC will review the connection application, initially focussing on the completeness of the application.	EPC will acknowledge receipt of a connection application within 2 business days. EPC will complete an initial review of a solar PV connection application within 10 business days – a non-solar PV application may take longer, in which case the applicant will be advised of the likely timetable.
Installer works with EPC as necessary to obtain EPC approval.	No specific timetable is possible here because review needs are situation-specific. EPC will act promptly to complete its review and will set

Requirements	Timeframe
	clear timeframe expectations with the installer at each step.

10.2.4 Sign a Connection Agreement with EPC

Requirements	Timeframe
Consumer and EPC sign a Connection Agreement, using the default Connection Agreement template, available on the EPC website https://www.epc.ws. EPC may require that any special conditions are drafted into Schedule 1 of the default Connection Agreement template if circumstances require this (eg if a non-solar PV technology is involved).	Consumer signs first and, if all details are correct, EPC will counter-sign within 3 business days of receipt of consumer-signed documents.

10.2.5 Apply to OoTR for a Generation License

Requirements	Timeframe
Section 13(1) of the Electricity Act 2010 requires that parties wishing to connect generation plant to the Grid first apply for and obtain a Generation License. See the Office of the Regulator (OoTR) website for details of the Generation License application process. Acting as the consumer's agent, the installer submits an application for a Generation License to the OoTR, including a copy of the signed Connection Agreement from the previous step.	Applicant consumer/installer controlled – take as much time as necessary.
The installer (and, if necessary, the consumer) works with the OoTR as necessary to obtain OoTR approval for a Generation License.	Per OoTR timetable – see the OoTR website for details of timeframe.
If the application is in order, the OoTR issues the Generation License.	Per OoTR timetable – see the OoTR website for details of timeframe.
The installer provides a copy of the Generation License to EPC.	Within 2 business days of issue by the OoTR.

Important Note: the requirement to obtain a Generation License is a legal requirement that is not under EPC's control – EPC strongly recommends that the installer and the consumer satisfy themselves that there are no barriers to obtaining a Generation License before proceeding with a project.

10.2.6 Install the generation plant

Requirements	Timeframe
Installer installs the generation plant, using a licensed electrician to carry out the 240/415 volt connections to the consumer's switchboard.	Applicant consumer/installer controlled – take as much time as necessary.
EPC to install and commission an appropriate metering installation with both import and export registers.	Within normal metering installation timeframes.

10.2.7 Notify EPC "ready for livening" then inspect, test and commission the generation plant

Requirements	Timeframe
The installer coordinates with the consumer and with EPC to arrange for final inspection, testing and commissioning.	EPC will provide appropriate connection field staff onsite within 5 business days of receipt of such request from the installer.
EPC engineering and field staff electrically liven the generation plant when all preliminary inspection and testing is complete.	On the agreed date.
Once inspection and testing is complete, and all defects have been remedied to EPC's satisfaction, EPC issues a notice of approval – the generation plant is at this point handed over to the consumer for normal operation, with ongoing installer support as agreed between the consumer self-supplier and the installer.	EPC issues notice of approval within 5 business days.
EPC updates consumer installation records, including GIS, metering installation, meter reading and customer billing records.	Internal EPC processes, to be completed within 5 business days.

10.2.8 Consumer self-supplier training and ongoing support

Requirements	Timeframe
Installer works with the consumer for user familiarisation of: • safety features • operational controls and displays • arrangements and contact details for future support, troubleshooting and servicing.	Consumer self-supplier/installer controlled – take as much time as necessary.

Important Note: EPC will not provide operational support or troubleshooting of generation plant issues to the consumer self-supplier. It is imperative that the consumer self-supplier arranges comprehensive ongoing support with a competent specialist service provider. EPC's rights and obligations related to grid connection of consumer self-supplier generation plant are set out in the Connection Agreement entered into with the consumer self-supplier prior to commissioning.

10.3 Summary of key requirements for a consumer self-supplier Grid connection

While section 10.2 is summary of the process steps in the order a consumer and their installer will likely implement them, the following is a checklist of key requirements.

Key Requirements	Details
Consumer self-supplier generation plant design and installation must conform with the Grid Code	Use a licensed designer/installer that is familiar and experienced with all relevant Grid Code requirements.
Maximum installed capacity must meet eligibility requirements – see section 8.1	Assess and compare existing annual energy consumption and expected energy generated
Installation may include a battery – see section 8.3.2	Consider costs and benefits of system design options with and without a battery
Applicant must apply to EPC for a Grid connection and gain formal approval	Designer/installer submits an application form to EPC on the consumer's behalf
Consumer self-supplier and EPC must enter into a Connection Agreement	Use default template, modify only as necessary to record consumer details

Key Requirements	Details
	and any special terms and conditions (Schedule 1)
Consumer self-supplier must obtain a Generation License from the Office of the Regulator	See OoTR website for details
Installation must comply with relevant requirements of AS/NZS 4777.1 – see section 9.2	Design and installation must meet electrical and general safety installation requirements for inverter energy systems
Proposed inverter must have been issued with a Declaration of Conformity with AS/NZS4777.2 – see section 9.2	Inverter make and model must adhere to requirements and must have been tested as specified in the standard
Proposed inverter must be capable of operating in specific power quality modes that are optional under AS/NZS 4777.2 and must have power quality and protection settings applied that conform with the Grid Code – see summary in section 9.3.	• Volt-watt response mode (see section 9.6.1) • Volt-var response mode (see section 9.6.2) • Power rate limit (see section 9.5) • Protective functions (see section 9.7)
Installation must incorporate both import and export meters	Separate registers for import and export energy enable net billing, as required by OoTR policy
Installation must comply with any/all relevant local resource planning requirements and other relevant regulations	Applicant (or the designer/installer acting as agent) must apply for, and be issued with, a Generation License from the Office of the Regulator – see OoTR website for application process detail
Installation must be inspected, tested and electrically livened by EPC engineering and connections field staff	Installer notifies EPC that the generation plant is ready for testing, livening and commissioning. EPC connection field staff attend on the agreed date and time.

10.4 Connection application form

Table 8 lists the information required in a consumer self-supplier connection application.

Note that Table 8 is not the application form itself but indicates the basic information required. Working with the installer, EPC may require additional clarifications and/or further information in specific circumstances.

A printable copy of the actual connection application form is available on the EPC website at https://www.epc.ws.

Table 8 – Basic information required to assess an application to connect consumer self-supplier generation plant to the EPC Grid

1. Agent/installer details – the person applying on the consumer's behalf

Name: ____

Company: ____

Address: ____

Phone: ____

Email: ____

2. Details of the EPC customer at premises where the generation plant is to be connected

Name: ____

Company: ____

Address: ____

Phone: ____

Email: ____

3. Connection/account number if an existing customer

Account number: ___________________________________

4. Details of proposed generation plant

(a) Connection type

- existing
- new
- residential
- business

(b) Renewable energy source/technology

- solar PV
- wind
- micro-hydro
- biomass
- other (specify)

(c) Inverter make and model

____

(d) Inverter rating (AC)

- ○ _____________ volts
- ○ _____________ amps
- ○ _____________ kVA
- ○ _____________ kW
- ○ _____________ phase (1 or 3)

(e) Inverter included in EPC approved inverter list?

○ yes ○ no

(f) If no, attach DoC to AS/NZS 4777.2

(g) Inverter capable of all mandatory power quality modes? See Grid Code sections 9.5 & 9.6

○ yes ○ no

(h) Details of any battery storage included

____

5. Name of licensed electrical contractor

Name: ____

Company: ____

Address: ____

Phone: ____

License number: ______________________________________