1. SCOPE

This document provides guidance for the technical requirements for Customer Export Limiting Schemes installed by customers within the SP Distribution and SP Manweb Distribution networks.

2. ISSUE RECORD

This is a Controlled document. The current version is held on the EN Document Library.

It is your responsibility to ensure you work to the current version.

Issue Date	Issue No.	Author	Amendment Details
January 2016	1	Osman Ali	Initial Issue
May 2017	2	Keith Evans	Updated to reflect changes to EREC G100
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3. ISSUE AUTHORITY

Author	Owner	Issue Authority
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4. REVIEW

This is a Controlled document and shall be reviewed as dictated by business / legislative change but at a period of no greater than 3 years from the last issue date.

5. DISTRIBUTION

This document is not part of a Manual maintained by Document Control and does not have a maintained distribution list. It is published on the SP Energy Networks website.

6. CONTENTS

7. REFERENCE AND RELATED DOCUMENTS

7.1 Legislation

The Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR).

The Electricity at Work Regulations 1989.

7.2 Relevant ENA Engineering Recommendations (ER / EREC)

EREC G59	Recommendations for the Connection of Generating Plant to the **Distribution Systems** of Licensed Distribution Network Operators
EREC G99	Requirements for the connection of generation equipment in parallel with public **Distribution Networks** on or after 27 April 2019
EREC G83	Recommendations for the Connection of Type Tested Small-scale Embedded Generators (Up to 16A per Phase) in Parallel with Low-Voltage **Distribution Systems**
EREC G98	Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage **Distribution Networks** on or after 27 April 2019
EREC P28	Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom
ER P29	Planning Limits for Voltage Unbalance in the United Kingdom for 132 kV and below
ER G5	Harmonic Voltage Distortion and the Connection of Harmonic Sources and/or Resonant Plant to Transmission systems and **Distribution Networks** in the United Kingdom
EREC G100	Technical Requirements for **Customer Export Limiting Schemes**

7.3 SPEN Documents

ESDD-01-005 Distributed Generation Connection Requirements

8. DEFINITIONS

Active Network Management	Using flexible network customers autonomously and in real-time to increase the utilisation of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs.
Active Power	The product of voltage and the in-phase component of alternating current measured in units of watts, normally measured in kilowatts (kW) or megawatts (MW).

Agreed Export Capacity	The maximum amount of power (expressed in kW) that is permitted to flow into the **Distribution System** through the **Connection Point**. The **Agreed Export Capacity** shall be no lower than 3.68kW per phase.
Agreed Import Capacity	The maximum amount of power (expressed in kW) which is permitted to flow out of the **Distribution System** through the **Connection Point**.
Apparent Power (VA)	The product of voltage and current at fundamental frequency, and the square root of three in the case of three-phase systems, usually expressed in kilovolt-amperes ('kVA') or megavolt-amperes ('MVA').
Connection Point	A point on the **Distribution System** that provides **Customer** with a connection allowing power to flow to or from the **Distribution System**. Typically, this would be the **SPEN** fused cut-out or the metering circuit breaker.
Control Unit (CU)	The equipment forming part of the **ELS**. The functions of the **CU** typically include: • To store the **Agreed Export Capacity** • To monitor the values being read by the **PMU** • To detect if the **PMU** value established by the **PMU** exceeds the **Agreed Export Capacity** • To send control signals to the **Generating Unit**(s) interface and load interface units • To detect any system error (**fail-safe** protection)
Customer	A person who is the owner or occupier of premises that are connected to the **Distribution System**.
Declared Voltage	In respect to **Low Voltage** supply shall be 230 Volts between phase and neutral conductors at the **Connection Point**. In respect to **High Voltage** supply the **Declared Voltage** shall be determined by **SPEN**. The voltage shall be defined between 2 phase conductors at the **Connection Point**.
Demand Control Unit (DCU)	A **DCU** provides a means for demand to be turned on/off to limit **Active Power** exported to the **Distribution System**. This provides an alternative to controlling the output of **Generating Units** (or an additional measure).
Distribution Licence	A **Distribution Licence** granted under Section 6(1)(c) of the Electricity Act 1989 (as amended including by the Utilities Act 2000 and the Energy Act 2004).
Distribution System	The system consisting (wholly or mainly) of electric lines owned or operated by the DNO and used for the distribution of electricity between the grid supply points or **Generating Unit** or other **Connection Points** to the points of delivery to **Customers** within Great Britain.
Export Limiting Scheme (ELS)	The system comprising of one or more functional units, sensors and control signals that interfaces with the **customer's Power**

	Station and/or load to control the net flow of electricity into the **Distribution System** to below an agreed value.
Fail-Safe	A design requirement that enables the **Export Limitation Scheme** to limit export to the **Agreed Export Capacity** irrespective of the failure of one or more its components.
Generating Unit	Any apparatus that produces electricity.
Generating Interface Unit (GIU)	The **GIU** provides the interface between the **CU** and the **Generating Unit**. The design and specification of the **GIU** depends on the nature of the **Generating Unit** and also the manner in which export restriction is achieved. In some cases, a number of **GIU**s may be required.
High Voltage (HV)	A voltage ≥1,000V to <20kV.
Low Voltage (LV)	In relation to alternating currents, a voltage exceeding 50V but not exceeding 1,000V.
Nominal Voltage	The **Distribution System** operates at **Nominal Voltages** of 132kV, 66kV, 33kV, 22kV, 11kV, 6.6kV, 6.3kV, 400V and 230V.
Power Station Capacity	The aggregated capacity of all the **Generating Units** associated with a single **Power Station**.
Power Factor	The ratio of **Active Power** to **Apparent Power**.
Power Measurement Unit (PMU)	The **PMU**s function is to measure the voltage and current flow between the **Distribution System** and the **Customer's** premises at the **Connection Point**.
Power Station	An installation comprising of one or more **Generation Units**.
Reactive Power	The imaginary component of the **Apparent Power** at fundamental frequency usually expressed in kilovar (kVAr) or Megavar (MVAr).
SP Distribution plc	The **Distribution Licence** Holder for the distribution service area formerly known as ScottishPower.
SP Manweb plc	The **Distribution Licence** Holder for the distribution service area formerly known as Manweb.
SPEN	ScottishPower Energy Networks, the brand name for the division of ScottishPower group of Companies that encompasses **SP Distribution** plc, SP Transmission plc, **SP Manweb** plc and SP Power Systems Ltd.
Statutory Voltage Limits	In the case of a **Low Voltage** supply, a variation not exceeding 10 per cent above or 6 per cent below the **Declared Voltage** at the declared frequency. In the case of a **High Voltage** supply operating at a voltage below 132,000 Volts, a variation not exceeding 6 per cent above or below the **Declared Voltage** at the declared frequency.

In the case of a **High Voltage** supply operating at a voltage above 132,000 Volts, a variation not exceeding 10 per cent above or below the **Declared Voltage** at the declared frequency.

9. INTRODUCTION

This document provides guidance on the connection of **Customer Export Limiting Schemes** (**ELS**) that operates in parallel with the **Distribution Systems**.

The guidance given is designed to facilitate the connection of **ELS** whilst maintaining the integrity of the **Distribution System**, both in terms of safety and supply quality.

This document shall be read in conjunction with ENA (Energy Networks Association) ERECs G83, G59, and from 27 April 2019 ERECs G98 and G99, and **SPEN** policy ESDD-01-005.

As the cost of generation continues to reduce, many **Customers** are now seeking to increase the amount of generation installed within their premises to offset their import requirements. Where **SPEN** has assessed that an increase in generation export capacity will require costly or time-bound upstream reinforcement, some **Customers** may choose to restrict the net export from their connection rather than wait for or contribute to the reinforcement.

A typical **ELS** may be used in the following scenarios:

- Over-sizing the generation and limiting the peak output
- Increasing flexibility of on-site demand at times of peak output
- Guaranteeing a defined export limit.

10. PURPOSE

This document applies to **ELS** installed by **Customers** to restrict the **Active Power** exported at the **Connection Point** or to prevent voltage limits on the **Distribution System** from being exceeded. For the avoidance of doubt, limitations on the connection or the operation of generation due to fault level exceedance will still apply.

This document does not apply:

- to control systems that are used to measure and control the output of a **Generating Unit** without reference to the exported **Active Power** or the voltage at the **Connection Point**
- where the **Power Station Capacity** is less than the **Agreed Export Capacity** at that **Connection Point**

This document applies to **HV** and **LV** connections but may be used at higher connection voltages at the discretion of **SPEN**.

An **ELS** may not be compatible with some flexible connections. For example, in an area managed under **Active Network Management**, an **ELS** might counteract the instructions issued by the management system thus restricting deployment. It will be the responsibility of **SPEN** to assess the suitability of an **ELS** in these situations and authorise accordingly.

11. REQUIREMENTS

11.1 Export Limitation Scheme Design

An **ELS** measures the **Active Power** at points within the **Customer**'s installation and then uses this information to either restrict generation output and/or balance the **Customers** demand in order to prevent the export to the **Distribution System** from exceeding the **Agreed Export Capacity**.

An **ELS** may include a secondary feature to restrict generation export when the voltage at the **Connection Point** exceeds **SPEN**'s Operational Voltage Limits and/or **Statutory Voltage Limits**. If this feature is required, **SPEN** shall specify this at the Quotation / Offer stage.

In order for the installation of an **ELS** to be an acceptable solution, **SPEN** must be satisfied that the control schemes will meet the requirements of section 11.5 under all circumstances.

It should be noted that the **Agreed Export Capacity** is expressed as an **Active Power** value (in kW or MW). In addition to this **Agreed Export Capacity**, **SPEN** will specify an export **Power Factor** or **Power Factor** range at the **Connection Point**, as applicable. The **ELS** shall be designed to measure and limit the **Active Power** only since the **Power Factor** and hence the **Apparent Power** and **Reactive Power** should be controlled by the **Customer** to satisfy the requirements of the Connection Agreement.

The **ELS** may be formed of discrete units, as shown in Appendix B, or integrated into a single packaged scheme. Where discrete units are used they should preferably be interconnected using metallic or fibre optic cables. Alternatively, the units may be interconnected using secure radio links but where this is the case these links shall be licensed (by OFCOM) and have a planned availability of 99.9% or higher. Irrespective of the media used for interconnecting between the discrete units, if the communication path fails the generation output shall be reduced to a nominal value stipulated by **SPEN** within a set response time (see section 11.5) to prevent the **Agreed Export Capacity** from being exceeded.

ELS installed at **Power Stations** with an **Agreed Export Capacity** exceeding 16A (i.e. 3.68kW) per phase must be fail-safe and must ensure that the **Agreed Export Capacity** is not exceeded if any single component, including the communication links between the discrete units, fail or lose their power supply.

Once installed and commissioned, the scheme settings should not be capable of being readily altered by the **Customer** and shall only be changed with the written agreement of **SPEN**.

The exported power at the **Connection Point** may be managed by increasing the **Customer's** demand within the **Customers** installation; however, the **ELS** must be able to turn down/reduce the generated power or disconnect one of more **Generation Units** if the demand is not available.

Additional reverse power protection shall be installed at all **HV** metered connections to back-up the **ELS**. See section 11.5 for further detail.

For **LV** connections, a reverse power protection relay may be deemed uneconomical to install. This protection will however be required if **SPEN** deems the scheme not to be **fail-safe**.

A description of the scheme, its settings, and a single line diagram shall be permanently displayed on site.

11.2 Maximum Power Station Capacity

An **ELS** will take a finite time (as specified in section 11.5) to operate and restrict the site export. During this period the exported power may be above the **Agreed Export Capacity** which could cause equipment current ratings, over-current protection settings, fuse ratings or **Statutory Voltage Limits** to be temporarily exceeded.

SPEN shall carry out an assessment at the design stage to determine the maximum acceptable **Power Station Capacity** above which either thermal limits, protection settings / fuse ratings or equipment voltage limits could be exceeded. Further guidance on these aspects is provided below.

11.2.1 Equipment Thermal Limit Assessment

Plant and equipment (e.g. switchgear, transformers, cables and overhead lines etc.) is normally capable of withstanding short periods of moderate overloading. In most cases thermal limits will not be exceeded due to detection and operation of the **ELS** and, where fitted, the reverse power protection.

11.2.2 Protection Assessment

In order to prevent mal operation of cut-out fuses and/or over-current protection and other protection equipment the **Power Station Capacity** shall typically be no greater than 1.25 x **Agreed Import Capacity** or 1.25 x **Agreed Export Capacity**, whichever is the higher. At some sites it may be possible for **SPEN** to agree a higher value depending upon the protection requirements and the Minimum Demand.

Where the site does not have an **Agreed Import Capacity** or **Agreed Export Capacity** the protection assessment shall be based on **SPEN**'s cut-out fuse rating or the over-current protection settings applied to the metering circuit breaker (operating at **Nominal Voltage**). In the absence of other information, the cut-out fuse should be assumed to be 60A.

For example, if the **Customer** has an 80A fuse, the maximum on-site generation shall be no greater than 1.25 times 80A = 100A.

11.2.3 Voltage Assessment

The **Power Station Capacity** shall be restricted to prevent equipment voltage ratings from being exceeded during the detection and operation time of the **ELS**. The highest network voltage shall not exceed the **Statutory Voltage Limit** + 1% (of the **Nominal Voltage**) before the **ELS** operates.

For **LV** networks, the **Declared Voltage** is 230V (phase to neutral) and the upper **Statutory Voltage Limit** is = 230V + 10% = 253V. Where a **Power Station Capacity** does not exceed 32A per phase and consists solely of Type Tested SSEGs a voltage assessment is not required. In all other circumstances the maximum **Power Station Capacity** should be restricted in order to prevent the network voltage exceeding 253V + (1% of 230V) = 255.3V.

For other network voltages the Operational Voltage Limit may be different to the **Statutory Voltage Limit**. If, for example, **SPEN** specifies an Operational Voltage Limit of 11.1kV for their 11kV network, the maximum **Power Station Capacity** must be restricted to prevent the highest network voltage exceeding 11.1kV + (1% of 11kV) = 11.21kV.

11.2.4 Other Restrictions

It is possible that other factors may restrict the maximum **Power Station Capacity** at the site, for example fault level contribution, or possible transmission system related restrictions. Where this is the case **SPEN** shall notify the **Customer** of the reason for the restriction. For example, **SPEN** may impose a further limitation in areas subject to a Statement of Works process or other transmission restrictions.

Examples of how the maximum **Power Station Capacity** is calculated are included Appendix E.

11.3 Maximum Capacity of Actively Controlled Demand

Where the **Agreed Export Capacity** is limited by actively controlling flexible on-site demand the **Agreed Import Capacity** could be exceeded if the generation is suddenly disconnected (e.g. if the EREC G59 or G99 interface protection operates). This could potentially cause equipment thermal limits and / or rapid voltage change limits to be exceeded. In order to prevent these issues, the maximum demand of the site, including the actively controlled demand, shall not exceed 1.25 x the **Agreed Import Capacity** of the site.

Where a site with an **LV Connection Point** does not have an **Agreed Import Capacity** the rating of the cut-out fuse or the over-current protection settings applied to the metering circuit breaker (operating at **Nominal Voltage**) shall be used instead. In the absence of other data, a 60A cut-out fuse shall be assumed.

11.4 Power Quality

All installations must comply with the power quality requirements defined in:

- ENA Engineering Recommendation P28
- ENA Engineering Recommendation P29
- ENA Engineering Recommendation G5

Compliance of individual components of the scheme will not guarantee the scheme as a whole will be compliant.

In accordance with the above documents and with BS7671 (The IET Wiring Regulations) and the Distribution Code**,** customers shall discuss and agree the connection of any potentially disturbing equipment with **SPEN**. Such equipment includes; motors, motor drives, pumps (including heat pumps), electric boilers, welders, furnaces, kilns, generators, switched capacitors etc.

In addition to the connected load and generation, **the ELS** may also create voltage disturbances and voltage distortion.

An **ELS** that quickly decreases or trips the generation or that quickly increases or decreases demand may give rise to rapid voltage changes and / or flicker. In such cases the **Customer** shall provide **SPEN** information on the maximum change in current or power, the characteristics of the change (e.g. step change, ramped change etc.). If the current is ramped up or down the maximum ramp rate and ramp duration shall also be provided. EREC P28 normally restricts rapid voltage changes to a maximum of 3%.

An **ELS** that relies on power electronics (e.g. converters etc.) to control the load shall also provide information demonstrating compliance with relevant harmonics standards (e.g. BSEN 61000-3-2 and/or BSEN 61000-3-12) or provide data on the harmonic current produced by the **ELS** in accordance with ENA EREC G5.

The scheme shall maintain the agreed **Power Factor** at the metering point.

SPEN reserves the right to retrospectively monitor the schemes for compliance.

11.5 Accuracy and Response Rates

The overall accuracy of the scheme shall be better than 5%. At the discretion of **SPEN**, a class "A" measurement instrument may be used to evaluate the overall scheme accuracy during commissioning.

The overall accuracy of **ELS** with regard to measurement and control of **Active Power** and, where applicable, voltage, shall be determined by the manufacturer of the system and published within its operating manual. These tolerances shall, as far as possible, take account of sensing / measurement errors, processing errors, communication errors and control errors. Consideration shall also be given to environmental factors (e.g. the expected ambient temperature range).

The settings applied to the **ELS** shall take account of the published tolerances to ensure the required export limits and voltage limits are maintained. For example, if an **ELS** is required to limit the export to 100kW and it has an overall tolerance of +/-5% at this value, it shall be set to limit the **Active Power** to 95kW (i.e. 95% of the required value).

The **Customer** shall provide details of the ramp up and ramp down rates of the generation on request.

The **ELS** must detect an excursion and reduce the export to the **Agreed Export Capacity** or less within 5 seconds.

Where communication delays (between the **ELS** and the **Generating Unit**s and actively controlled demand) mean that the 5 second operating time may not be satisfied, a back-up system shall be installed that detects an excursion and operates within 5 seconds. In such circumstances the back-up system should be programmed to act at the **Agreed Export Capacity** and the **ELS** at a lower value. This backup system should have an **Active Power** accuracy of +/-3% or better.

For example, for a site with a nominal 50kW export limit, the **ELS** could be set to 48kW, with a back-up disconnection device set at 50kW; under normal operation, the dynamic system will keep the site limited to 48kW export, but should the export peak over 50kW, the generation will be disconnected within 5 seconds by device back-up disconnection system.

Where an **ELS** relies on a backup disconnection systems to achieve the 5 seconds limit the arrangement must satisfy the power quality requirements, including the EREC P28 rapid voltage change and flicker requirements.

For all **High Voltage** metered connections, protection (known as reverse power protection) shall disconnect the **Generating Unit** if the exported power exceeds the **Agreed Export Capacity** for more than 5 seconds. It shall be the responsibility of the **Customer** to specify and satisfy **SPEN** that the protection meets this requirement.

11.6 Excursions

The **Active Power** may, under abnormal conditions, temporarily exceed the **Agreed Export Capacity**. The **ELS** shall be designed so that under normal operating conditions the thermal limits and **Statutory Voltage Limits** are not exceeded.

In recognising that the **ELS** may have a delayed response under abnormal conditions, up to 5 seconds response time is assumed to allow the **ELS** to bring the export equal to, or below the **Agreed Export Capacity**. Where frequent excursions of the **Agreed Export Capacity** take place under normal operating conditions, **SPEN** may request that the **Active Power** thresholds are lowered to reduce the number and the magnitude of the excursions.

The **Connection Agreement** may need to be amended in the event of an excursion to the **Agreed Export Capacity**.

Breeches of the **Agreed Export Capacity** may result in the **Connection Agreement** being withdrawn or further monitoring and/or remote control being installed at the **Customer's** cost.

12. MONITORING

Upon written request, the generator will provide suitable access to enable **SPEN** to monitor performance of the **ELS**. **SPEN** may also utilise the standard metering flows for the purpose of on-going enforcement.

13. APPLICATION AND ACCEPTANCE

Customers shall provide information on the proposed **ELS** to enable **SPEN** to make an assessment on the risk to the network. A flowchart on the acceptability criteria is shown in Appendix D.

The following information shall be provided with the **ELS** application:

- Single Line Diagram of **ELS**
- Manufacturers G100 Product Declaration as shown in Appendix C
- Explanation of **ELS** operation
- Description of any **fail-safe** functionality (interruption of sensor signals, disconnection of load, loss of power, internal fault detection etc.)

14. WITNESS TESTING AND COMMISSIONING

The following section only applies to **ELS**s at installations with an aggregate **Generating Unit** capacity exceeding 16A (3.68kW) per phase.

14.1 General

The **Customer** is responsible for demonstrating that the **ELS** complies with the requirements detailed in this document.

Where the **ELS** is used at a site with a combined on-site generation capacity of 50kW or less, **SPEN** may, at its discretion, not require to witness the **Fail-Safe** operation. Witness the testing of the **ELS** and protection on larger installations will normally be carried out, in accordance with ESDD-01-005.

Where the **ELS** commissioning tests are witnessed by **SPEN** it is expected that this will be carried out in the same visit as the generation commissioning tests are witnessed.

In order to safely and effectively test an **ELS**, it is necessary to be able to simulate instances where the **ELS** is expected to operate.

A means of ensuring the applied settings are tamper proof will need to be demonstrated. A copy of any additional settings associated with the **ELS** shall be displayed on site alongside any EREC G59 protection settings.

14.2 Preventing the export limit being exceeded during setup/testing

Care shall be taken whilst testing and commissioning the **ELS** so that the **Agreed Export Capacity** or the **Agreed Import Capacity** is not breeched so as to not put the **Distribution Network** at risk. This may involve setting the export limit to a lower threshold for demonstration purposes.

A combination of the following measures should be considered to ensure that **Agreed Export Capacity** or the **Agreed Import Capacity** is not exceeded during setup/testing:

- Temporarily programming the export limit value to zero, or setting it to 50% (or less) than the true export limit
- Restricting the maximum output of the generation (e.g. on a PV system with multiple inverters, turning off a number of the inverters)
- Operating a temporary load or load bank – to maintain a minimum on-site load throughout the test sequence.

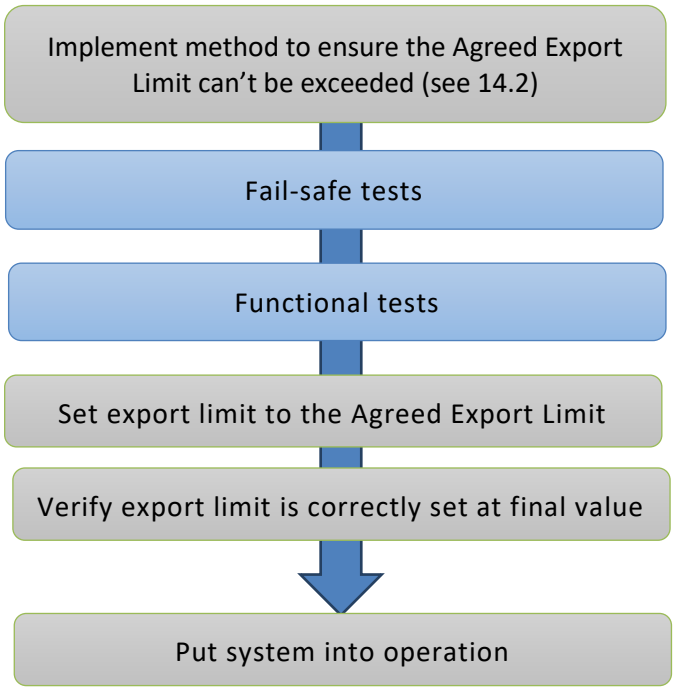
If **ELS** settings need to be changed in order to demonstrate operation, then they must be restored and confirmed once testing is complete.

14.3 Commissioning Sequence

ELS commissioning should only be undertaken after the generation commissioning has been successfully completed.

In order to ensure system safety, the following commissioning sequence shall be followed. This should be performed in the sequence indicated and the process should only proceed to the next stage once the preceding stage has been successfully undertaken:

The **Customer** shall provide all relevant scheme drawings and information to enable safe, informed commissioning of the **ELS.**



14.4 Fail-safe tests

Fail Safe tests are not required at installations with a **Power Station Capacity** up to 7.36kW per phase (i.e. 32A per phase at 230V) and an **Agreed Export Capacity** up to 3.68kW per phase (i.e. 16A per phase at 230V).

The purpose of the **Fail-Safe** tests is to ensure that should any part of the **ELS** fail, the **Active Power** exported across the **Connection Point** will drop to the **Agreed Export Capacity** or less within the specified time.

There are three potential options to reducing the **Active Power**.

1. The **Generation Units** switches off completely.

2. A section of the **Generating Units** may remain operating as long as the aggregate capacity of the **Generating Units** remaining operational is equal or less than the **Agreed Export Capacity**.

3. All **Generating Units** may operate at a restricted output as long as the aggregate export from the **Generating Unit**s remaining operational is equal or less than the **Agreed Export Capacity**.

The **Fail-Safe** test process comprises a sequence of tests on each individual piece of equipment forming the **ELS**. Each piece of equipment needs to have, where relevant, its communication and its power supply cables removed as separate tests.

At no time during the **Fail-Safe** test sequence should the **Active Power** rise above the programmed export limit for a duration longer than the specified reaction time.

NOTE: Some power supplies may take a short while to power down (due to power stored in capacitors). This will cause a slight delay in the response time of the system. In such cases the reaction time is measured from the point at which the unit powers down, not the point at which the power supply is disconnected.

14.5 Test Sequence

The following table describes a typical test sequence. Not all systems will have all of the components listed and others may have additional components that need to be included in the list. An example can be found at Appendix B. The system shall be restored after each test below.

No.	Component	Test
1	**Power Monitoring Unit (PMU)**	Remove power supply to **PMU**
2	**Control Unit (CU)**	Remove power supply to any **CU**
3	**Generator Interface units (GIU)**	Remove power supply to all **GIU**s
4	**Demand Control Unit (DCU)**	Remove power supply to all **DCU**s
5	Network hub / switches	Remove power supply
6	**PMU** → **CU** communication cable	Unplug cable
7	**CU** → **GIU** communication cable	Unplug cable (repeat where additional **GIU** units)
8	**GIU** → Generator communication cable	Unplug cable (repeat where additional **GIU** units)
9	**CU** → **DCU** communication cable	Unplug cable (repeat where additional **DCU** units)
10	**DCU** → load communication cable	Unplug cable (repeat where additional **DCU** units)
11	Controlled Load(s)	Turn off load (e.g. activate thermostat)

14.6 Functional Tests

In order to safely and effectively test an **ELS**, it is necessary to be able to simulate instances where the **ELS** is expected to operate. Two different means may be employed to simulate system operation.

1. Manual control over the loads operating on the site; or

2. Injection testing using a calibrated test set.

The method adopted will depend on the nature of the site. On larger sites with multiple distributed loads (e.g. an office, factory or school), injection testing will be the only practical option.

Particular attention should be paid to the correct orientation of the **PMU** current monitoring connections (including CT orientation) during testing.

14.6.1 Functional testing – manual load control

Three site factors can be adjusted and a generic test method could be:

1. The export limit is adjusted (set to zero or a percentage of the final figure)

2. The site loads are manually increased / decreased

3. The output from the Generation Units is manually increased / decreased

Pass-Fail criteria: During the test sequence the power exported from the site does not rise above the programmed export capacity for a duration longer than the specified reaction time.

14.6.2 Functional testing – Injection testing

Export limit conditions can be simulated by temporarily connecting the power monitoring unit (**PMU**) to a calibrated injection test set.

When using an injection test set, there is no feedback loop between the **ELS** and the injection test set. This has two significant implications for the test process:

1. As soon as the **ELS** begins to operate, because it sees no corresponding decrease in export levels, the control loop will keep running until the **Generation Units** output is reduced to the programmed export capacity or below.

2. To ensure that the **ELS** is reacting by the correct amount and within an acceptable time period, a step change needs be applied by the test set to the **PMU**.

The following test sequence should be performed:

Test		Step change final value
1	Step change A	Export = 105% of programmed export limit value
2	Step change B	Export = 110% of programmed export limit value
3	Step change C	Export = 120% of programmed export limit value

The procedure for performing the test is as follows:

- Initially apply 100% of **Nominal Voltage** and inject current (at unity **Power Factor**) to mimic an exported **Active Power** equivalent to of 95% of the export limit setting. Check that the **ELS** does not operate.

- Step up the current to give an export **Active Power** equivalent to 105% of the export **Active Power** limit (for Test A), Check that change in export level is “seen” by the **PMU**.

- Check that the **Active Power** exported by the generation reduces to a value at least 5% below the export limit setting within the specified reaction time. The test shall be repeated at the maximum **Statutory Voltage Limit** (i.e. at 110% of **Nominal Voltage** at **LV** connections or at 106% at **HV** connections) and also at the minimum **Statutory Voltage Limit** (i.e. 94% of **Nominal Voltage** for both **LV** and **HV** connections).

- All the above tests shall also be repeated for step increases from 95% to 110% of the export limit and from 95% to 120% of the export limit as detailed in Table 2.

When injection testing is complete, the correct orientation of any current monitoring connections (including CT orientations) which may have removed for the test must be checked and verified as correct.

If settings need to be changed in order to demonstrate operation, then they must be restored and confirmed once testing is complete.

15. MANUFACTURERS G100 PRODUCT DECLARATION

Manufacturers of **ESL**s having undertaken the required tests shall complete the G100 Product Declaration as set out in Appendix C. Copy of this declaration shall be provided to the **Customer**. The **Customer** will then provide a copy of the product declaration to **SPEN** as set out in section 13 of this guidance policy.

APPENDIX A – INFORMATION REQUEST

ENQUIRY – EXPORT LIMITATION SCHEME

This form should be used by all applicants considering installing an **ELS** as part of their connection application. This form should accompany your application for a connection.

Customer Name _____	**Project Name** : _____
ENA Form Application submission date: _ _ / _ _ / _ _ _ _	**DNO Ref No** _____

The following information shall be submitted with the enquiry:

Copy of Single Line Diagram of **Export Limitation Scheme**
Explanation / description of **Export Limitation Scheme** operation including a description of the fail-safe functionality e.g. the response of the scheme following failure of a: • **Power Monitoring Unit** • **Control Unit** • **Generator Interface Unit** • **Demand Control Unit** • **Communication Equipment** *Note, fail-safe operation is not mandatory where the installation has an aggregate **Generating Unit** capacity of 16A (i.e. 3.68kW) per phase or less. **Fail Safe** tests are not mandatory at installations with a **Power Station Capacity** up to 7.36kW per phase (i.e. 32A per phase at 230V) and an **Agreed Export Capacity** up to 3.68kW per phase (i.e. 16A per phase at 230V).*
Is additional reverse power protection to be provided (mandatory for connection voltages above 1,000V) Yes / No* * (delete as necessary)
Required Import Capacity (kW):
Proposed Export Capacity (kW) if known:
Total **Power Station Capacity**** (kW): ** aggregate kW rating of all the electrical energy sources (**Generating Units** including storage)

APPENDIX B – EXPORT LIMITATION SCHEME INSTALLATION AND COMMISSIONING TESTS

Commissioning test requirements for **Export Limitation Scheme**s, in addition to those required by EREC G83/G98 or G59/G99.

DNO Ref. No.: _ _ _ _ _ _ _	**MPAN[1] (21/13-digits):** _
Customer Name	……
Address of ELS (where equipment will be used)	…… …… …… ……
Installer	……
Installer Address	…… …… …… ……

Information to be Provided	
Description	Confirmation
Final copy of Single Line Diagram of **Export Limitation Scheme**	Yes / No*
Explanation of **Export Limitation Scheme** operation	Yes / No*
Description of the fail-safe functionality (Interruption of sensor signals, disconnection of load, loss of power, internal fault detection etc.) *"Note, **fail safe** operation is not mandatory where the **Power Station Capacity** does not exceed 7.36kW per phase and the **Export Capacity** does not exceed 3.68kW per phase."*	Yes / No*
Agreed Export Capacity as provided by the **DNO**	_____kW
Export Limitation Scheme export setting	_____kW
The **Export Limitation Scheme** has secure communication links between the various component parts of the **Export Limitation Scheme** as specified in section 11.1	Yes / No*

Commissioning Checks	
The **Export Limitation Scheme** is fail-safe and limits export if any of the discrete units or communication links that comprise the **Export Limitation Scheme** fail or lose their source of power. All components have been tested in line with section 14.	Yes / No*
When the **Export Limitation Scheme** operates it reduces the exported **Active Power** to a value that is equal to, or less than, the **Agreed Export Capacity** within 5s.	Yes / No*
A reverse power relay is fitted which will disconnect the generation if the export goes 5% above the **Agreed Export Capacity** for longer than 5s (not required for fail-safe **LV** metered connections).	Yes / N/A Setting _____kW Time _____Sec
On completion of commissioning, all settings are restored to normal operating values and password protected or sealed to prevent **Customer** access. A description of the scheme, its settings, and a single line diagram is displayed on site.	Yes / No*

* Circle as appropriate. If "No" is selected the **Power Station** is deemed to have failed the commissioning tests and the **Generating Units** shall not be put in service.

Additional Comments / Observations:

Insert here any additional tests which have been carried out

Declaration – to be completed by Generator or Generators Appointed Technical Representative.	
I declare that the **Export Limiting Scheme** and the installation comply with the requirements of this document and the additional commissioning checks noted above have been successfully completed in addition to those required by EREC G83 or G59	
Signature:	Date:
Position:	
Declaration – to be completed by DNO Witnessing Representative	
I confirm that I have witnessed the tests specified in this document on behalf of _____and that the results are an accurate record of the tests.	
Signature:	Date:

This form should be appended to those provided in appendix 3 of EREC G83 / G98 or appendix 13.2 and 13.3 in EREC G59 / G99.

APPENDIX C - MANUFACTURERS G100 PRODUCT DECLARATION

Name of Product- ……

Manufacturer- ……

1. Introduction

Engineering Recommendation G100: Technical Guidance for Customer Export Limiting Schemes "defines the technical design requirements for Export Limitation Schemes which limit the net site export to below an agreed maximum and are installed on the Customer's side of the Connection Point".

While G100 does not describe a type test procedure, it does describe a number of system requirements. This document describes how an (insert product name here) installation performs relative to key G100 requirements.

2. Description of Operation

G100 Requirement:

A description of the scheme, its settings, and a single line diagram should be permanently displayed on site.

1. When installed in conjunction with a (*insert name of system here e.g. Solar PV System*) , the *(insert product name here)* operates in "*xxxx xxxxxxx mode*". The following text can be used to describe this operational mode

Please insert operational mode here:

3. Power Quality Requirements

G100 Requirement:

Where *(insert product name here)* relies on power electronics (e.g. Converters etc) to control the load it shall also provide information demonstrating compliance with relevant harmonics standards (e.g. BSEN 61000-3-2 and/or BSEN 61000-3-12) or provide data on the harmonic produced in accordance with ER G5.

Please confirm product complies with relevant harmonic standards:

(Manufacturer name here) confirms that *(insert product name here)* complies with the requirements of the relevant harmonic standards and that the relevant harmonic data has been provided as required by ER G5.

4. System Schematic

A *(insert product name here)* installation is formed of *(insert number of)* main elements:

Document the main elements and provide a system schematic.

1. Main elements:
   - *(Describe main elemnents)*
   - *(Describe main elements)*
   - *(Describe main elements)*

2. System Schematic: *(Insert System Schematic below)*

System Schematic

5. Component Interconnection/Fail Safe Operation

G100 requirement:
The ELS may be formed of discrete units or integrated into a single packaged scheme. Where discrete units are used they should preferably be interconnected using metallic or fibre optic cables. Alternatively, the units may be interconnected using secure radio links but where this is the case these links should be licensed (by OFCOM) and have a planned availability of 99.9% or higher. Irrespective of the media used for interconnecting between the discrete units, if the communication path fails the generation output should be reduced to a nominal value stipulated by the DNO within a set response time to prevent the Agreed Export Capacity from being exceeded.

5.1 Describe Component Interconnection here: (text or diagram)

5.2 Provide System fail-safe test results here (enter all test results below):

No	Test	System Response	Time	Pass
			<Xs	Y/N
			<Xs	Y/N

(Please add more rows if required)

6. Accuracy & Response time

G100 Requirements

The overall accuracy of **ELS** with regard to measurement and control of Active Power and, where applicable, Voltage, shall be determined by the manufacturer of the system and published within its operating manual. The *(enter product name)* has been tested for the following function errors:

Sensing passed test	Yes		No	
Measurement passed test	Yes		No	
Processing passed test	Yes		No	
Communication passed test	Yes		No	
Control passed	Yes		No	
Environmental factors[1] passed test	Yes		No	

1(e.g. the expected ambient temperature range)

Operating Manual is available	Yes		No	
The settings applied to *(enter product name)* have taken account of the published tolerances to ensure the required export limits and voltage limits will be maintained.	Yes		No	

G100 requirement

The ELS must detect an excursion and reduce the export to the Agreed Export Capacity or less within 5 seconds.

- Under normal operating conditions, *(enter product name)* response time is less than *Xs*
- Under loss of communications, or loss of power to Meter/Gateway, response time is less than *Xs*

7. Password Protection

G100 requirement:

Once installed and commissioned, the scheme settings should not be capable of being readily altered by the Customer and should only be changed with the written agreement of the DNO.

- All (*enter product name here*) settings are password protected and cannot be altered by the customer.

8. *(enter product name here)* G100 Installation Requirements

Please insert here G100 installation requirements

9. Manufacturers G100 Product Declaration

The *(enter product name here)* complies with the Energy Networks Association, Engineering Recommendation G100 Issue 1 Amnd 2 2018, Technical Guidance for Customer Export Limiting Schemes, when installed in accordance with this Engineering Recommendation G100 application guide.

ER G100 should be read in conjunction with the product installation, operation and maintenance manuals.

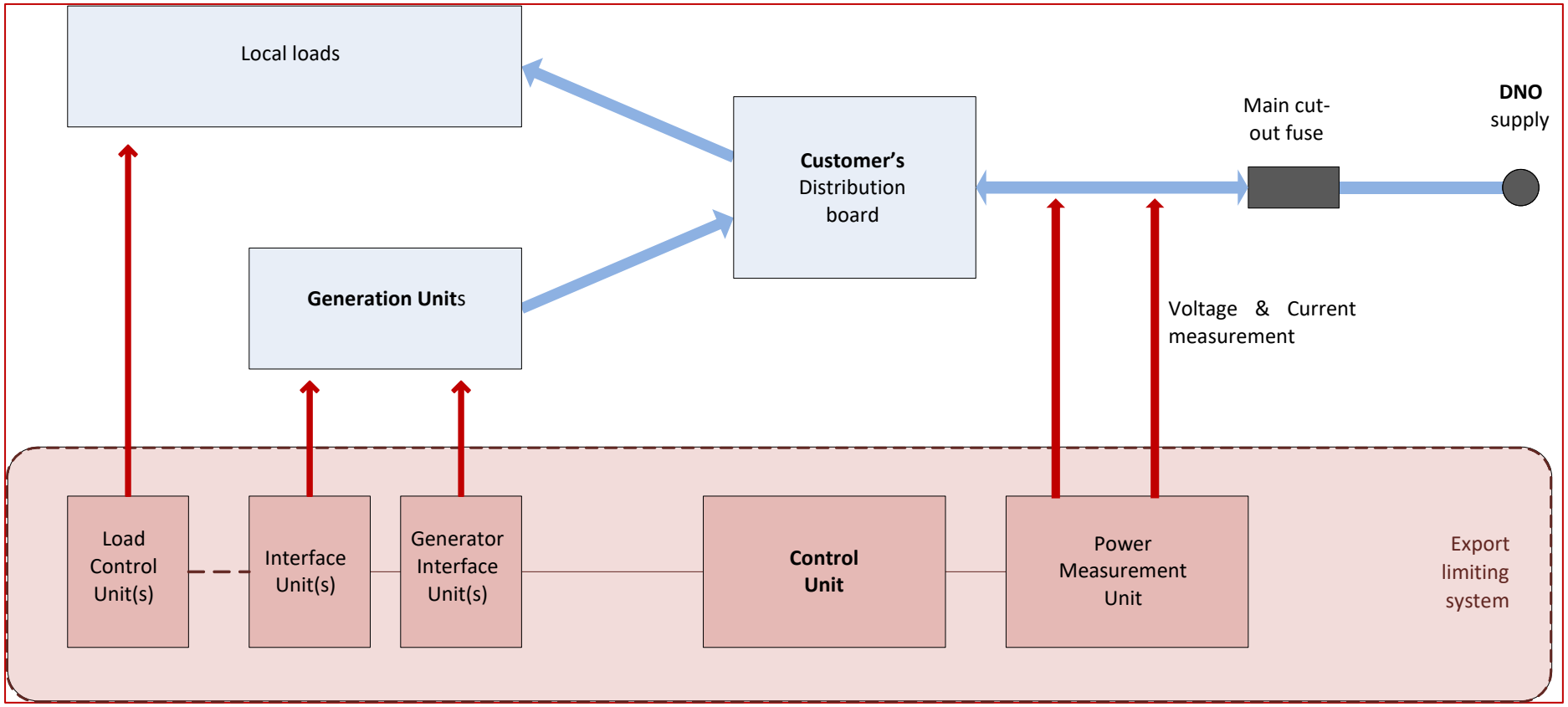
Name: *(enter full name here)*

Signature here

Title: *(enter title here)*

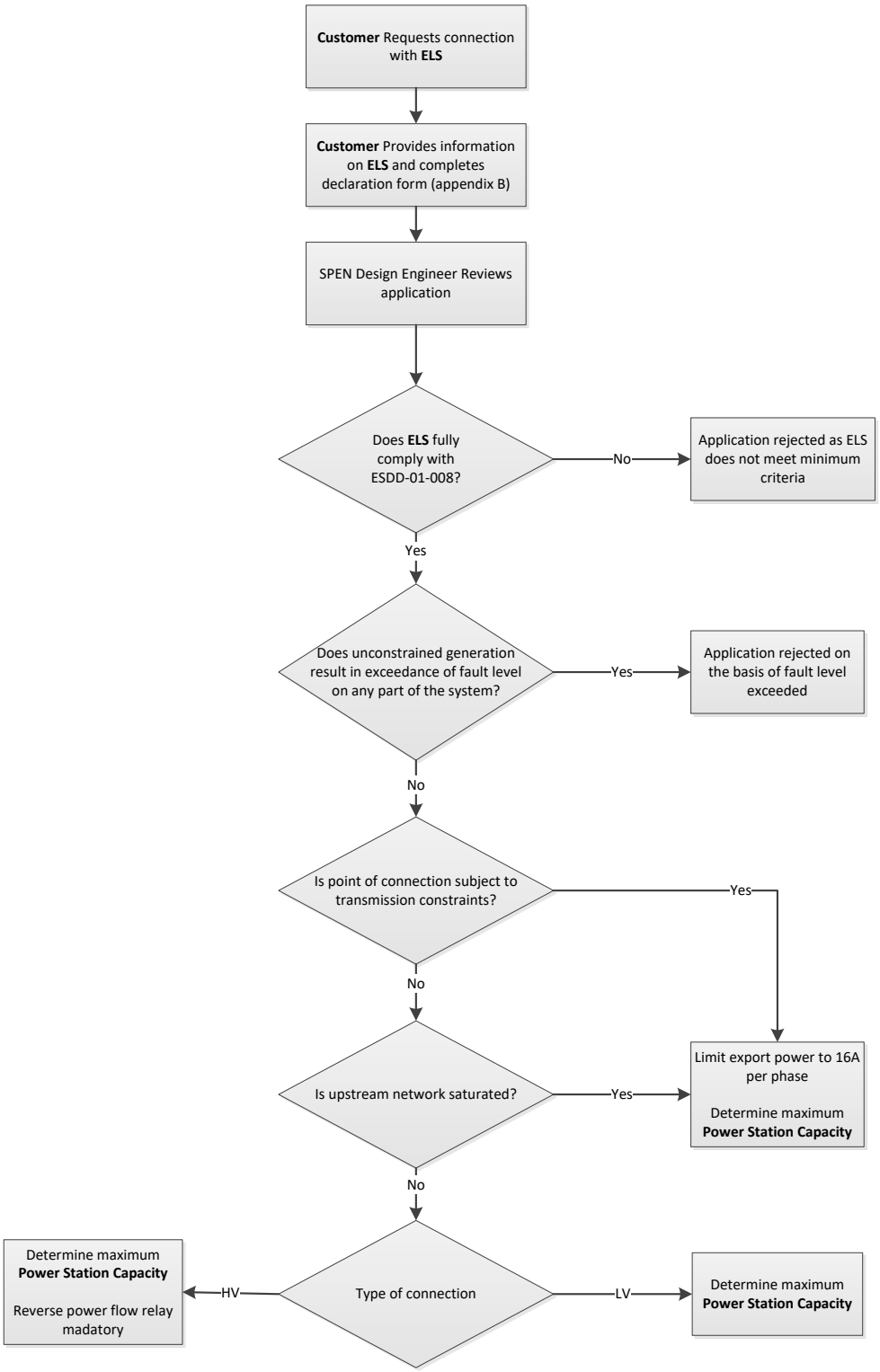
Date: *xx/xx/xxxx*

APPENDIX D – (INFORMATIVE)
EXPORT LIMITATION SCHEME DIAGRAM



Typical Scheme Design for an Export Limitation Scheme Arrangement for an Asynchronous Generator

APPENDIX E – (INFORMATIVE)
EXPORT LIMITATION SCHEME APPLICATION FLOW CHART



APPENDIX F – (INFORMATIVE) POWER STATION CAPACITY EXAMPLES

Example 1 – PV installation at a large Domestic Property

A domestic **Customer** wishes to install a PV system but **SPEN** has restricted the **Agreed Export Capacity** to 3.68kW due to concerns relating to voltage rise. The cut-out fuse rating is 80A. An **ELS** is to be installed so that the capacity of the PV installation can be maximised.

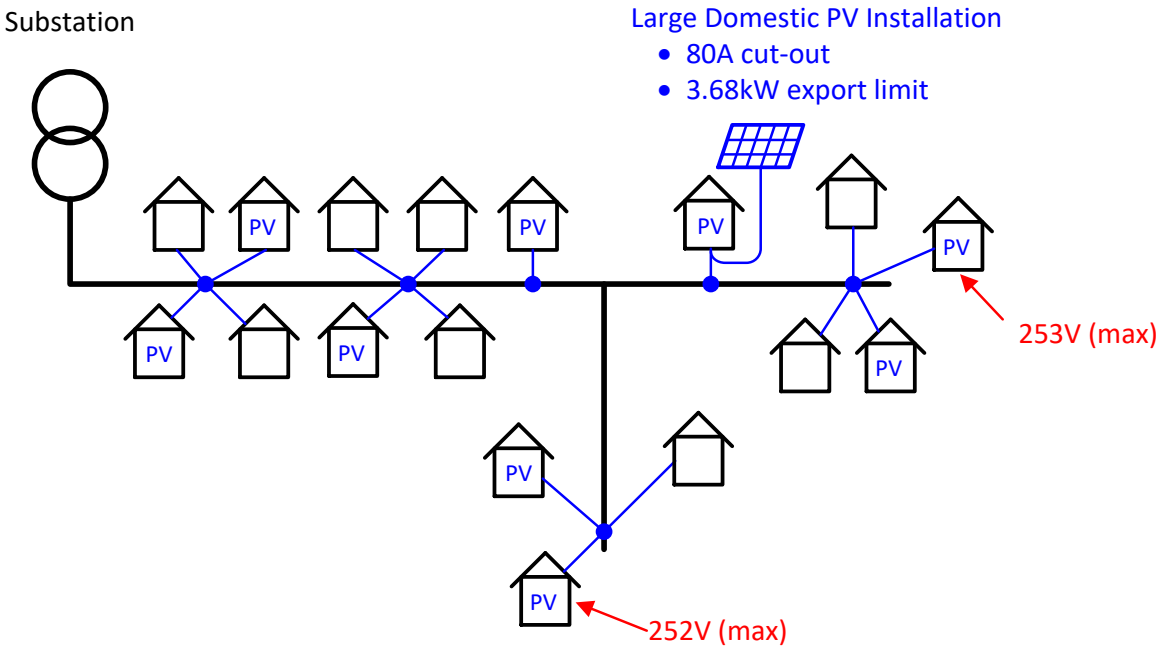


Figure F1 Large PV Installation at a Domestic property

SPEN determines the maximum acceptable **Power Station Capacity**, as follows:

Thermal Assessment:

The continuous rating of the cut-out and service cable are both in excess of 80A (18.4kW) and the 5s rating is substantially higher than this. **SPEN** determines that the thermal rating of the installation does not, in practice, limit the **Power Station Capacity**.

Protection Assessment:

The protection assessment restricts the **Power Station Capacity** to the higher of:

- 1.25 x **Agreed Import Capacity** = 1.25 x 80A x 230V = 23.0kW
- 1.25 x **Agreed Export Capacity** = 1.25 x 3.68kW = 4.6kW

The higher of the two values is 23kW.

Voltage Assessment:

The highest voltage that can be accepted on the **LV** network (during the 5s period before the **ELS** operates and restricts the export) is the upper **Statutory Voltage Limit** + (1% of the **Nominal Voltage**) = 253V + 1% of 230V = 255.3V.

SPEN calculates that when 10kW of generation is connected at the property the voltage at the end of the circuit reaches 255.3V.

Conclusion

If an **ELS** is installed that limits the export to 3.68kW the maximum acceptable **Power Station Capacity** is the lower the results from the thermal assessment, protection assessment and voltage assessment. In this case the **Power Station Capacity**, i.e. the aggregate rating of the PV inverters, must be no higher than 10kW.

Example 2 – Wind Turbine Installation at a Farm

A farmer would like to install a wind turbine with a capacity of 200kW. The farm has an **LV** connection with an **Agreed Import Capacity** of 200kW (3 phase) but it does not have an **Agreed Export Capacity**. After carrying out a design study **SPEN** is only able to offer an **Agreed Export Capacity** of up to 150kW due to the voltage rise at the **LV Connection Point**. The installer recommends the use of an **ELS** to allow the 200kW wind turbine to be installed.

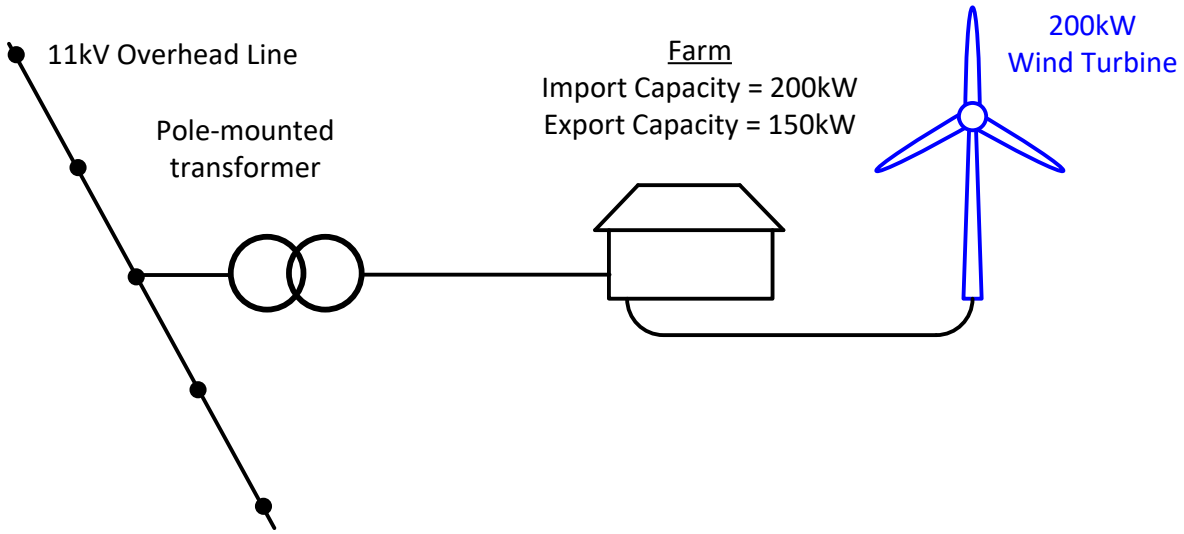


Figure F2 Wind Turbine Installation at a Farm

SPEN carries out the following assessments:

Thermal Assessment

SPEN establishes that the existing **HV** and **LV** network can accommodate 150kW of export continuously and substantially more than 200kW of export for 5s, from a thermal perspective.

Protection Assessment:

The protection assessment restricts the **Power Station Capacity** to the higher of:

- 1.25 x **Agreed Import Capacity** = 1.25 x 200kW = 250kW
- 1.25 x **Agreed Export Capacity** = 1.25 x 150kW = 187.5kW

The proposed 200kW wind turbine satisfies the protection assessment since the greater of the two values is 250kW.

Voltage Assessment:

SPEN assesses the generator's impact on the **LV** network voltage and the **HV** network voltage under minimum demand / maximum generation conditions. The voltage rise on the **HV** network voltage is found to be minimal, but the **LV** voltage is estimated to rise to 254.5V when the 200kW wind turbine operates at its maximum capacity (before the **ELS** restricts its output).

For the purposes of assessing the maximum acceptable **Power Station Capacity** the voltage must be no higher than the upper **Statutory Voltage Limit** + (1% of the **Nominal Voltage**) = 253V + (1% of 230V) = 255.3V is used. The estimated value of 254.5V satisfies this requirement.

Conclusion

In this case the proposed 200kW wind turbine is below the maximum acceptable **Power Station Capacity** and therefore if an **ELS** is installed that limits the export to 150kW, the proposal is acceptable.

Example 3 – A new PV farm connection

A **Customer** wishes to install a 5,000kW PV farm in a rural area. The PV farm also requires an Import Capacity of 100kW to power the ancillary supplies.

SPEN carried out as assessment and offers an **Agreed Export Capacity** of 2,000kW pending reinforcement works. Once the network has been reinforced the full 5000kW export capacity can be provided.

The **Customer** proposes to temporarily install an **ELS** until the reinforcement works are completed to maximise the capacity of PV installation during the interim period

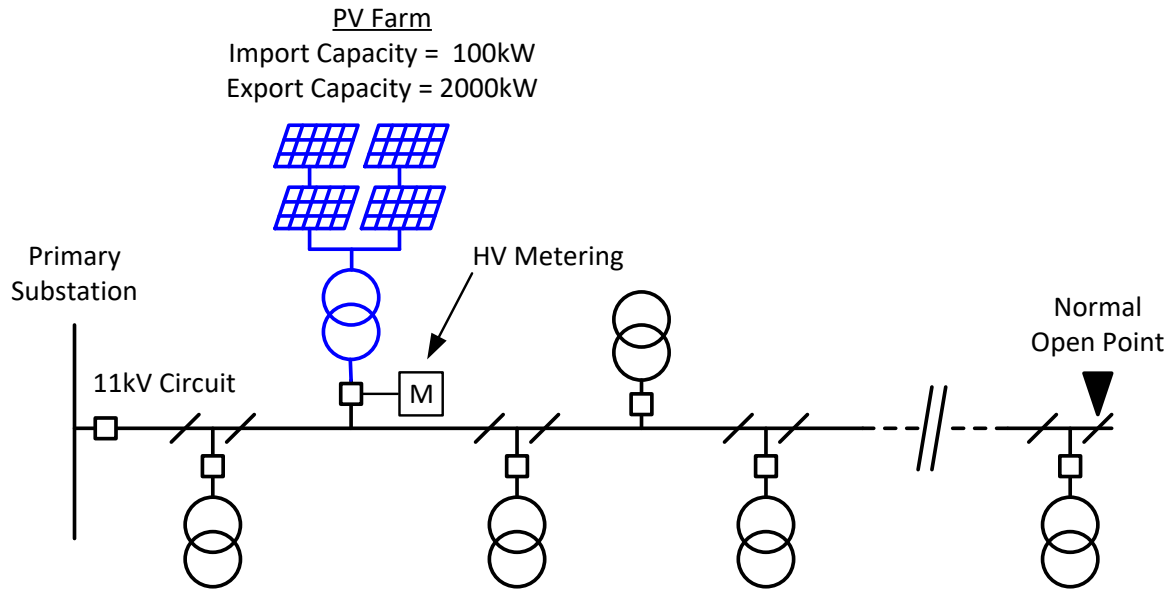


Figure F3 New PV Farm

SPEN assesses the maximum generation capacity, as follows:

Thermal Assessment

SPEN assesses the network is only capable of withstanding an export of 3,000kW for the 5 second operating time of the **ELS**.

Protection Assessment

The protection assessment restricts the capacity of the generation to the larger of:

- 1.25 x **Agreed Import Capacity** = 1.25 x 100kW = 125kW
- 1.25 x **Agreed Export Capacity** = 1.25 x 2,000kW = 2,500kW

The protection assessment restricts the **Power Station Capacity** to 2,500kW.

Voltage Assessment:

SPEN assesses the generator's impact on the 11kV network under minimum demand / maximum generation conditions. **SPEN** specifies an upper voltage limit of 11.2kV to prevent the voltage on the local **LV** network from exceeding statutory limits.

For the purposes of assessing the maximum acceptable **Power Station Capacity** the voltage must not exceed upper voltage limit + (1% of the **Declared Voltage**) = 11.2kV + (1% of 11kV) = 11.31kV during the 5s operating time of the **ELS**.

SPEN calculates that the voltage will increase to 11.31kV if the site exports 4,500kW.

Conclusion

If an **ELS** is installed (that limits the export to 2000kW) the maximum acceptable **Power Station Capacity** (i.e. the maximum capacity of the PV farm) is the lower of results from the thermal assessment (i.e. 3000kW) the voltage assessment (2,500kW) and the protection assessment (4,500kW). In this case the **Power Station Capacity** must be temporally restricted to 2,500kW until the reinforcement work is completed.

APPENDIX G – (INFORMATIVE) AC POWER AND DIRECTION OF POWER FLOW

Types of Power Measurement

Three different types of Power are applicable to A.C. systems, **Apparent Power**, **Active Power** and **Reactive Power**.

(a) **Apparent Power** = Voltage x Current and has units of Volt-Amperes (e.g. VA, kVA or MVA).
(b) **Active Power** = Voltage x Current x COS Θ, where Θ is the angle between the Voltage and Current waveforms. **Active Power** is expressed in Watts (e.g. W, kW or MW).
(c) **Reactive Power** = Voltage x Current x SIN Θ, where Θ is the angle between the Voltage and Current waveforms. **Reactive Power** is expressed in VARs (e.g. VAr, kVAr or MVAr)

COS Θ is often referred to as the **Power Factor**

Direction of Power Flow

AC current, voltage and **Apparent Power** are, by themselves, non-directional quantities. The direction of active and **Reactive Power** flow depends on the relationship (angle) between the voltage waveform and the current waveform. This relationship can be shown in two ways, as a diagram of voltage and current by angular displacement (as shown in Figure G1) or as a vector diagram (as shown in Figure G2).

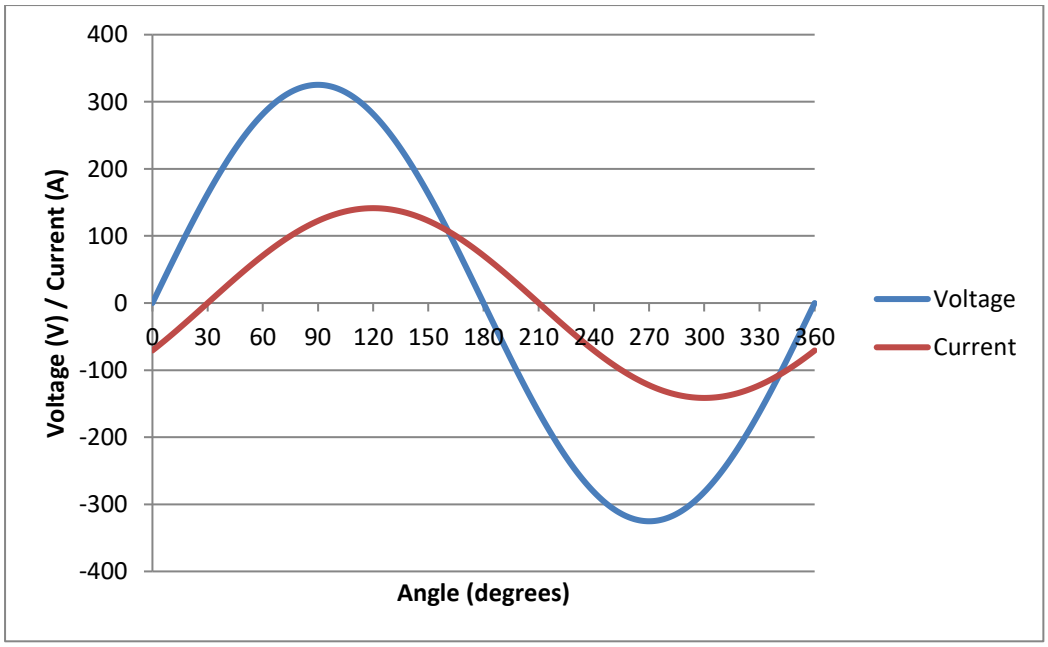


Figure G1 Current & Voltage V Waveforms - Current lagging Voltage by 30º

Note, A compete cycle (i.e. 360º) has a duration of 20ms where the frequency is 50Hz.

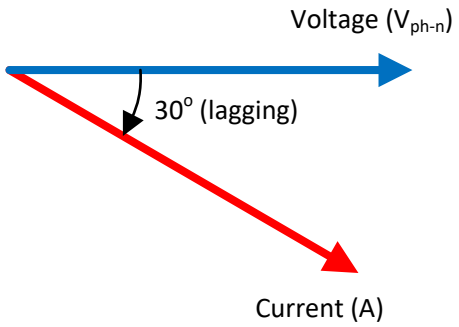


Figure G2 Vector Diagram – Current Lagging Voltage by 30°

Active Power

If the current lags or leads the voltage by 90° or less the **Active Power** is positive. If the current lags or leads the voltage by more than 90° the flow of **Active Power** is negative.

Reactive Power

If the current lags the voltage more than 90° and by less than 180° the **Reactive Power** is positive. If the current leads the voltage by more than 90° and less than 180° the flow of **Reactive Power** is negative.

Figure G3 shows the relationship between **Apparent Power**, **Active Power** and **Reactive Power**. In this case both **Active Power** and **Reactive Power** are positive since the current is lagging the voltage by less than 90°.

Figure G4 and G5 show how the direction of power flow changes as the angle between the current and voltage varies. Four examples are provided:

- I1 lags the voltage by approximately 20° and, in this case, the **Active Power** and **Reactive Power** are both positive.
- I2 leads the voltage by approximately 20° and in this case the **Active Power** is positive and the **Reactive Power** is negative.
- I3 lags the voltage by approximately 160° and so in this case the **Active Power** is negative and the **Reactive Power** is positive.
- I4 leads the voltage by approximately 160° and so in this case both the **Active Power** and the **Reactive Power** are negative.

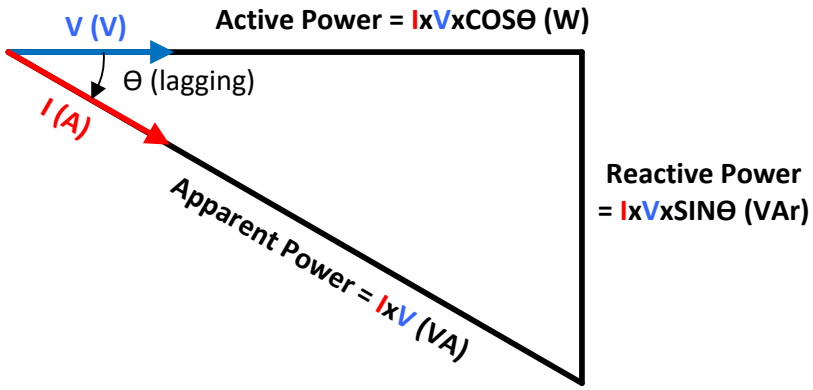
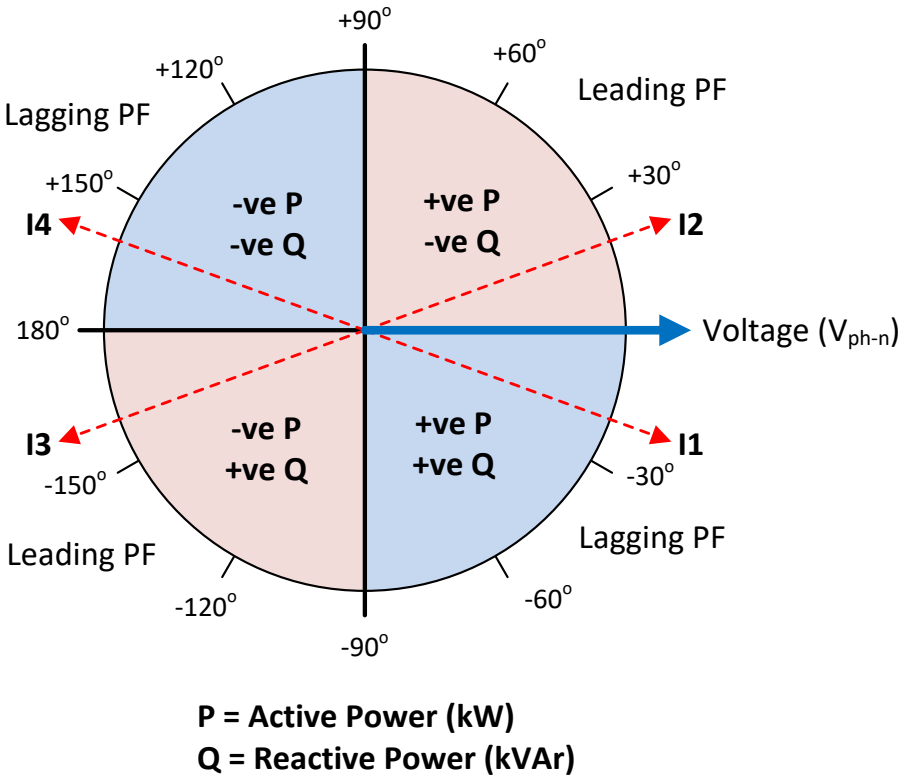
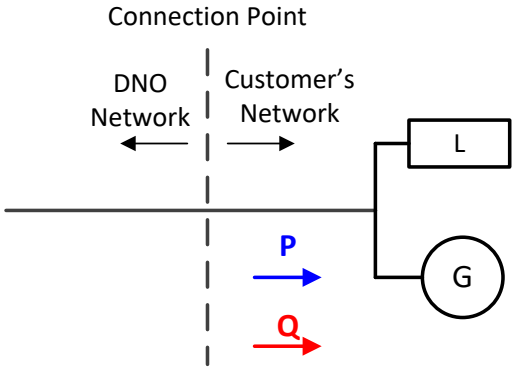


Figure G3 Apparent Power, Active Power and Reactive Power

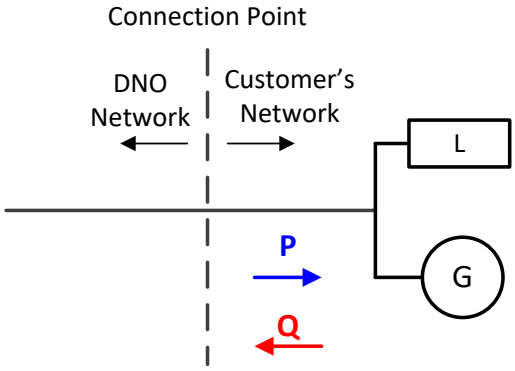


P = Active Power (kW)
Q = Reactive Power (kVAr)

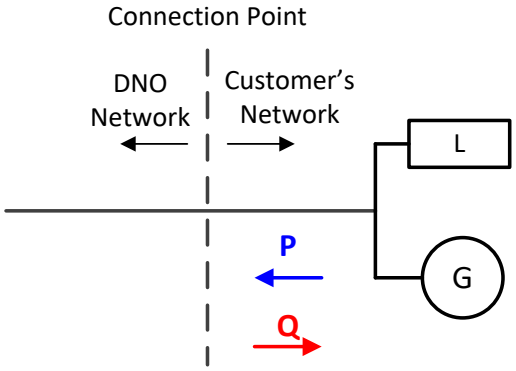
Figure G4 Four Quadrant Diagram - Direction of Power Flow



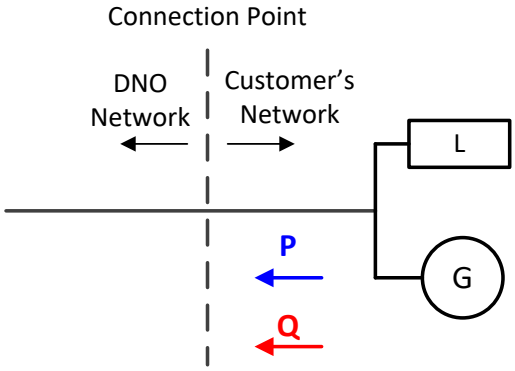
Current I1 Lagging Voltage by ≤ 90°



Current I2 Leading Voltage by ≤ 90°



Current I3 Lagging Voltage by >90° and <180°



Current Leading I4 Voltage by >90° and <180°

KEY:

Generating Units = G

Demand = L

Figure G5 Direction of Power Flow