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Technical Guidance for Customer Export Limiting Schemes

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Foreword

This Engineering Recommendation (EREC) is published by the Energy Networks Association (ENA) and comes into effect from July, 2016. It has been prepared under the authority of the ENA Engineering Policy and Standards Manager and has been approved for publication by the ENA Electricity Networks and Futures Group (ENFG). The approved abbreviated title of this engineering document is “EREC G100”, which replaces the previously used abbreviation “ER G100”.

This document 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**.

1 Purpose

The purpose of this Engineering Recommendation (EREC) is to provide guidance on the connection of **Customer Export Limiting Schemes (ELS)** that operates in parallel with the **Distribution Systems** of licensed **Distribution Network Operators (DNOs)**.

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 EREC is intended to provide guidance to **Customers** planning to use an **ELS** and to **DNO**s.

This document should be read in conjunction with EREC G83 and G59.

As the cost of generation continues to reduce, many **Customer**s are now seeking to increase the amount of generation installed within their premises to offset their import requirements. Where the **DNO** has assessed that an increase in generation export capacity will require costly or time-bound upstream reinforcement, some **Customer**s 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.

2 Scope

This document applies to **ELS**s 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 the **DNO**.

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 the **DNO** to assess the suitability of an **ELS** in these situations and authorise accordingly.

3 Normative references

The following referenced documents, in whole or part, are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

3.1 Standards publications

BS 7671	Requirements for Electrical Installations. IET Wiring Regulations.
BS EN 61000-3-2	Limits for harmonic current emissions (equipment input current ≤16 A per phase)
BS EN 61000-3-3	Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current 16 A per phase and not subject to conditional connection
BS EN 61000-3-11	Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75A and subject to conditional connection
BS EN 61000-3-12	Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase.

3.2 Other publications

Engineering Recommendation G5	Planning levels for harmonic voltage distortion and connection of non-linear equipment to transmission systems and distribution networks in the United Kingdom
Engineering Recommendation G59	Recommendations for the connection of generation plant to the **Distribution System**s of licensed **Distribution Network Operator**s
Engineering Recommendation G83	Requirements for the connection of small scale embedded generators (up to 16A per phase) in parallel with Public **Low Voltage** Distribution Networks
Engineering Recommendation P2	Security of Supply
Engineering Recommendation P28	Planning Limits for Voltage Fluctuations Caused By Industrial, Commercial and Domestic Equipment in the UK

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply. Words and expressions printed in bold type throughout the document are defined in this section.

4.1 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.

4.2 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).

4.3 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** should be no lower than 3.68kW per phase.

4.4 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**.

4.5 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').

4.6 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 **DNOs** fused cut out or the metering circuit breaker.

4.7 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 Limit**
- To send control signals to the **Generating Unit**(s) interface and load interface units
- To detect any system error (fail-safe protection)

4.8 Customer

A person who is the owner or occupier of premises that are connected to the **Distribution System**.

4.9 Declared Voltage

In respect to **Low Voltage** supply should be 230 Volts between phase and neutral conductors at the **Connection Point**.

In respect to **High Voltage** supply the **Declared Voltage** will be determined by the **DNO**. The voltage should be defined between 2 phase conductors at the **Connection Point**.

4.10 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).

4.11 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).

4.12 Distribution Network Operator (DNO)

The person or legal entity named in Part 1 of the **Distribution Licence** and any permitted legal assigns or successors in title of the named party. For the avoidance of doubt, this includes **Independent Distribution Network Operator**s.

4.13 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 Point**s to the points of delivery to **Customer**s within Great Britain.

4.14 Export Limitation Scheme (ELS)

The system comprising of one or more functional units, sensors and control signals that interfaces with the **Customer**'s generation and/or load to control the net flow of electricity into the **Distribution System** at the **Connection Point** so as not to exceed the **Agreed Export Capacity.**

4.15 Fail Safe

A design requirement that enables the **Export Limitation Scheme** to limit export to the **Agreed Export Limit** irrespective of the failure of one or more its components.

4.16 Generating Unit

Any apparatus that produces electricity.

4.17 Generating Unit or 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.

4.18 High Voltage (HV)

A voltage exceeding 1,000V.

4.19 Independent Distribution Network Operator (IDNO)

A **DNO** that does not have a Distribution Services Obligation Area in its **Distribution Licence** and is not an ex Public Electricity Supplier

4.20 Low Voltage (LV)

In relation to alternating currents, a voltage exceeding 50V but not exceeding 1,000V.

4.21 Power Station Capacity

The aggregated capacity of all the **Generating Units** associated with a single **Power Station**.

4.22 Nominal Voltage

The **Distribution System** operates at **Nominal Voltage**s of 132kV, 66kV, 33kV, 22kV, 11kV, 6.6kV, 400 volts and 230 volts.

4.23 Power Factor

The ratio of **Active Power** to **Apparent Power**.

4.24 Power Measurement Unit (PMU)

The **PMU**s function is to measure the voltage and current flow between the **Distribution System** and the **Customers'** premises at the **Connection Point**.

4.25 Power Station

An installation comprising of one or more **Generation Unit**s.

4.26 Reactive Power

The imaginary component of the **Apparent Power** at fundamental frequency usually expressed in kilovar (kVAr) or Megavar (MVAr).

4.27 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.

5 Requirements

5.1 Export Limitation Scheme Design

An **Export Limitation Scheme** 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 from 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 the **Statutory Voltage Limits**. If this feature is required, the **DNO** shall specify this at the quotation / offer stage.

In order for the installation of an **ELS** to be an acceptable solution, the **DNO** must be satisfied that the control schemes will meet the requirements of section 5.6 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, DNOs** will specify an export **Power Factor** or **Power Factor** range at the **Connection Point**, as applicable. The **ELS** should 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 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 (see section 5.5) to prevent the **Agreed Export Capacity** from being exceeded.

ELSs installed at **Power Stations** with an aggregate **Generating Unit** capacity exceeding 16A (i.e. 3.68kW) per phase must be fail-safe and must ensure that the **Agreed Export Limit** 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 should only be changed with the written agreement of the **DNO**.

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 should be installed at all **HV** metered connections to back-up the **ELS**. See section 5.5 for further detail.

For **LV Connection Points**, a reverse power protection relay is only required if the **DNO** deems the **ELS** not to be fail-safe.

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

5.2 Maximum Power Station Capacity

An **ELS** will take a finite time (as specified in section 5.5.) 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.

The **DNO** will 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.

5.2.1 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.

5.2.2 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** should 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 a **DNO** 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 should be based on the **DNO**'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 **DNOs** cut-out fuse should be assumed to be 60A.

5.2.3 Voltage Assessment

The **Power Station Capacity** should be restricted to prevent **DNO** equipment voltage ratings from being exceeded during the detection and operation time of the **ELS**. It is recommended that the highest network voltage is no greater than 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 **DNO's** upper **Statutory Voltage Limit** is = 230V + 10% = 253V. The maximum **Power Station Capacity** should therefore be restricted in order to prevent the network voltage exceeding 253V + (1% of 230V) = 255.3V.

For **HV** networks an upper voltage limit is defined by the **DNO** to ensure the voltage at **LV Connection Point**s remains within **Statutory Voltage Limits.** For example, where a **DNO** specifies an upper voltage limit of 11.3kV (phase to phase) for an **HV** network, the maximum **Power Station Capacity** must be restricted to prevent the highest network voltage exceeding 11.3kV + (1% of 11kV) = 11.41kV.

5.2.4 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 the **DNO** will notify the **Customer** of the reason for the restriction.

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

5.3 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 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, should 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**) should be used instead. In the absence of other data a 60A cut-out fuse should be assumed.

5.4 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

In accordance with the above documents, with BS7671 (The IET Wiring Regulations) and the Distribution Code, **Customers** will need tol discuss and agree the connection of any potentially disturbing equipment with the **DNO**.

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** will need to provide the **DNO** with 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 will also need to 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 should 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.

5.5 Accuracy and Response Rates

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

The settings applied to the **ELS** should 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 should be set to limit the **Active Power** to 95kW (i.e. 95% of the required value).

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 Units** and actively controlled demand) mean that the 5 second operating time may not be satisfied, a back-up system should 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** system 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) should disconnect the **Generating Unit** if the exported power exceeds the **Agreed Export Capacity** for more than 5 seconds. It will be the responsibility of the **Custome**r to specify and satisfy the relevant **DNO** that the protection meets this requirement.

5.6 Excursions

The **Active Power** may, under abnormal conditions, temporarily exceed the **Agreed Export Capacity**. The **ELS** should 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, the **DNO** 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 **Customers'** cost.

6 Application and Acceptance

Customers are required to provide information on the proposed **ELS** to enable **DNO**s to make an assessment on the risk to the network. A flowchart on the acceptability criteria is shown in Appendix C.

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

- Single Line Diagram of **ELS**
- Explanation of **ELS** operation
- Description of any fail-safe functionality (interruption of sensor signals, disconnection of load, loss of power, internal fault detection etc.)

7 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.

7.1 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, the **DNO** may, at its discretion, not require to witness the **Fail Safe** operation. For larger installations **DNOs** normally witness the tests on the **ELS**.

Where the **ELS** commissioning tests are witnessed by the **DNO** 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** will need to be displayed on site alongside any EREC G59 protection settings.

7.2 Preventing the export limit being exceeded during setup/testing

Care should 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

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

7.3 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 should 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** will be required to provide all relevant scheme drawings and information to enable safe, informed commissioning of the **ELS.**

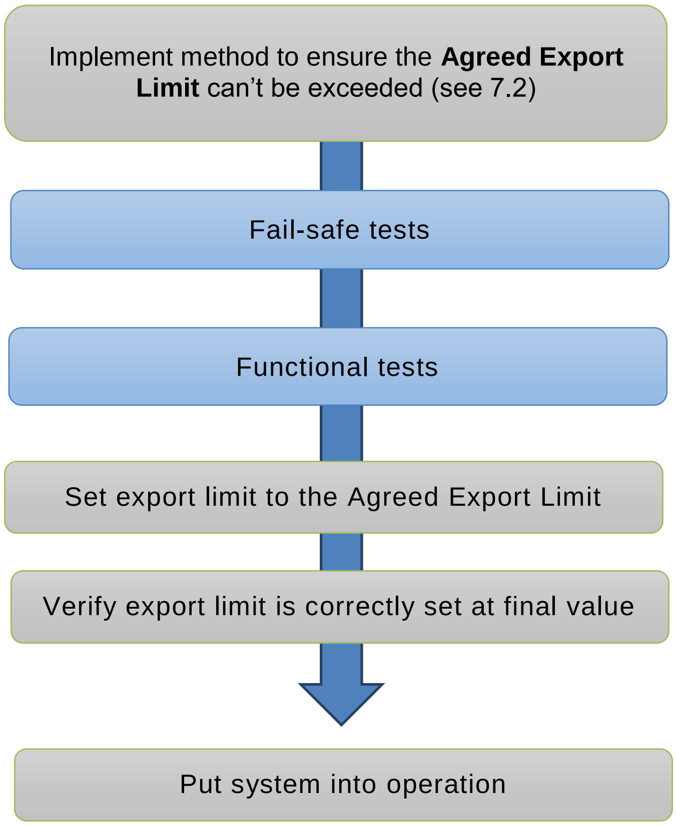

Figure 1 Commissioning Sequence

7.4 Fail-safe tests

Fail-safe tests are not required for installations with an aggregate **Generating Unit** capacity of 16A (i.e. 3.68kW) per phase or less.

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 Units** 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.

7.5 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 should 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)

Table 1 Test Sequence

7.6 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.

7.6.1 <u>Functional testing – manual load control</u>

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 Unit**s 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.

7.6.2 <u>Functional testing – Injection testing</u>

Export limit conditions can be simulated by temporarily connecting the **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

Table 2 Step Change Tests

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 should be repeated at the maximum statutory voltage (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 should 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.

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 should 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.*
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 or G59.

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 installation has an aggregate **Generating Unit** capacity of 16A (i.e. 3.68kW) per phase or less.*	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 5.1.3	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 7.	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** should 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 or appendix 13.2 and 13.3 in EREC G59.

Appendix C – (informative)
Export Limitation Scheme Diagram

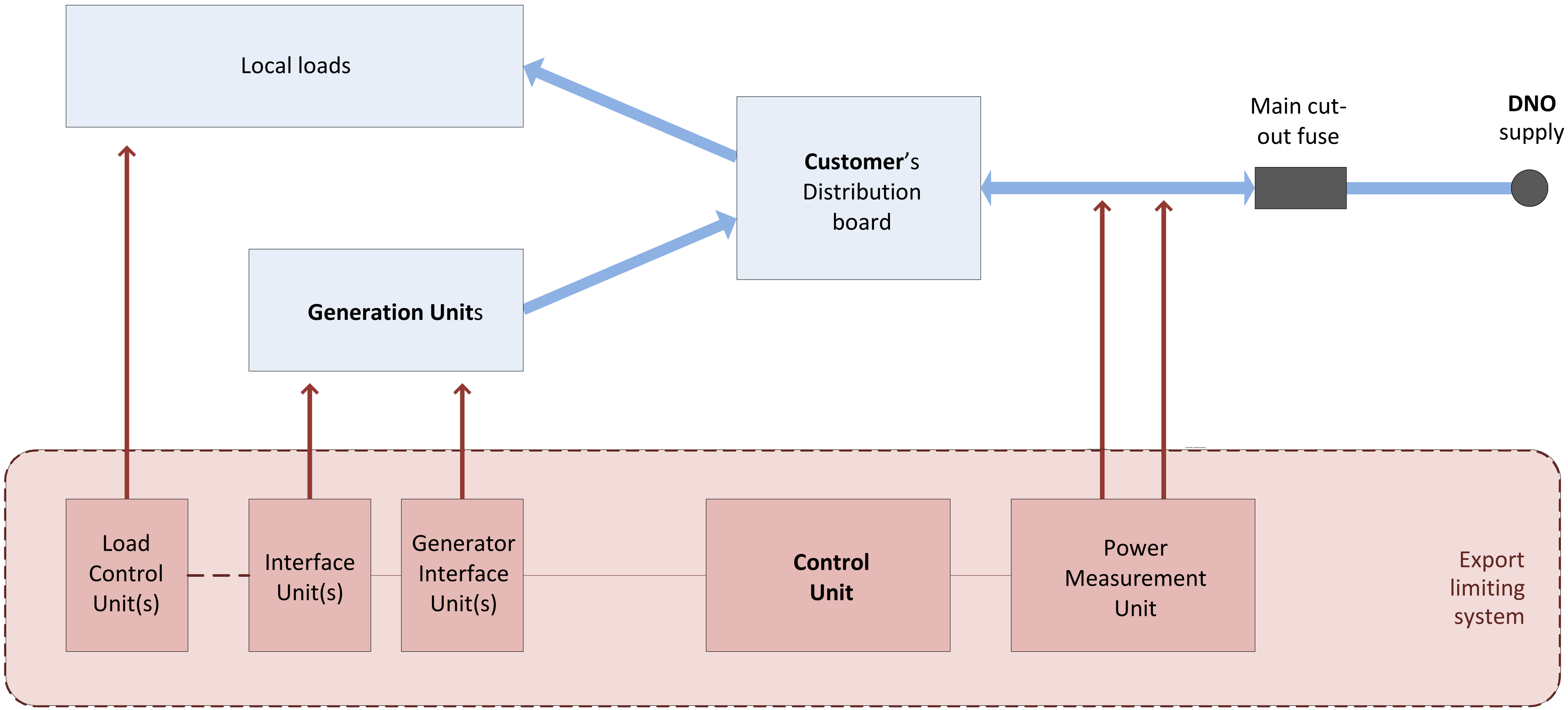

Figure C1 Typical Scheme Design for an Export Limitation Scheme Arrangement for an Asynchronous Generator

Appendix D – (informative)
Export Limitation Scheme Application Flow Chart

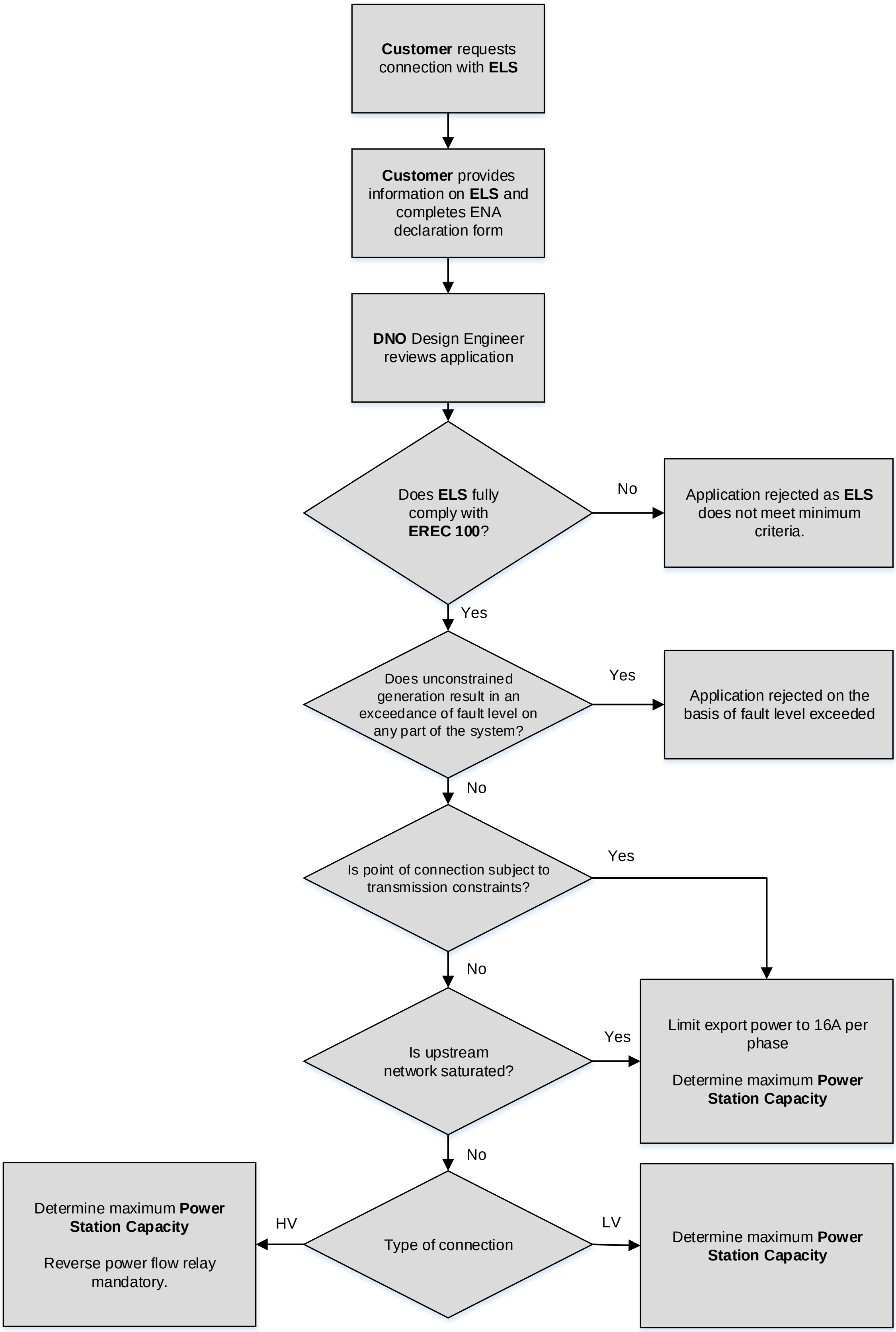

Figure D1 Export Limitation Scheme Application Flow Chart

Appendix E – (informative)
Power Station Capacity Examples

Example 1 – Large PV installation at a Domestic Property

A domestic **Customer** wishes to install a PV system but the **DNO** has restricted the **Agreed Export Capacity** to 3.68kW due to concerns over 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.

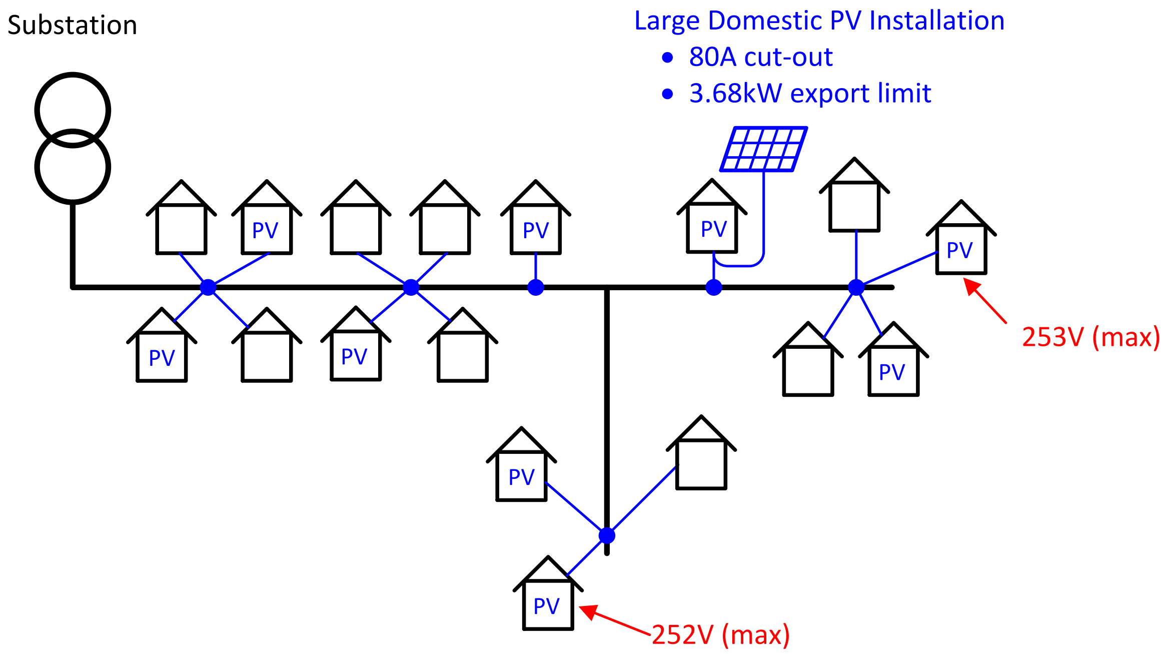

Figure E1 Large PV Installation at a Domestic property

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

<u>Thermal Assessment:</u>

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. The DNO determines that the thermal rating of the installation does not, in practice, limit the **Power Station Capacity**.

<u>Protection Assessment</u>:

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.

The **DNO** 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 the **DNO** 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.

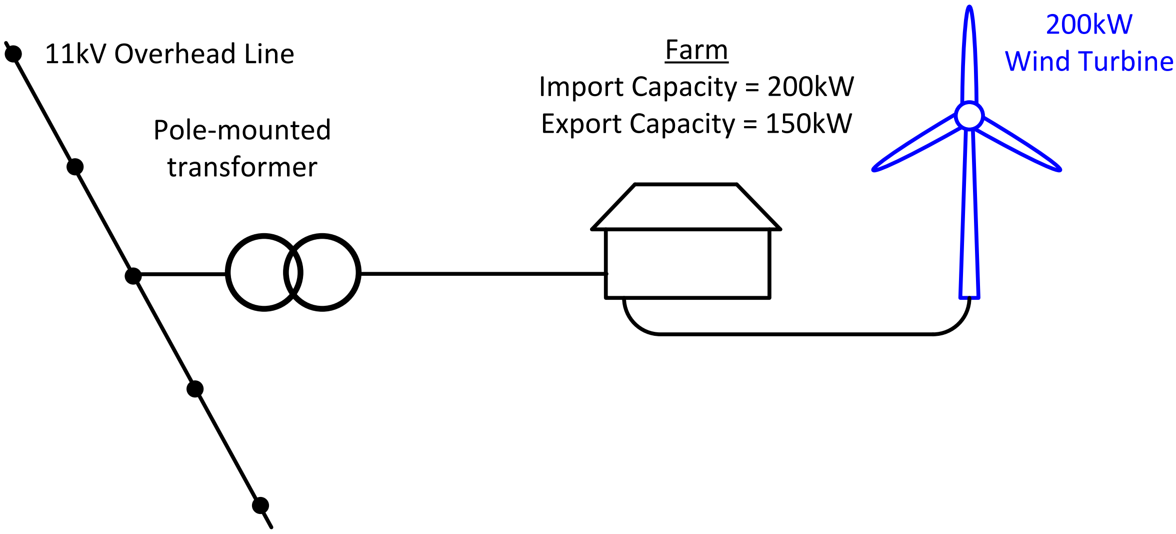

Figure E2 Wind Turbine Installation at a Farm

The **DNO** carries out the following assessments:

Thermal Assessment

The **DNO** 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:

The **DNO** 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.

<u>Conclusion</u>

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.

The **DNO** 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

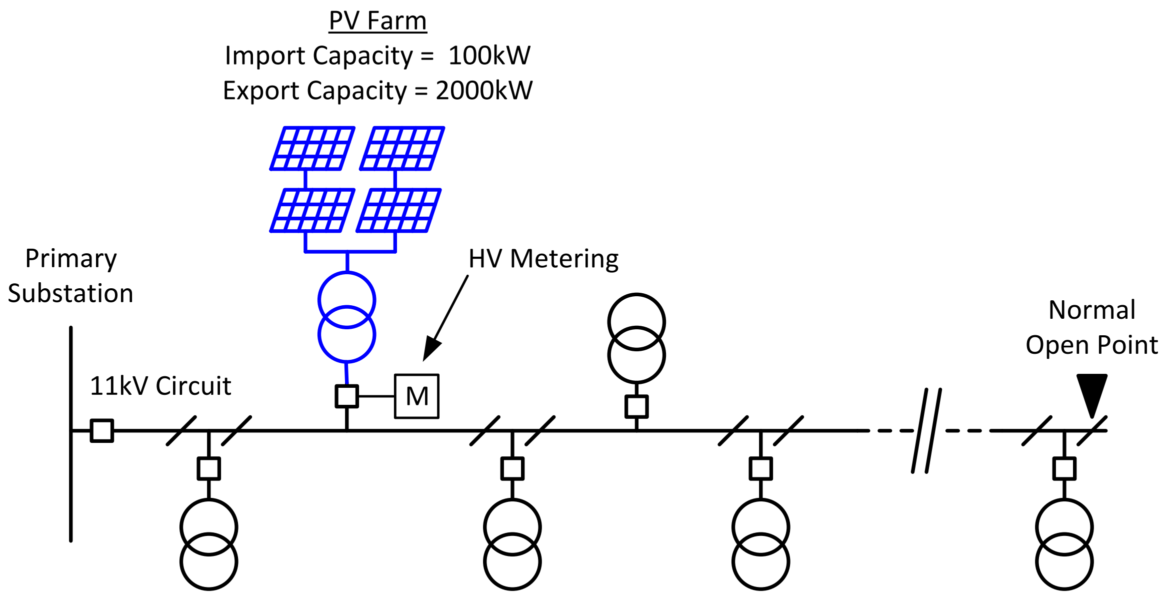

Figure E3 New PV Farm

The **DNO** assesses the maximum generation capacity, as follows:

Thermal Assessment

The **DNO** 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:

The **DNO** assesses the generator's impact on the 11kV network under minimum demand / maximum generation conditions. The **DNO** 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. .

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

<u>Conclusion</u>

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 F – (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 F1) or as a vector diagram (as shown in Figure F2).

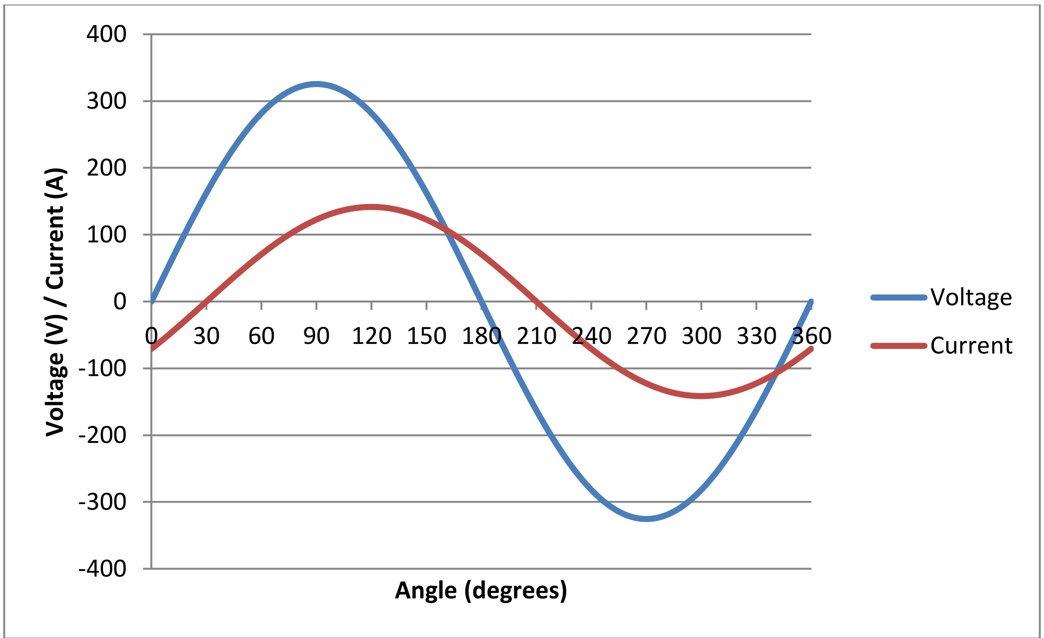

Figure F1 Current & Voltage V Waveforms - Current lagging Voltage by 30º

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

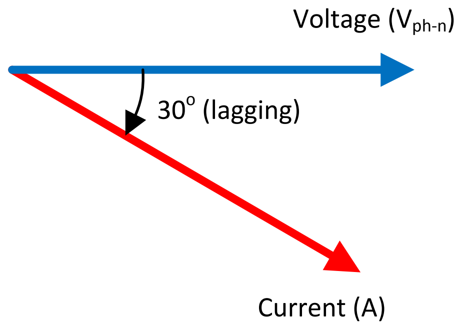

Figure F2 Vector Diagram – Current Lagging Voltage by 30°

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 0° and by less than 180° the **Reactive Power** is positive. If the current leads the voltage by more than 0° and less than 180° the flow of **Reactive Power** is negative.

Figure F3 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 F4 and F5 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.

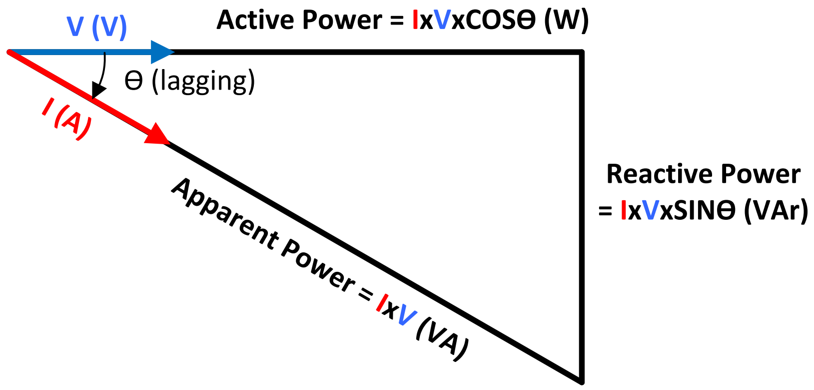

Figure F3 Apparent Power, Active Power and Reactive Power

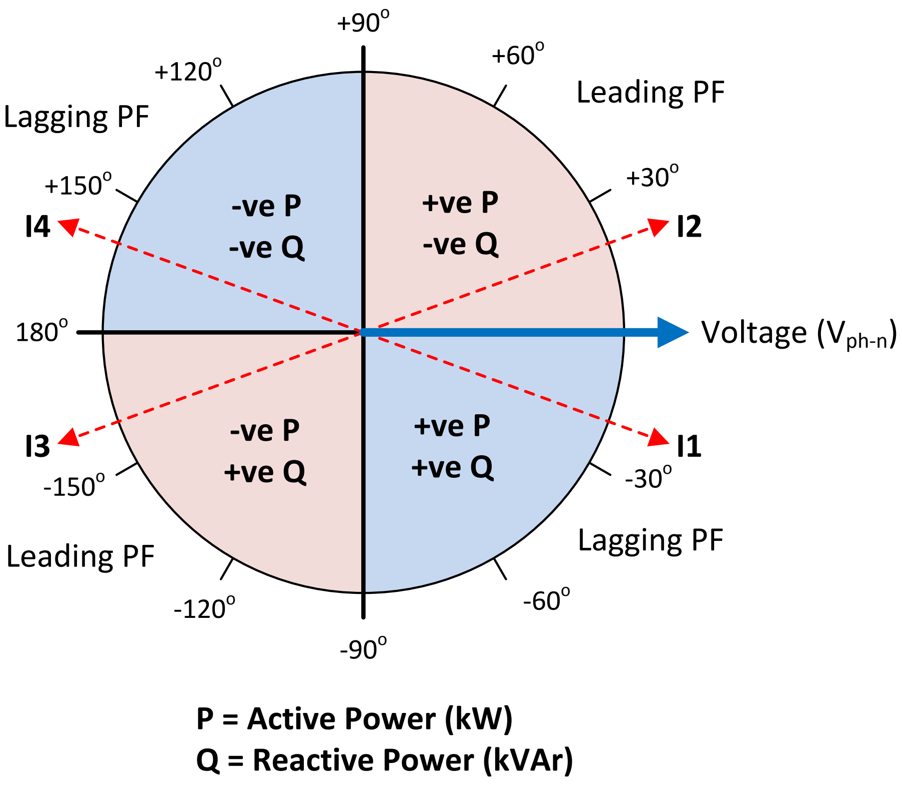

Figure F4 Four Quadrant Diagram - Direction of Power Flow

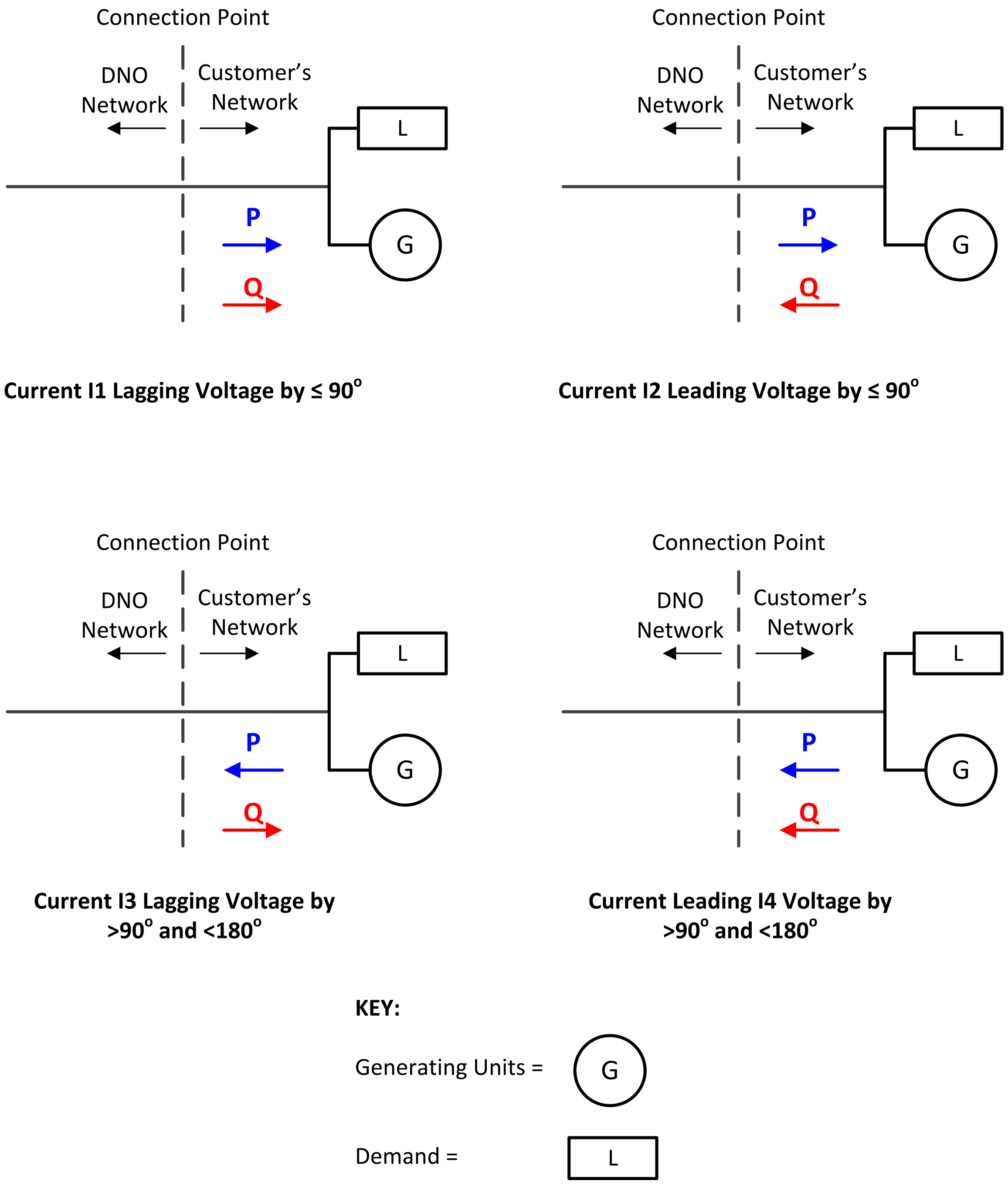

Figure F5 Direction of Power Flow