Ministry of Energy

Connection Guidelines for Small-Scale Renewable Generating Plant

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1. INTRODUCTION AND SCOPE

1. These guidelines are the product of a project aimed at facilitating the development and connection to the electricity network of small renewable energy generators. Whilst they have no regulatory status, they do represent international good practice and reflect the network operator's statutory obligation to manage the operation and safety of his system in a responsible manner. Some of the requirements come directly from the Grid Code. It is in both the system user and the system operator's interest to have a stable electricity network, so these guidelines should be read by those planning to operate Generating Plant prior to installation and connection.

2. The purpose of these guidelines is to establish procedures and equipment to protect personnel, equipment, and network operator's systems from any harmful effects arising from connection and operation of Generating Plant supplied and operated by others, herein referred to as Generators. They are intended to inform Generators of the host network operator's requirements for Generating Plant being connected to its System.

3. These guidelines are designed to facilitate the connection of Generating Plant whilst maintaining the safety of, and supply quality from the network. This applies to all Generating Plant irrespective of the type of electrical equipment used to produce electrical energy. They do not however provide advice for the design, specification, protection or operation of Generating Plant itself which is the sole responsibility of the Generator, noting the connection guidance given in this document.

4. The guidelines apply to systems where the Generating Plant can be paralleled with a Transmission/Distribution System or where either the Generating Plant or a Transmission/Distribution System with Generating Plant connected can be used as an alternative source of energy to supply the same electrical load.

5. These guidelines are for information only and are subsidiary to the mandatory requirements governing the connection of Generators which are generally set out in the Grid Code.

6. These guidelines generally apply to small and medium scale Generating Plant with a capacity up to 10MW.

2. DEFINITIONS

These definitions are provided to assist the interpretation of these Guidelines. Where equivalent terms are defined within statutory instruments, those definitions will take precedence over these in this document.

Act	The Energy Act 2006
AVC	Automatic Voltage Controller
AVR	Automatic Voltage Regulator
Combined Heat and Power (CHP)	A plant that generates electricity and supplies thermal energy, to an industrial or other heating or cooling requirement.
Connection Agreement	An agreement between the host network operator and the Generator setting out the terms relating to a connection to that network.
Connection Point	An Entry Point or an Exit Point of a network.
Connection Voltage	The nominal voltage at which the Grid Connection is made.
Customer	A person who is the owner or occupier of premises that are connected to the network.
Customer's Installation	The electrical installation on the Customer's side of the supply terminals together with any equipment permanently connected or intended to be permanently connected thereto.
Customer Average Interruption Duration Index (CAIDI)	A performance measure of a Distribution Network. It is calculated as the average number of minutes that the supply is not available per connected customer
Customer Interruption (CI) also known as System Average Interruption Frequency Index (SAIFI)	A performance measure of a distribution network. It is measure of the number of events per year where the interruption lasts more than 3 minutes.
Dispatchable Generation	The output of a Generating Plant where the production profile is subject to dispatch instruction by the network system operator's control centre.
Distribution Network	An electricity supply network operating at or below 33kV which is connected to Kenya's electricity transmission grid or operating as an isolated mini-grid.
Distribution Network Operator (DNO)	The licensee responsible for the operation of the distribution network..
Embedded Generator	A Generator connected to a distribution network.
Entry Point	The point at which a Generator or other Users connect to a network where power flows into the network under normal circumstances.
Exit Point	The point of supply from a network to a User where power flows out from the network under normal circumstances.

Export of Electrical Energy	Provision of Electrical Energy by a Generator to a Network.
Fault Level	Prospective current that would flow into a short-circuit at a stated point in the System and which may be expressed in kA or, if referred to a particular voltage, in MVA.
Generating Plant	A power station including any Generation Set therein.
Generation Unit	Any apparatus which produces electricity.
Generator	A person who generates electricity under licence or exemption. A person who has connected a Generating Set which is less than 16A per phase in parallel with a Low Voltage Distribution Network and where this is their only Generation Set is not classed as a Generator but is subject none the less to the requirements of ENA G83.
Grid Code	The code as prepared by the national energy regulator.
Grid Connection	A link between a Network and a Generator's electricity system, made for the purpose of Exporting or Importing Electrical Energy.
Grid Substation	A substation in the main grid where electrical energy at particular voltage transformed into another voltage for the purpose of transmission or a Distribution. In Kenya transmission volatages are 400kV, 220kV, and 66kV and distribution voltages are 33kV,and 11kV.
Host network operator:	The licensed operator of the Distribution System or Transmission System to which a Customer (Generator or Consumer) is connected.
High Voltage (HV)	In Kenya, nominal voltage exceeding 33,000V between conductors.
Import of Electrical Energy	Receipt of Electrical Energy by a Generator from a Network.
Interface Protection	The electrical protection required to ensure that any Generating Unit is disconnected for any event that could impair the integrity or degrade the safety of the host network.
Islanding	The process whereby a Network is separated into two or more parts, with Generators supplying loads connected to some of the separated parts.
Islanded Operation	The situation that arises when a part of a Network is disconnected from the grid and is energised by one or more Generators connected to it.
Loss of Mains Protection (LoM)	A protection regime to achieve (amongst other things) disconnection of the Generating Plant from the Distribution System in the event of loss of one or more phases of the host network operators supply.
Low Voltage (LV)	A voltage greater than 50V but not exceeding 1000V between conductors and [600]V between

	conductors and earth.
Medium Voltage (MV)	In Kenya, a nominal voltage, exceeding 1,000V but less than 33,000V between conductors.
Mini-grid	A power system that may be operated in isolation to the Kenya national grid and operated under the regulatory supervision of national Energy Regulator.
Neutral Voltage Displacement (NVD)	A technique to measure the displacement of the neutral voltage with respect to earth.
Normal Operating Frequency	The number of Alternating Current cycles per second, expressed in Hertz at which the System normally operates, in Kenyan the normal operating frequency is . 50 Hertz.
Over-current Protection (OC)	A form of protection in an electric circuit which prevents damage resulting from excessive current and interrupts the flow of current at a predetermined value.
Over-frequency Protection (OF)	A form of protection in an electric circuit which prevents damage resulting from a difference in in the frequency of two interconnecting systems
Over-voltage Protection (OV)	A form of protection in an electric circuit that protects downstream circuitry from damage due to excessive voltage.
Operating Voltage	The value of the voltage under normal conditions at a given instant and at a given point in the system.
Point of Common Coupling (PCC)	The location on an existing network where a connection is made for a Customer's installation.
Point of Supply (POS)	The point of electrical connection between apparatus owned by the network operator and apparatus owned by the Customer. It is normally the Entry/Exit Point and the Measurement Point.
Power Factor	The ratio of Active Power to apparent power (Active power is the measured power using a wattmeter, expressed in Watts. And standard multiples thereof, while apparent power is the product of voltage and alternating current measured in volt-amperes and standard multiples thereof, ie VA, kVA, MVA).
Power Park	A collection of Generation Sets, usually operated in parallel, which are controlled as a single Generating Plant e.g. a wind farm
Power Purchase Agreement(PPA)	An agreement between a Generator and a buyer for the purchase of Electrical Energy.
Power System Stabiliser (PSS)	Equipment controlling the output of a Generating Unit in such a way that power oscillations of the unit are damped.
Protection	The provisions for detecting abnormal conditions in a System and initiating fault clearance or actuating signals or indications.

Rate-of-change of Frequency Protection (RoCoF) also known as Vector Shift Protection (VS)	A relay that will trip the Generating Unit if the grid fails. This avoids the grid returning when the Generating Unit is not synchronised which would cause a short-circuit fault.
Reactive Power	The product of voltage and current and the sine of the phase angle between them which is normally measured in kilovar (kVAr) or megavar (MVAr).
Restricted Earth Fault Protection	Is a unit form of protection scheme which takes care of a particular defined zone of an equipment, while disregarding all faults outside the zone.
Reverse Power Protection (RP)	A system of protection that detects power transfer in the opposite direction to that expected under normal operation.
Standby Earth Fault Protection (SBEF)	A back up protection system to effect earth fault protection after a time delay to permit the principal protection system to operate.
Step Voltage	The difference in surface potential experienced by a person bridging a distance of 1m with his feet without contacting any other grounded structure.
Step Voltage Change	Following system switching, a fault or a planned outage, the change from the initial voltage level to the resulting voltage level after all the Generating Unit automatic voltage regulator (AVR) and static VAR compensator (SVC) actions, and transient decay (typically 5 seconds after the fault clearance or system switching have taken place), but before any other automatic or manual tap-changing and switching actions have commenced.
Synchronism	The condition under which a Generating Unit or System is connected to another System so that the frequencies, voltage and phase relationships of that Generating Unit or System, as the case may be, and the System to which it is connected are similar within acceptable tolerances.
System Stability	The ability of the System, for a given initial operating condition, to regain a state of operating equilibrium, after being subjected to a given system disturbance, with most System variables within acceptable limits so that practically the whole System remains intact.
Touch Potential	The potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing, where at the same time having his hands in contact with a grounded structure. GPR is defined as the maximum voltage that a station grounding grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. The touch voltage could be from hand to hand as well.
Terra Neutral Combined-Separate	A form of TNS in which part of the system uses a

Earthing (TNCS)	combined protective earth and neutral (PEN) conductor, which is at some point is segregated into separate PE and N lines. The combined PEN conductor typically occurs between the substation and the entry point into the building.
Terra Neutral Separate Earthing (TNS)	In this earthing (grounding) system, the host network operator provides separate neutral and protective conductors throughout the system. The protective conductor is connected to the neutral of the source. All exposed conductive parts of a consumer's installation are connected to the protective conductor provided by the host network operator via the main earthing terminal of the consumer's installation.
Transmission System Operator (TSO)	Entity mandated to operate the National Transmission System.
Terra Terra Earthing (TT)	An earthing (grounding) system where all exposed conductive parts of an installation are connected to an earth electrode provided by the consumer which is electrically independent of the source earth.
Type Verified	A class of equipment which has been tested and approved as compliant to an internationally recognised engineering standard.
Under-frequency Protection (UF)	See over-frequency protection
Under-voltage Protection (UV)	See under-voltage protection
Vector Shift Protection (VS)	[see RoCoF Protection]
Voltage Level	One of the Nominal Voltage values used in a given system.

3. NORMAL LEGAL CONTEXT

1. Generators are normally required to enter into a Power Purchase Agreement (PPA) with the host network operator. This specifies the terms and conditions including technical, operating, safety and other requirements under which the Generating Plant is entitled to remain connected to the network. PPAs normally include site specific commercial issues, including recovery of costs associated with the connection, use of system charges and the applicable energy loss adjustment factors.

2. Generators are bound by their licences or by their PPA, or both, to comply with the Grid Code.

3. A site responsibility schedule detailing ownership, maintenance, safety and control responsibilities is normally produced when details of the interface between a Generating Plant and the host network have been agreed.

4. Network operators normally have statutory and licence obligations within which they have to offer the most economic, technically feasible option for connecting Generating Plant to their systems. The main general design obligations imposed on the network operators, amongst others, are to:

   a. Maintain supplies to their Customers within defined statutory voltage and frequency limits;
   b. Ensure that the networks at all voltage levels are adequately earthed;
   c. Comply with legal ‘security of supply’ criteria;
   d. Meet improving standards of supply in terms of Customer Average Interruption Duration Index (CAIDI) and the number of customer interruptions (CIs);
   e. Maintain a safe operating network;
   f. Facilitate competition in the connection, generation and supply of electricity.

   The first two criteria, amongst others, define the actions needed to allow ‘islanded’ operation of the Generating Plant or to ensure that the Generating Plant is rapidly disconnected from the network under ‘islanded’ conditions. The third and fourth criteria influence the type of connection that may be offered without jeopardising regulated standards or other customers.

5. Network operators do not have to commence or continue to supply a Customer's Installation if it is considered to be dangerous or have the potential to cause undue interference with the System or the supply to other Customers. The host network

operator can also disconnect any part of the Customer's Installation which presents a similar risk.

6. No person should operate Generating Plant in parallel with a public network without the agreement of the host network operator and the national energy regulator.

7. Generators will need appropriate contracts in place for the purchase of any energy that is exported from the Generators' Generating Plant, and for any energy imported. .

8. Generators wishing to trade ancillary services for transmission system management purposes will need appropriate contracts in place with the TSO.

4. CAPACITY LIMITS AND CONNECTION VOLTAGE

1. The following table provides a guide to the approximate upper limits of generating capacity that can be connected at a given voltage. In practice, there are a number of other considerations (e.g. distance from the network) which may require a higher voltage than suggested by the table.

Nominal Voltage	Maximum Aggregate Generating Unit Capacity Exported at a Point of Supply
415V	250kW
11kV	3MW
33kV	10MW

Table 1: Voltages and Connection Capacities

2. It is to be noted that on the Kenyan distribution system there are significant differences in inflow levels on the 11kV system. Some sub-stations are fed by a single 2.5MVA transformer and at the other extreme some by a pair of 30MVA transformers. This will affect the allowable generator size.

5. CONNECTION APPLICATION

1. General

    1. The generic connection arrangement and terminology is shown in Figure 1. The asset boundary is the Point of Supply.

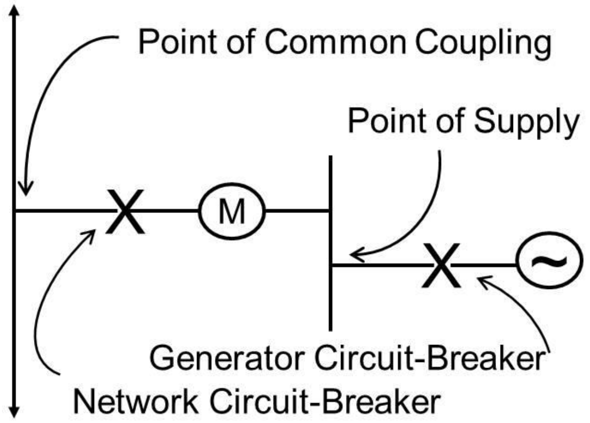

Figure 1: Generic Connection Schematic

The connection process is characterised by the size of the Generating Unit that is proposed to be connected.

2. Table 2 below defines the Generating Unit size and describes key features of the connection process.

Requirement	Generating Unit Characteristic
	>50kW at all supply voltages
Generator to conduct impact assessment/electrical studies	Yes
Protection requirement	Type Verified equipment may be accepted
Commissioning tests	DNO will witness for MV and LV

Table 2: Connection Process

3.

4. Generating Units >50kW 3 phase (or 17kW single phase) are bound by the requirements of the Grid Code. Where Grid Code requirements apply, it is the Generator's responsibility to comply with the Grid Code requirements.

5. The application process and commissioning requirements must be based on generating capacity (i.e. the aggregate capacity of all the Generating Units to be installed in any one installation).

2. Application for Connection

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1. Information about the Generating Plant is needed by the host network operator so that it can assess the effect that the Generating Plant may have on the network. In order to simplify the connection process application forms are often used to reflect the fact that less information is required to connect a smaller Generating Unit than a larger one.

   The information provided with the application based on using Type verified equipment, connected to the Generator's own local distribution and utilising approved metering means that simplified arrangements can be adopted in all cases.

2. On receipt of the application using Standard Application Form, the host network operator will assess whether any network studies are required and whether there is a requirement to witness the commissioning tests. The information provided with the application should be sufficient to demonstrate whether the Generating Unit can be considered to be Type Verified so that the simplified arrangements can be applied. In some cases studies to assess the impact on the Distribution System may need to be undertaken before a firm quotation can be provided to the Generator. Any works at the connection site and any associated facilitating works will need to be completed before the Generating Unit can be commissioned. On successful completion of the commissioning tests by the commissioning engineer, the host network operator will sanction permanent connection of the Generating Unit.

3. For Generating Units below 10MW 3-phase detailed system studies will be required and consequently the Generator to provide additional information.

3. System Analysis for Connection Design
   1. Host network operators use a variety of modelling tools to undertake system analysis. Their exact needs for data and models will vary dependent on the voltage level, size, and location of the connection. Generally the host network operator will require the key information from the Generator via the application form, usually in a series of exchanges.

   2. In the course of planning and designing a power system, it is often necessary to model a small section of the wider system in detail. This could be an embedded system at 33kV or less, which is connected to the Transmission System via one or more step-down transformers.

   3. For plant connected at MV, it is generally necessary to build an equivalent model of the Distribution System. This model will typically include equivalent source representing existing Generating plant fault level arising from asynchronous plant, interconnection impedances, loads, and possibly the Generator's proposal for reactive compensation plant. The parameters of these elements will depend upon

the selection of the boundary nodes between the equivalent and detailed networks in the model.

4. It may be beneficial to model some of the 'active' elements in full detail. Main grid, grid primary and other transformers can be considered active for the purpose of determining voltage control limits. Knowledge of the voltage control set points, transformer tap changing 'tolerances, and control methods is often essential. Also a knowledge of which items of Generating plant are mainly responsible for the range of fault contributions offered at the connection point by the host network operator is a useful addition.

   Further fault contribution may also arise from other rotating plant within the Generator infrastructure which may be enhanced under fault conditions.

5. The equivalent System model will not accurately represent the fast dynamic (sub second) behaviour of the active elements within the Distribution and Transmission System.

6. For synchronous machines, control systems for Generating Units and prime movers have traditionally been provided and modelled in transparent transfer function block diagram form. These models have been developed over many years and include lead/lag elements, gains, limiters and non-linear elements and may be 'tuned' to obtain a satisfactory response for the particular Generating Unit and grid connection. The requirement to submit models in this form for directly connected synchronous Generating Units is written into the Grid Code.

7. For other generation technologies, the Grid Code includes the requirement to submit validated detailed models in respect of non-synchronous Generating Units which are aggregated into a 'Power Park Module'. A similar requirement may exist where the host network operator deems it necessary to ensure System Stability and security.

8. Distribution network operators generally have a Grid Code obligation to ensure that validated detailed models are obtained in respect of Generating Units embedded within their Distribution Systems unless they are connected at a voltage level below that of the lower voltage side of the relevant transmission grid transformer. This requires the Generating Plant manufacturer to submit a Generating unit or Power Park model in a format suitable for the TSO usually in a documented block diagram format.

9. For the host network operator's own purposes, should a model be required, it would normally be requested in a compiled form suitable for use with the particular variety of power system analysis software they use. Recently there is a

move by manufacturers to create 'black-box' models of their Generating Plant or Power Parks using their Generating units. These are programmed for compatibility with industry standard power analysis modelling packages. This is in order to protect the manufacturers' intellectual property and so lessen the need for confidentiality agreements between parties. There are potential advantages and disadvantages to this approach, but must be generally welcomed provided that the two main disadvantages of this approach, as described below, can be resolved:

a. The model must not be software version-specific i.e. will work in all future versions, or has an assurance of future upgrades for a particular software package;
b. The Generator must provide assurance that the black box model correctly represents the performance of the Generating Plant for load flow, fault level and transient analysis for the typical range of faults experienced by host network operators.
c. The Generator must provide assurance that their system will operate effectively both during commissioning (when the plant is islanded) and in an export mode.

6. CONNECTION ARRANGEMENTS

1. Operating Modes

1. Generating Plant may be designed for one of three operating modes. These are termed:
   - long-term parallel operation;
   - infrequent short-term parallel operation; and,
   - switched alternative-only operation.

   For the purpose of these guidelines all renewable energy sources are assumed to be long-term parallel operation with very short periods of infrequent short-term paralleling operations only during commissioning, maintenance or under fault considerations which may result in islanded conditions. Switched alternative mode operation is therefore not considered further in this guide.

The following application notes are therefore included for long and short term paralleling operation only.

2. Long-Term Parallel Operation

1. This refers to the frequent or long-term operation of Generating Plant in parallel with the host network. Unless otherwise stated, all sections in these guidelines are applicable to this mode of operation.

7. GENERATING PLANT CONNECTION DESIGN AND OPERATION

1. General Criteria

   1. The Distribution System, and any Generating Plant connection to that

      System, shall be designed:

      a. to comply with the obligations (to include security, frequency and voltage; voltage disturbances and harmonic distortion; auto reclosing and single phase protection operation).
      b. according to design principles in relation to Distribution System's plant and equipment, earthing, voltage regulation and control, and protection, subject to any modification to which the host network operator may reasonably consent.

   2. Generating Plant should meet a set of technical requirements in relation to its performance with respect to frequency and voltage, control capabilities, protection coordination requirements, phase voltage imbalance requirements, neutral earthing provisions, islanding and black start capability.

2. Generating Plant Connection Designs

   1. The connection of new Generators, to a Distribution System should not generally increase the risk of interruption to existing Customers. For example, alterations to existing Distribution System designs that cause hitherto normally closed circuits to have to run on open standby such that other Customers might become disconnected for the duration of the auto-switching times are to be avoided.

      The security requirements for the connection of Generating Plant are subject to economic consideration by the host network operator and the Generator. A firm connection for Generating Plant should allow the full MVA capacity to be exported via the host network at all times of the year and after one outage on any one circuit of that network.

2. Where the host network operator expects the Generating Plant to contribute to system security, the Generating Plant should either remain synchronised and in parallel with the Distribution System under the outage condition being considered, or be capable of being resynchronised within the specified time period. There may be commercial issues to consider in addition to the connection cost and this may influence the technical method which is used to achieve the desired security or availability of supply.

3. When designing a scheme to connect Generating Plant, consideration must be given to the contribution which that Generating Plant will make to short-circuit current flows on the Distribution System. The assessment of the fault level contribution from Generating Plant and the impact on the suitability of connected switchgear are discussed in Section 7.4.

4. Unwanted tripping of the Generating Plant, particularly where the Generating Plant is providing Distribution System or System security should be avoided. The quality of supply and Stability of Generating Plant performance are discussed in Sections 7.6 and 7.7 respectively.

5. Generating Plant may be connected via existing circuits to which load and/or existing Generating Plant and other Customers are also connected. The duty on such circuits, including load cycle, real and reactive power flows, and voltage implications on the network will need to be carefully reviewed by the host network operator, taking account of maximum and minimum load and generation export conditions during system intact conditions and for maintenance outages of both the Distribution System and Generation Plant.

6. A host network operator assessing a proposed connection of Generating Plant must also consider its effects on the Distribution System voltage profile and voltage control employed on the Distribution System. Voltage limits and control issues are discussed in Section 7.5.

3. Generating Plant Performance and Control Requirements

1. The rated power output of a Generating Unit should not be affected by voltage changes within the statutory limits declared by the host network operator unless otherwise agreed with the host network operator.

2. Under abnormal conditions automatic low-frequency load-shedding provides for load reduction down to 47Hz. In exceptional circumstances, the frequency of the host Distribution System could rise above 50.5Hz. Therefore, in the absence of confirmation from the host network operator, all Generating Plant should be capable of continuing to operate in parallel with the Distribution System in accordance with the following criteria:

    a. 47Hz-47.5Hz Operation for a period of at least 20 seconds is required each time the frequency is within this range
    b. 47.5Hz-51.5Hz Disconnection by over-frequency or under-frequency protection is not permitted in this range
    c. 51.5 Hz-52Hz Operation for a period of at least 90 seconds is required each time the frequency is within this range

3. The operational characteristics of the control systems of Generating Plant control systems (e.g. excitation, speed governor, voltage and frequency controls if applicable) must be co-ordinated with other voltage control systems influencing the voltage profile on the Distribution System. The host network operator will specify whether a continuously acting fast response automatic excitation control system is required to control the Generation Set voltage without instability over the entire operating range of the Generating Plant.

    This will be dependent on the size and type of Generating Plant and the overall electrical characteristics of the network to which it is connected.

4. Following consultation with the Generator and dependent on Distribution System voltage studies, a host network operator will agree the reactive power and voltage control requirements for all Generating Units that are connected to its network. It should be noted that the connection to the Distribution System may impose restrictions on the capability of Generation Plant to operate in accordance with the assumptions of Grid Code and the TSO should be advised of any restrictions.

5. Each item of Generating Plant and its associated control equipment must be designed for stable operation in parallel with the local network.

6. Load flow and System Stability studies may be necessary to determine any output constraints or post fault actions necessary for fault and planned outages. (Commonly referred to as n-1 and n-2 conditions are the first and second outage conditions). It may be necessary under these fault conditions, where the combination of Generating Plant output, load and through flow levels leads to circuit overloading, to rapidly disconnect or constrain the Generating Plant.

4. Fault Level Contributions and Switchgear Considerations

1. The Generator and the host network operator have legal duties to ensure that their respective systems are capable of withstanding the short-circuit currents associated with their own equipment and any in-feed from any other connected system.

2. The Generator may accept that protection installed on the network can help discharge some of his legal obligations relating to fault clearance and, if requested, the host network operator should consider allowing such faults on the Generator's system to be detected by network protection systems and cleared by the host network operator's circuit breaker. The host network operator will not allow the Generator to close the network operator's circuit breaker nor to synchronise using that circuit breaker. In all such cases the exact nature of the protection afforded by the host network operator's equipment should be agreed and documented. The host network operator may make a charge for the provision of this service.

3. The design and safe operation of the Generator’s and the host network operator's installation’s depend upon accurate assessment of the contribution to the short-circuit current made by all the Generating Plant operating in parallel with the Distribution System at the instant of fault and the Generator should discuss this with the host network operator at the earliest possible stage.

4. Short-circuit current calculations should take account of the contributions from all synchronous and asynchronous in-feeds including induction motors. The prospective short-circuit ‘make’ and ‘break’ duties on switchgear should be

calculated to ensure that plant is not potentially over-stressed. The maximum short-circuit duty might not occur under maximum generation conditions; it may occur during planned or automatic operations carried out either on the Distribution System or Transmission System. Studies must therefore consider all credible Distribution System running arrangements which are likely to increase Distribution System short-circuit levels. The level of load used should also reflect committed projects as well as the existing loads.

5. The connection of Generating Plant can raise the Distribution System reactance/resistance (X/R) ratio.

   In some cases, this will place a more onerous duty on switchgear by

   a) Increasing the duration and proportion of the DC component of fault current from fault inception.

   b) Delay the occurrence of current zeros with respect to voltage zeros during the interruption of fault current.

   The performance of connected switchgear must be assessed to ensure safe operation of the Distribution System. The protection performance may also be impaired by partial or complete saturation of current transformers resulting from an increase in Distribution System X/R ratio.

6. Newly installed protection systems and circuit breakers for Generating Unit connections should be designed, specified and operated to account for the possibility of out-of-phase operation. It is expected that the host network operator's metering/interface circuit breaker will be specified for this duty, but in the case of existing circuit breakers on the Distribution System, the host network operator will need to establish the possibility or otherwise of the host network operators protection (or the Generator’s protection if arranged to trip the host network operator's circuit breaker) initiating a circuit breaker trip during a period when one of more Generating Units might have lost Synchronism with the System. Where necessary, switchgear replacement, improved security arrangements and other control measures should be considered to mitigate this risk.

7. When connection of Generating Plant is likely to increase short-circuit currents above Distribution System design ratings, consideration should be given to the following:-

   a) Installation of reactors.

   b) Sectionalising networks.

   c) Connecting the Generating Plant to part of the Distribution System operating at a higher voltage.

   d) Changing the Generating Unit specification or other means of limiting short-circuit current in-feed.

   If fault limiting measures are not cost effective or feasible or have a material detrimental effect on other users, Distribution System plant with the potential to be subjected to short-circuit currents in excess of its rating should be replaced or reference made to the relevant manufacturer to determine whether or not the existing plant rating(s) can be enhanced. In situations where Distribution System design ratings would be exceeded in infrequent Distribution System configurations, then constraining the Generating Plant off during periods of such Distribution System configurations may provide a suitable solution but noting the requirements of any commercial agreements.

   When assessing short-circuit currents against Distribution System design ratings, suitable safety margins should be allowed to cater for tolerances that may exist in the Distribution System data and Generating Unit parameters used in system modelling programs.

8. For busbars with three or more direct connections to the rest of the System, consideration may be given to reducing fault levels by having one of the connections 'open' and on automatic standby. This arrangement will only be acceptable provided that the loss of one of the remaining circuits will not cause the group to come out of Synchronism, cause unacceptable voltage excursions or overloading of Distribution System or Transmission System plant and equipment.

9. Disconnection of Generating Plant must be achieved by the separation of mechanical contacts unless the disconnection is at Low Voltage and the equipment at the point of disconnection contains appropriate self-monitoring of the point of disconnection, in which case an appropriate electronic means such as a suitably

rated semiconductor switching device would be acceptable. The self-monitoring facility shall incorporate fail safe monitoring to check the voltage level at the output stage. In the event that the solid state switching device fails to disconnect the Generating Unit, the voltage on the output side of the switching device must be reduced to a value below 50V within 0.5s to provide LoM disconnection and earth fault protection.

5. Voltage Limits and Control

1. Where Generating Plant is remote from a network voltage control point it may be required to withstand voltages outside the normal statutory limits. In these circumstances, the host network operator should agree with the Generator the declared voltage and voltage range at the Connection Point. As a guide acceptance of the Generating Plant to voltage changes of ±10% of the declared voltage is recommended, subject to assessment of individual cases.

2. The connection of a Generating Plant to the Distribution System shall be designed in such a way that operation of the Generating Plant does not adversely affect the voltage profile of and voltage control employed on the Distribution System. Host network operators have a number of methods for overcoming voltage control limitations.

3. Where it is agreed that the Generation Plant should operate in voltage control (PV) mode or where there is a need to operate to a ‘setpoint voltage’ and ‘slope’, the Generating Plant will have a specific role to control the Distribution System voltage. The final responsibility for control of Distribution System voltage does however remain with the host network operator.

4. Automatic Voltage Control (AVC) schemes employed by the host network operator assume that power flows from parts of the System operating at a higher voltage to parts of the System operating at lower voltages. Export from Generating Plant in excess of the local loads may result in power flows in the reverse direction. In this case AVC referenced to the low voltage side will not operate correctly without an import of reactive power and relay settings appropriate to this operating condition. When load current compounding is used with the AVC and the penetration level of Generating Plant becomes significant compared to normal loads, it may be necessary to switch any compounding out of service.

5. Generating Plant can cause problems if connected to networks employing AVC schemes which use negative reactance compounding and line drop compensation due to changes in active and reactive power flows. Techniques such as removing the generation circuit from the AVC scheme using cancellation CTs can address this.

6. An agreement between the host network operator and the Generator may allow the use of voltage control techniques other than those previously mentioned. Such an agreement would normally be reached during the negotiating stage of the connection.

7. The Step Voltage Change caused by the connection and disconnection of Generating Plant from the Distribution System must be considered and be subject to limits to avoid unacceptable voltage changes being experienced by other Customers connected to the System. The magnitude of a Step Voltage Change depends on the method of voltage control, types of load connected and the presence of local generation.

   Typical limits for Step Voltage Change caused by the connection and disconnection of any Customers equipment to the Distribution System should be ±3% for infrequent planned switching events or planned outages. For unplanned outages such faults it will generally be acceptable to design to a Step Voltage Change of ±10%.

8. The voltage reduction arising from transformer magnetising inrush current is a short-time phenomenon not generally easily captured by the definition of Step Voltage Change used in this document. In addition the quantum is dependent on the exact point on the cycle of switching and the duration of the depression is relatively short in that the voltage recovers substantially in less than one second.

9. Customer Installations should be designed such that transformer magnetising inrush current associated with normal routine switching operations does not cause voltage fluctuations outside ±3%. To achieve this it may be necessary to install switchgear so that sites containing multiple transformers can be energised in stages.

10. Situations will arise from time to time when complete sites including a significant proportion of interconnected transformers are energised as a result of post fault switching, post fault maintenance switching or carrying out commissioning tests on the Distribution System. In these situations it will generally be acceptable to design to an expected depression of around 10% recognising that a worst case energisation might result in a larger depression, such events are considered to be rare and it is difficult to predict the exact depression because of the uncertainty when the switching occurs on the cycle. Should these switching events become more frequent than once per year then the design should revert to aiming to limit depressions to less than 3%.

11. These threshold limits should be complied with at the Point of Common Coupling.

6. Power Quality

1. The connection of Generating Plant can cause a voltage distortion of the Distribution System waveform resulting in fluctuations, harmonics or phase voltage unbalance. Table 3 suggests phase voltage unbalance requirement that any Generating Plant connected to the Distribution System would need to comply with.

	LV Connected		MV Connected	
	Setting	Time (s)	Setting	Time
U/V stage 1	Vφ-n‡-13%	*2.5	Vφ-φ†-13%	*2.5
U/V stage 2	Vφ-n‡-20%	0.5	Vφ-φ†-20%	0.5
O/V stage 1	Vφ-n‡+10%	1.0	Vφ-φ†+10%	1.0
O/V stage 2	Vφ-n‡+15%	0.5	Vφ-φ†+15%	0.5
U/F stage 1	47.5Hz	20.0	47.5Hz	20.0
U/F stage 2	47Hz	0.5	47Hz	0.5
O/F stage 1	51.5Hz	90.0	51.5Hz	90.0
O/F stage 2	52Hz	0.5	52Hz	0.5
LoM (vector shift)	K1 x 6°		K1 x 6°#	
LoM (RoCoF)	K2 x 0.125Hz/s		K2 x 0.125Hz/s#	

Table 3: Protection Settings (Long-Term Parallel Operation)

Where:

φ-n; φ-φ denotes RMS phase to neutral and phase-phase values respectively of the voltage at the Connection Point

‡ a value in the range 230-240V to suit the system

† a value to suit the voltage of the connection point

* might need to be reduced if auto-reclose times are <3s

intertripping may be considered as an alternative to the use of a Loss of Mains relay

K1 = 1.0 (for low impedance networks) or 1.66 – 2.0 (for high impedance networks)

K2 = 1.0 (for low impedance networks) or 1.6 (for high impedance networks)

A fault level of less than 10% of the system design maximum fault level should be classed as high impedance. Note that the times in Table 3 are the time delays to be set on the appropriate relays. Total protection operating time from condition initiation to circuit breaker opening will be of the order of 100ms longer than the time delay settings in the table.

2. Where the input motive power of the Generating Plant may vary rapidly, causing corresponding changes in the output power, flicker may result. Any run up or synchronizing effects on voltage waveform that give rise to flicker must not be greater than a short-term value P_{st} = 1.0 or in integrated value in any 2 hours of 0.8.

3. Harmonic voltages and currents produced within the Generator's system may cause excessive harmonic voltage distortion in the Distribution System. The Generator's installation must be designed and operated to comply with the local planning criteria for harmonic voltage distortion. For reference, the UK values are shown in Table 4.

Voltage at PCC	Harmonic Distortion Limit
400V	5%
6.6 – 20kV	4%

22kV – 400kV	3%

Table 4: Total Harmonic Voltage Distortion

4. Where the Generating Plant is connected via a long cable circuit the likelihood of a resonant condition is greatly increased, especially at 132kV. This arises from the reaction of the transformer inductance with the transmission cable capacitance. Resonance is likely in the low multiples of the fundamental frequency (8^{th}-11^{th} harmonic). The resonant frequency is also a function of the System fault level, so if there is the possibility that this can change significantly (e.g. by the connection of another Generating Plant) then a full harmonic study should be done.

5. Generating Units should be capable of performing satisfactorily under the condition of connection supplied by the host network operator. The existing voltage unbalance on an urban Distribution System should not exceed 0.5% but higher levels, in excess of 1%, may be experienced at times of high load and when outages occur at voltage levels above 11kV. 1% may exist continuously due to unbalance of the system impedance (common on remote rural networks). In addition account can be taken of the neutralising effect of rotating plant, particularly at 11kV and below.

6. The level of voltage unbalance at the Point of Common Coupling should be no greater than 1.3% for systems with a nominal voltage below 33kV, or 1% for other systems with a nominal voltage no greater than 132kV. Overall, voltage unbalance should not exceed 2% when assessed over any one minute period.

7. Power factor correction equipment is sometimes used with asynchronous Generating Units to decrease reactive power flows on the Distribution System. Where the power factor correction equipment is of a fixed output, stable operating conditions in the event of loss of the host network operator supply are extremely unlikely to be maintained, and therefore no special protective actions are required in addition to the standard protection specified in this document. In this respect the Generator must make his own provisions.

7. System Stability

1. Instability in Distribution Systems may result in poor quality of supply and tripping of Customers' plant. In severe cases, instability may cascade across a Distribution System, resulting in widespread tripping and the loss of both demand and generation. There is also a risk of damage to plant.

2. In general, System Stability is an important consideration in the design of Generating Plant connections to the Distribution System especially at 33kV but may also be appropriate for some Generating Plant connections at lower voltages. The risks of instability generally increase as Generating Plant capacity increases relative to the fault level in-feed from the Distribution System at the Connection Point.

3. System Stability may be classified into several forms, according firstly to the main system variable in which instability can be observed, and secondly to the size of the system disturbance. In Distribution Systems, the forms of stability of interest are rotor angle stability and voltage stability.

   - Rotor angle stability refers to the ability of synchronous machines in an interconnected system to remain in synchronism after the system is subjected to a disturbance.
   - Voltage stability refers to the ability of a system to maintain acceptable voltages throughout the system after being subjected to a disturbance.

4. Both rotor angle stability and voltage stability can be further classified according to the size of the disturbance.

   - Small-disturbance stability refers to the ability of a system to maintain stability after being subjected to small disturbances such as small changes in load, operating points of Generating Units, transformer tap-changing or other normal switching events.
   - Large-disturbance stability refers to the ability of a system to maintain stability after being subjected to large disturbances such as short-circuit faults or sudden loss of circuits or Generating Units.

5. Generating Plant and its connection to the Distribution System should be designed to maintain stability of the Distribution System for a defined range of initial operating conditions and a defined set of system disturbances.

   The range of initial operating conditions should be based on those which are reasonably likely to occur over a year of operation. Variables to consider include system loads, system voltages, system outages and configurations, and Generating Plant operating conditions.

The system disturbances for which stability should be maintained should be selected on the basis that they have a reasonably high probability of occurrence. It is recommended that these include short-circuit faults on single Distribution System circuits (such as transformers, overhead lines and cables) and busbars, that are quickly cleared by main protection.

It should be noted that it is impractical and uneconomical to design for stability in all circumstances. This may include double circuit fault outages and faults that are cleared by slow protection.

Generating Units that become unstable following system disturbances should be disconnected as soon as possible.

6. Various measures may be used, where reasonably practicable, to prevent or mitigate system instability. These may include Distribution System and Generating Plant solutions, such as:

    - improved fault clearance times by means of faster protection;
    - improved performance of Generating Plant control systems (excitation and governor/prime mover control systems; Power System Stabilisers to improve damping);
    - improved system voltage support (provision from either Generating Plant or Distribution System plant);
    - reduced plant reactances (if possible);
    - Protection to identify pole-slipping;
    - Increased fault level in-feed from the Distribution System at the Connection Point.

    In determining mitigation measures which are reasonably practicable, due consideration should be given to the cost of implementing the measures and the benefits to the Distribution System Generators and Customers in terms of reduced risk of system instability.

8. Island Mode

1. A fault or planned outage, which results in the disconnection of a Generating Unit, together with an associated section of Distribution System, from the remainder of the System, creates the potential for island mode operation. This may also occur during the initial commissioning stages when there are advantages in not connecting the Generating plant to the wider network. The key potential advantage of operating in Island mode is to maintain continuity of supply to the portion of the Distribution System containing the Generating Unit. The principles discussed in this section generally also apply where Generation Plant on a Customer's site is designed to maintain supplies to that site in the event of a failure of the host network operator supply.

2. When considering whether Generating Plant can be permitted to operate in island mode, detailed studies need to be undertaken to ensure that the islanded system will remain stable and comply with all statutory obligations and relevant planning standards when separated from the remainder of the System. Before operation in island mode can be allowed, a contractual agreement between the host network operator and Generator must be in place and the legal liabilities associated with such operation must be carefully considered by the host network operator and the Generator. Consideration should be given to the following areas:

   a. load flows, voltage regulation, frequency regulation, voltage unbalance, voltage flicker and harmonic voltage distortion;
   b. earthing arrangements;
   c. short-circuit currents, adequacy of protection arrangements;
   d. System Stability;
   e. resynchronisation to the System;
   f. safety of personnel.

3. Suitable equipment will need to be installed to detect that an island situation has occurred and an intertripping scheme is preferred to provide absolute discrimination at the time of the event. Confirmation that a section of Distribution System is operating in island mode, and has been disconnected from the network will need to be transmitted to the Generating Unit(s) protection and control schemes.

4. Supplies to Customers must be maintained within statutory limits at all times i.e. when they are supplied normally and when operating in island mode. Detailed system studies including the capability of the Generating Plant and its control/ protections systems will be required to determine the capability of the Generating

Plant to meet these requirements immediately as the island is created and for the duration of the island mode operation.

5. Distribution Systems must also be earthed at all times. Generators, who are not permitted to operate their installations and plant with an earthed star-point when in parallel with the Distribution System, must provide an earthing transformer or switched star-point earth for the purpose of maintaining an earth on the system when islanding occurs. The design of the earthing system that will exist during island mode operation should be carefully considered to ensure statutory obligations are met and that safety of the Distribution System to all users is maintained. Further details are provided in Section 9.

6. Detailed consideration must be given to ensure that protection arrangements are adequate to satisfactorily clear the full range of potential faults within the islanded system taking into account the reduced fault currents and potential longer clearance times that are likely to be associated with an islanded system.

7. Switchgear shall be rated to withstand the voltages which may exist across open contacts under islanded conditions. The host network operator may require interlocking and isolation of its circuit breaker(s) to prevent out of phase voltages occurring across the open contacts of its switchgear, intertripping or interlocking should be agreed between the host network operator and the Generator where appropriate.

8. Generally it will not be permissible to interrupt supplies to host network operator Customers for the purposes of resynchronisation. The design of the islanded system must ensure that synchronising facilities are provided at the point of isolation between the islanded network and the host network operator supply. Specific arrangements for this should be agreed and recorded in the Connection Agreement with the host network operator.

8. PROTECTION

1. General

1. The main function of the protection systems and settings described in this document is to prevent the Generating Plant supporting an islanded section of the

Distribution System when it would or could pose a hazard to the Distribution System or customers connected to it. The settings recognize the need to avoid nuisance tripping and therefore require a two stage approach where practicable, i.e. to have a long time delay for smaller excursions that may be experienced during normal Distribution System operation, to avoid nuisance tripping, but with a faster trip for greater excursions.

2. In accordance with established practice it is for the Generator to install, own and maintain this protection. The Generator can therefore determine the approach, i.e. per Generating Unit or per installation, and where in the installation the protection is sited.

2. Protection Requirements

1. The basic requirements for protection are laid out in Table 3. It is in the interest of Generators, DNOs and the TSO that Generating Plant remains synchronised to the Distribution System during system disturbances, and conversely to disconnect reliably for true Loss of Mains situations.

2. Other protection could be required and may include the detection of:

- Neutral Voltage Displacement (NVD)
- Over Current
- Earth Fault
- Reverse Power

This protection will normally be installed on equipment owned by the host network operator unless otherwise agreed between the host network operator and Generator. This additional protection which is required by the host network operator to supplement over current and earth fault protection and protect the Distribution System from the Generating Plant may be installed and arranged to operate the host network operator interface circuit breaker or any other breakers, subject to the agreement of the host network operator and the Generator.

When intertripping is considered to be a practical alternative, for detecting a LoM event, to using discriminating protection relays, the intertripping equipment would be installed by the host network operator.

3. The protective equipment, provided by the Generator, to meet the requirements of this section must be installed in a suitable location that affords immediate visual inspection of the relays but is secure from interference by unauthorised personnel.

4. If automatic resetting of the protective equipment is used, there must be a time delay to ensure that healthy supply conditions exist for a minimum continuous period of 60s. Reset times may need to be co-ordinated where more than one Generating Plant is connected to the same feeder. The automatic reset must be inhibited for faults on the Generator's installation.

5. Protection equipment is required to function correctly within the environment in which it is placed and should satisfy international standards such as:

    - BS EN61000 (Electromagnetic Standards) BS EN60255 (Electrical Relays);
    - BS EN61810 (Electrical Elementary Relays);
    - BS EN60947 (Low Voltage Switchgear and Control gear); BS EN60044 (Instrument Transformers).

6. Protection equipment and protection functions may be installed within, or form part of the Generating Plant control equipment as long as:

    a. the control equipment satisfies all the requirements of Section 8.
    b. the Generating Plant shuts down in a controlled and safe manner should there be an equipment failure that affects both the protection and control functionality, for example a power supply failure or microprocessor failure.
    c. the equipment is designed and installed so that protection calibration and functional tests can be carried out easily and safely using secondary injection techniques (i.e. using separate low voltage test equipment).

3. Loss of Mains (LoM)

1. In addition to protection installed by the Generator for his own purposes, the Generator must install protection to achieve (amongst other things) disconnection of the Generating Plant from the Distribution System in the event of loss of one or more phases of the host network operators supply. This LoM protection is required to ensure that the Generating Plant is disconnected, to ensure that the requirements for Distribution System earthing, and out-of-Synchronism closure are complied with and that Customers are not supplied with voltage and frequencies outside statutory limits.

2. A problem can arise for Generators who operate Generating Plant in parallel with the Distribution System prior to a failure of the network supply because if their Generating Plant continues to operate in some manner, even for a relatively short period of time, there is a risk that when the network supply is restored the Generating Plant will be out of Synchronism with the System and suffer damage. LoM protection can be employed to disconnect the Generating Plant immediately after the supply is lost, thereby avoiding damage to the Generating Plant.

3. Some Customers may be connected to parts of Distribution Systems which are automatically re-energised within a relatively short period following a fault; with dead times typically between 1s and 180s. The use of such schemes is likely to increase in future as host network operators seek to improve supply availability by installing automatic switching equipment on their Distribution Systems.

4. Where the amount of Distribution System load that the Generating Plant will attempt to pick up following a fault on the Distribution System is significantly more than its capability the Generating Plant will rapidly disconnect, or stall. However depending on the exact conditions at the time of the Distribution System failure, there may or may not be a sufficient change of load on the Generating Plant to be able to reliably detect the failure. The Distribution System failure may result in one of the following load conditions being experienced by the Generating Plant:

   a. The load may slightly increase or reduce, but remain within the capability of the Generating Plant. There may even be no change of load;

   b. The load may increase above the capability of the prime mover, in which case the Generating Plant will slow down, even though the alternator may maintain voltage and current within its capacity. This condition of speed/frequency reduction can be easily detected; or

c. The load may increase to several times the capability of the Generating Plant, in which case the following easily detectable conditions will occur:

- Overload and accompanying speed/frequency reduction
- Over current and under voltage on the alternator

5. Conditions (b) and (c) are easily detected by the under and over voltage and frequency protection required in this document. However condition (a) presents most difficulty, particularly if the load change is extremely small and therefore there is a possibility that part of the Distribution System supply being supplied by the Generating Plant will be out of Synchronism with the System. LoM protection is designed to detect these conditions. In some particularly critical circumstances it may be necessary to improve the dependability of LoM detection by using at least two LoM techniques operating with different principles or by employing a LoM relay using active methods. LoM signals can also be provided by means of intertripping signals from circuit breakers that have operated in response to the Distribution System fault. Both these methods are discussed below.

6. The LoM protection can utilise one or a combination of the passive protection principles such as reverse power flow, reverse reactive power, rate of change of frequency (RoCoF) and voltage vector phase shift. Alternatively, active methods such as reactive export error detection or frequency shifting may be employed. These may be arranged to trip the interface circuit breaker at the host network operator Generator interface, thus, leaving the Generating Plant available to satisfy the load requirements of the site or the Generating Plant circuit breaker can be tripped, leaving the breaker at the interface closed and ready to resume supply when the Distribution System supply is restored.

   The most appropriate arrangement is subject to agreement between the host network operator and Generator.

7. Protection based on measurement of reverse flow of real or reactive power can be used when circumstances permit and must be set to suit the Generating Plant rating, the site load conditions and requirements for reactive power.

8. Where the Generating Plant capacity is such that the site will always import power from the Distribution System, a reverse power relay may be used to detect failure of the supply. It will usually be appropriate to monitor all three phases for reverse power.

9. However, where the Generating Plants normal mode of operation is to export power, it is not possible to use a reverse power relay and consequently failure of the supply cannot be detected by measurement of reverse power flow. The protection should then be specifically designed to detect loss of the mains connection using techniques to detect the rate of change of frequency or sudden phase shifts of voltage vector and/or power factor. All these techniques are susceptible to Distribution System conditions and the changes that occur without islanding taking place. These relays must be set to prevent islanding but with the best possible immunity to unwanted nuisance operation.

10. Both RoCoF and vector phase shift relays use a measurement of the period of the mains voltage cycle. The RoCoF technique measures the rate of change in frequency caused by any difference between prime mover power and electrical output power of the embedded Generating Plant over a number of cycles. RoCoF relays should normally ignore the slow changes but respond to relatively rapid changes of frequency which occur when the Generation Plant becomes disconnected from the System. The voltage vector shift technique tries to detect the shift in the voltage vector caused by a sudden change in the output of Generating Plant or load over one or two cycles (or half cycles). The main advantage of a vector shift relays is its speed and response to transient disturbances which are common to the onset of islanding but often difficult to quantify. Speed of response is also very important where high speed auto reclosing schemes are present.

11. The LoM relay that operates on the principle of voltage vector shift can achieve fast disconnection for close up Distribution System faults and power surges, and under appropriate conditions can also detect islanding when normally a large step change in generation occurs. The relay measures the period for each half cycle in degrees and compares it with the previous one to determine if this exceeds its setting. A typical setting is 6 degrees, which is normally appropriate to avoid operation for most normal vector changes in low impedance Distribution Systems. This equates to a constant rate of change of frequency of about 1.67Hz/s and hence the relay is insensitive to slow rates of change of frequency. When vector shift relays are used in higher impedance Distribution Systems, and especially on rural Distribution Systems where auto-reclosing systems are used, a higher setting may be required to prevent nuisance tripping. Typically this is between 10 and 12 degrees however these figures are given as a guide and confirmation must be sought from the DNO.

12. Raising settings on any relay to avoid spurious operation may reduce a relay's capability to detect islanding and it is important to evaluate fully such changes. In some circumstances it may be necessary to employ a different technique, or a combination of techniques to satisfy the conflicting requirements of safety and avoidance of nuisance tripping. In those cases where the host network operator requires LoM protection this must be provided by a means not susceptible to spurious or nuisance tripping, e.g. intertripping.

13. For a radial or simple Distribution System controlled by circuit breakers that would clearly disconnect the entire circuit and associated Generating Plant, for a LoM event an intertripping scheme can be easy to design and install. For meshed or ring Distribution Systems, it can be difficult to define which circuit breakers may need to be incorporated in an intertripping scheme to detect a LoM event and the inherent risks associated with a complex system should be considered alongside those associated with using a simple, but potentially less discriminatory LoM relay.

14. It is the responsibility of the Generator to incorporate the most appropriate technique or combination of techniques to detect a LoM event in his protection systems. This will be based on knowledge of the Generating Unit, site and network load conditions. The host network operator will assist in the decision making process by providing information on the Distribution System and its loads. The settings applied must be biased to ensure detection of islanding under all practical operating conditions.

4. Neutral Voltage Displacement Protection

   1. NVD protection can be used to prevent the unsafe situation where Generating Plant inadvertently becomes operating in island mode, as described in Section 7.8 above, and where there is an earth fault existing on the host network operators MV system. In these Circumstances the NVD protection fitted on the host network operators MV switchgear will detect the earth fault, and disconnect the MV System from the island.

   2. Host network operators need to consider specific investigation of the need for NVD protection when, downstream of the same prospective island boundary, there are one or more Generating Units (with an output greater than 200kVA per unit) having the enabled capacity to dynamically alter real and reactive power output in order to maintain voltage profiles, and where such aggregate embedded generation output exceeds 50% of prospective island minimum demand.

3. As a general rule for generation installations smaller than 5MW and connected at 20kV or lower voltages host network operators will not require NVD protection for the following circumstances;

   - Single new Generating Unit connection, of any type with an output less than 200kVA.
   - Multiple new Generating Unit connections, of any type, on a single site, with an aggregated output less than 200kVA.
   - Single or multiple new Generating Unit connections, of any type, where the voltage control is disabled or not fitted, on a single site, and where the aggregate output is greater than 200kVA.
   - Single or multiple new Generating Unit connections, of any type, and where the voltage control is enabled, on a single site, where the aggregate output is greater than 200kVA ,but where the aggregate output is less than 50% of the prospective island minimum demand.

4. If the assessed minimum load on a prospective island is less than twice the maximum combined output of new Generator(s) consideration should be given to use of NVD protection as a part of the interface protection. The consideration should include an assessment of:

   - The specification of capability of the LoM protection, including the provision of multiple independent detection techniques.
   - The influence of activation of pre-existing NVD protection already present elsewhere on the same prospective island.
   - The opportunity arising from asset change/addition associated with the proposed new Generator(s) connection e.g. the margin of additional cost associated with NVD protection.

5. With arc suppression coil systems, the NVD relay should be arranged to provide an alarm only.

5. Protection Settings

1. The protection systems and settings can have an impact on the behaviour of Generating Plant when the System is in distress. Where Generating Plant has the capability to operate at the extremes of the possible operating range of the System, it would be inappropriate to artificially impose protection settings that

would cause Generating Plant to be disconnected where it would otherwise be capable of remaining connected and help to maintain the integrity of the System. It is not the intention that this Section specifies the performance requirements of Generating Plant connected to Distribution Systems, only that protection settings do not aggravate the stress on the System by tripping before there is a definite need in those circumstances. The settings for long-term parallel operation are given in Table 3. For infrequent short-term parallel operation, the settings should be as shown in Table 5.

	LV Connected		MV Connected	
	Setting	Time (s)	Setting	Time
U/V	Vφ-n‡-6%	0.5	Vφ-φ†-6%	0.5
O/V	Vφ-n‡+10%	0.5	Vφ-φ†+6%	0.5
U/F	49.5Hz	0.5	49.5Hz	0.5
O/F stage 1	50.5Hz	0.5	50.5Hz	0.5

Table 5: Protection Settings (Short-Term Parallel Operation)

Where:

φ-n; φ-φ denote RMS phase to neutral and phase-phase values respectively of the voltage at the Connection Point

‡ a value in the range 230-240V to suit the system

† a value to suit the voltage of the connection point

2. Under Voltage

In order to help maintain System Stability, the protection settings should be such as to facilitate fault ride through capability, especially for larger Generating Units (except where local auto-reclose dead times are 1s or less as a reclose on to a fault is more likely to destabilise generation that is still recovering stability from the first fault). The overall aim is to ensure that Generating Plant is not disconnected from the Distribution System unless there is material disturbance on the Distribution System, as disconnecting generation unnecessarily will tend to make an under voltage situation worse.

3. Over Voltage

Over voltages are potentially more dangerous than under voltages and hence the acceptable excursions form the norm are smaller and time delays shorter, a 2-Stage over voltage protection is as follows:

- Stage 1 (LV and MV) should have a permitted time delay of 1.0s and a setting of +10% (i.e. the LV statutory upper voltage limit of 10%, but with a time delay to avoid nuisance tripping for short duration excursions).
- Stage 2 (LV) should have a setting of +15%, 0.5s (i.e. recognising the need to disconnect quickly for a material excursion).
- Stage 2 (MV) should have a setting of +13%, 0.5s (i.e. recognising the need to disconnect quickly for a material excursion).

To achieve high utilisation and Distribution System efficiency, it is common for the MV Distribution System to be normally operated near to the upper statutory voltage limits. The presence of Generating Plant within such Distribution Systems may increase the risk of the statutory limit being exceeded, e.g. when the Distribution System is operating abnormally. In such cases the host network operator may specify additional over voltage protection at the Generating Plant connection point.

This protection will typically have an operating time delay long enough to permit the correction of transient over voltages by automatic tap-changers.

4. Over and Under voltage protection must operate independently for all three phases in all cases.

5. Over Frequency

In order to provide the necessary regulation to control the System frequency to a satisfactory level and to prevent the unnecessary disconnection of a large volume of smaller Generating Plant, all LV and MV connected Generating Plant should have a 2-stage protection:

- Stage 1 should have a time delay of 90s and a setting of 51.5Hz. The 90s setting should provide sufficient time for the TSO to bring the System frequency below this level. Should the frequency rise be the result of a genuine islanding condition which the LoM protection fails to detect, this setting will help to limit the duration of the islanding period.

- Stage 2 should have a time delay of 0.5s and a setting of 52Hz (i.e. to co-ordinate with the Grid Code requirement with a practical time delay that can be tolerated by most Generating Plant). If the frequency rise to and above 52Hz is the result of an undetected islanding condition, the Generating Plant will be disconnected within 0.5s.

6. Under Frequency

   For all LV and MV connected Generating Plant, the following 2-stage under frequency protection should be applied:

   - Stage 1 should have a setting of 47.5 Hz (time delayed by 20s)

   - Stage 2 should have a setting of 47.0 Hz (time delayed by 0.5s) which are in line with the Grid Code requirements.

7. Loss of Mains (LoM)

   In order to avoid unnecessary disconnection of Generating Plant during Distribution System faults or switching events and the consequent disruption to Generators and customers, as well as take into account the aggregate effect caused by multiple LoM operations on System Stability, consideration should be given to use of the appropriately sensitive settings which can be adjusted to take into account Generating Plant type & rating and Distribution System fault level. Example setting formulae are indicated in the notes below Table 3.

8. The settings in Table 3 should generally be applied to all Generating Plant. In exceptional circumstances Generators have the option to agree alternative settings with the host network operator if there are valid justifications in that the Generating Plant may become unstable or suffer damage with the settings specified in Table 3. The agreed settings should be recorded in the Connection Agreement.

9. Once the settings of relays have been agreed between the Generator and the host network operator they must not be altered without the written agreement of the host network operator. Any revised settings should be recorded again in the amended Connection Agreement.

10. The Under/Over Voltage and Frequency protection may be duplicated to protect the Generating Plant when operating in island mode although different settings may be required.

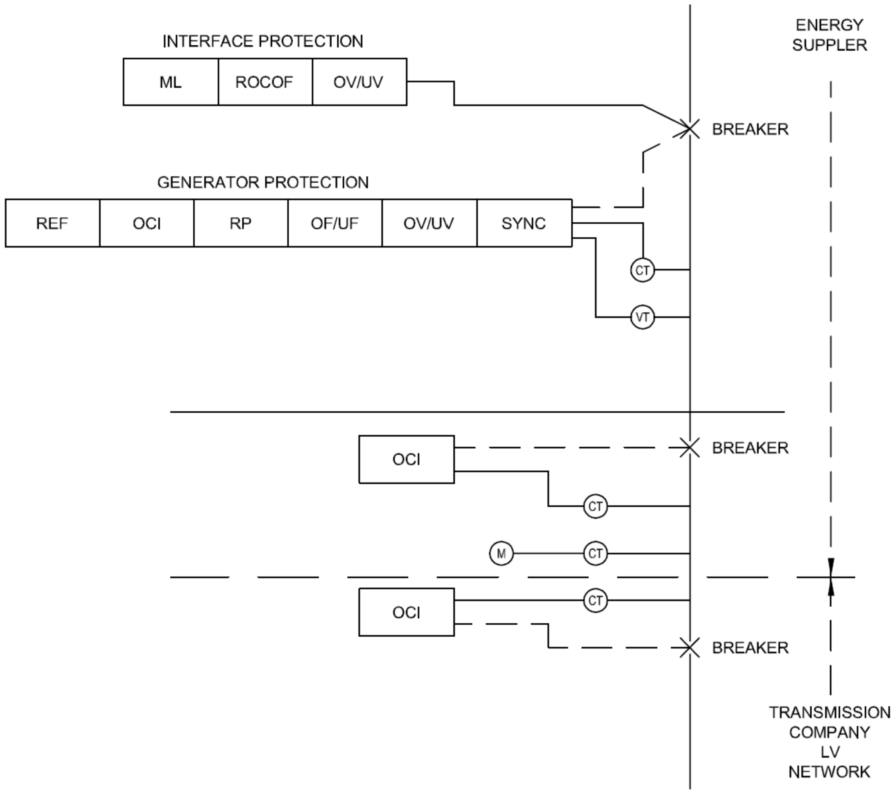
11. Co-ordination with existing protection equipment and any existing auto-reclose scheme is also required. In particular the Generator's protection should detect a LoM situation and disconnect the Generating Plant in a time shorter than any auto-reclose dead time. This should include an allowance for circuit breaker operation and generally a minimum of 0.5s should be allowed for this. For auto-reclosers set with a dead time of 3s, this implies a LoM response time of 2.5s. A similar response time is expected from Under and Over Voltage relays. Where auto-reclosers have a dead time of less than 3s, there may be a need to reduce the operating time of under and over voltage relays.

12. If automatic resetting of the protective equipment is used, as part of an auto-restore scheme for the Generating Plant, there must be a time delay to ensure that healthy supply conditions exist for a continuous period of at least 60s. The automatic reset must be inhibited for faults on the Generator's installation. Staged timing may be required where more than one Generating Plant is connected to the same feeder.

13. Where an installation contains power factor correction equipment which has a variable susceptance controlled to meet the reactive power demands, the probability of sustained generation is increased. For LV installations, additional protective equipment provided by the Generator, is required as in the case of self-excited asynchronous machines.

14. Typical protection arrangements for MV and LV connected Generating Plant are shown in Figures 2 and 3.

Figure 2: Typical Protection Arrangements for LV Connected Generating Plant



The following should be noted in respect of the diagrams:

a. Reverse Power Protection
Reverse power protection may be either a standard three phase reverse power relay set to operate at above the agreed level of export into the Distribution System, or a more sensitive relay if no export is permitted.

b. Directional Protection
In some cases overcurrent protection may afford adequate back-up protection to the Distribution System during system faults. However, where increased sensitivity is required, three phase directional overcurrent IDMT relays, or alternative voltage based protection may be used.

c. Load Limitation Relay
Three phase definite time overcurrent relays, in addition to providing overload protection, could be arranged to detect phase unbalance. This condition may be due to pulled joints or broken jumpers on the incoming host network operator underground or overhead MV supply.

NB Items (b) and (c) are alternatives and may be provided as additional protection.

d. Phase Unbalance Protection
Three phase thermal relays for detecting phase unbalance on the incoming host network operator MV supply, e.g. pulled joints, broken jumpers or uncleared unbalanced faults.

e. Supply Healthy Protection

Some form of monitoring or protection is required to ensure that the host network operator's supply is healthy before synchronizing is attempted. This could be simply under and over voltage monitoring of all phases on the host network operator side of the synchronising circuit breaker. Alternatively automatic under and over voltage monitoring, applied across all three phases, together with synchronising equipment designed such that closing of the synchronising circuit breaker cannot occur unless all three phases of the supply have frequency and voltages within statutory limits and have a voltage phase balance within 1.3% for individual connections.

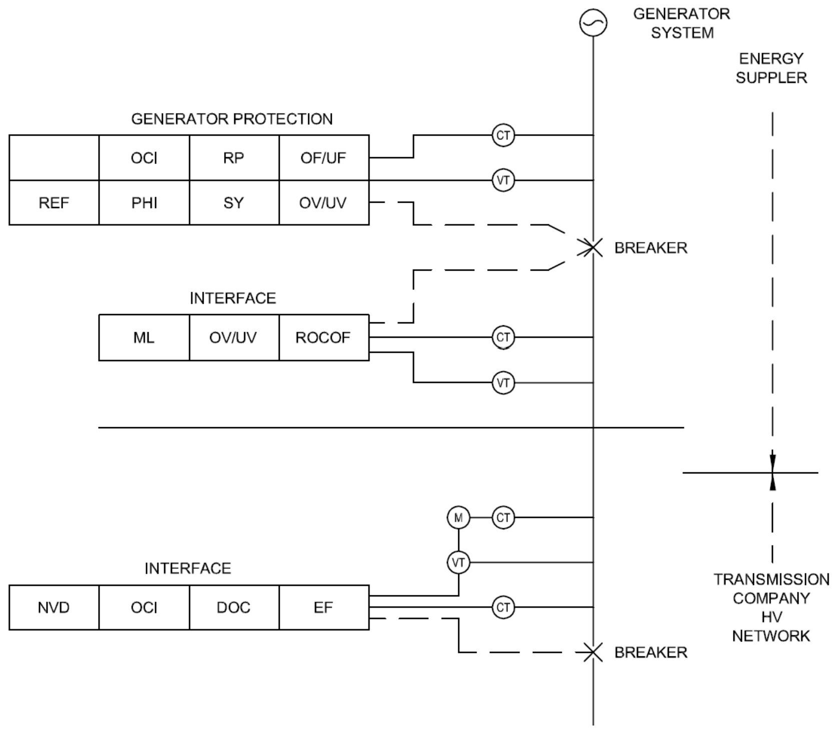


Figure 3: Typical Protection Arrangements for MV Connected Generating Plant

9. EARTHING

1. MV Generating Plant

1. MV Distribution Systems may use direct, resistor, reactor or arc suppression coil methods of earthing the Distribution System neutral. The magnitude and duration of fault current and voltage displacement during earth faults depend on which of these methods is used. The method of earthing therefore has an impact on the design and rating of earth electrode systems and the rating of plant and equipment.

2. To ensure compatibility with the earthing on the Distribution System the earthing arrangements of the Generating Plant must be designed in consultation and formally agreed with the network operator. The actual earthing arrangements will also be dependent on the number of Generating Units in use and the Generator's system configuration and method of operation. The system earth connection shall have adequate electrical and mechanical capability for the duty.

3. MV Distribution Systems operating at voltages at or below 33kV are generally designed for earthing at one point only and it is not normally acceptable for MV Generators to connect additional MV earths when operating in parallel. One common exception to this rule is where the Generating Plant uses an MV voltage transformer (VT) for protection, voltage control or instrumentation purposes and this VT requires an MV earth connection to function correctly.

   Systems operating at 132kV are generally designed for multiple earthing, and in such cases the earthing requirements should be agreed in writing with the TSO.

4. In some cases the host network operator may allow the Generator to earth the Generator's MV System when operating in parallel with the Distribution System. The details of any such arrangements shall be agreed in writing between the relevant parties.

5. Generators must take adequate precautions to ensure their Generating Plant is connected to earth via their own earth electrodes when operating in isolation from the Distribution System.

6. Earthing systems must be designed, installed, tested and maintained to a recognised international standard. Precautions shall be taken to ensure hazardous Step and Touch Potentials do not arise when earth faults occur on MV systems. Where necessary, MV earth electrodes and LV earth electrodes shall be adequately segregated to prevent hazardous earth potentials being transferred into the LV Distribution System.

7. Typical earthing arrangements for MV connected plant are shown in Figure 4 and Figure 5.

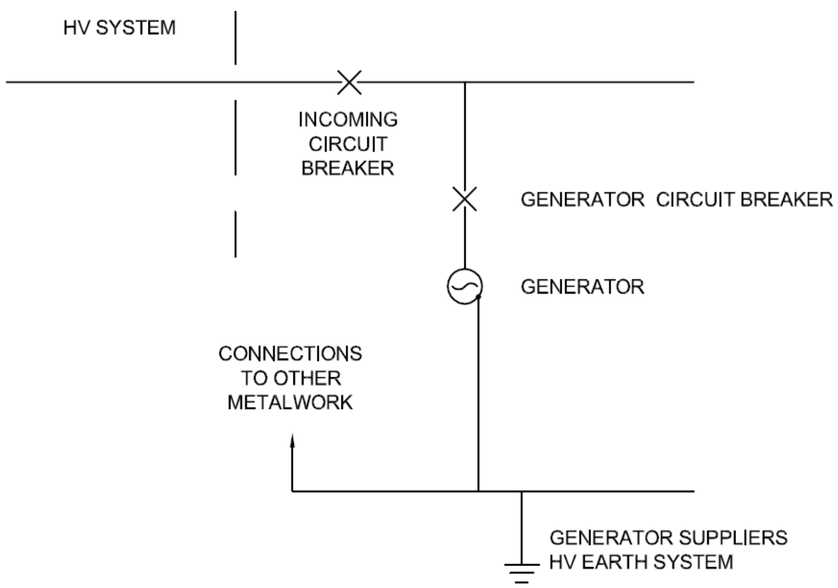
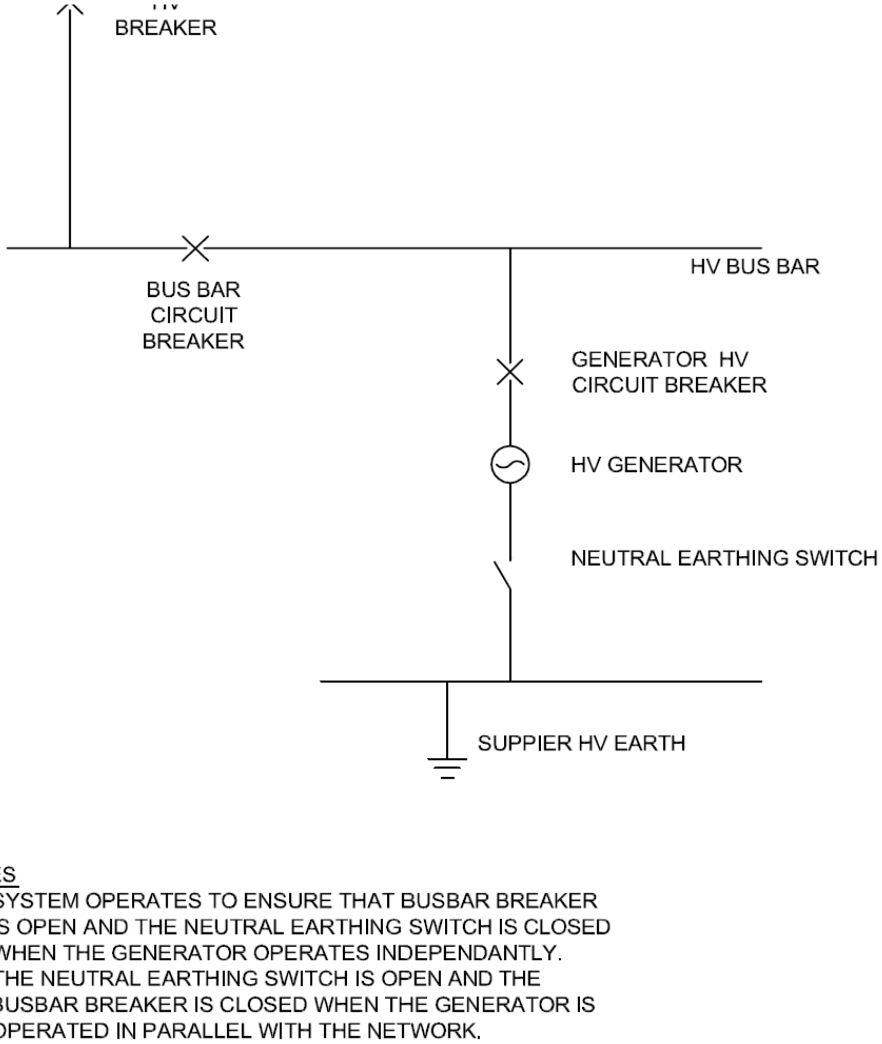


Figure 4: Typical Earthing Arrangement for MV Generator Configured for Parallel Operation (network MV earth not shown)

Figure 5: Typical Earthing Arrangement for MV Connected Generator Configured for both Standby and Parallel Operation



2. LV Generating Plant

1. LV Distribution Systems are always solidly earthed, and the majority are multiple earthed.

2. Where an earthing terminal is provided by the host network operator it may be used by a Generator for earthing the Generating Plant, provided the earth connection is of adequate capacity. Where use of the host network operator's earthing terminal is retained, it must be connected to the Generating Plant earthing system by means of a conductor at least equivalent in size to that required to connect the host network operator's earthing terminal to the installation.

3. Where the Generating Plant may be operated as a switched alternative only to the host network, the Generator must provide an independent earth electrode.

4. Where it is intended to operate in parallel with the LV System with the star point connected to the neutral and/or earthing system, precautions will need to be taken to limit the effects of circulating harmonic currents. It is permissible to insert an impedance in the supply neutral of the Generating Plant for this purpose, for those periods when it is paralleled with the host network. However, if the Generating Plant is operating in isolation from the Distribution System it will be necessary to have the Generating Plant directly earthed.

5. Where the Generating Plant is designed to operate independently from the Distribution System the switchgear that is used to separate the two Systems shall break all four poles (3 phases and neutral). This prevents any phase or neutral current, produced by the Generating Plant, from flowing into the Distribution System when it operates as a switched alternative only supply.

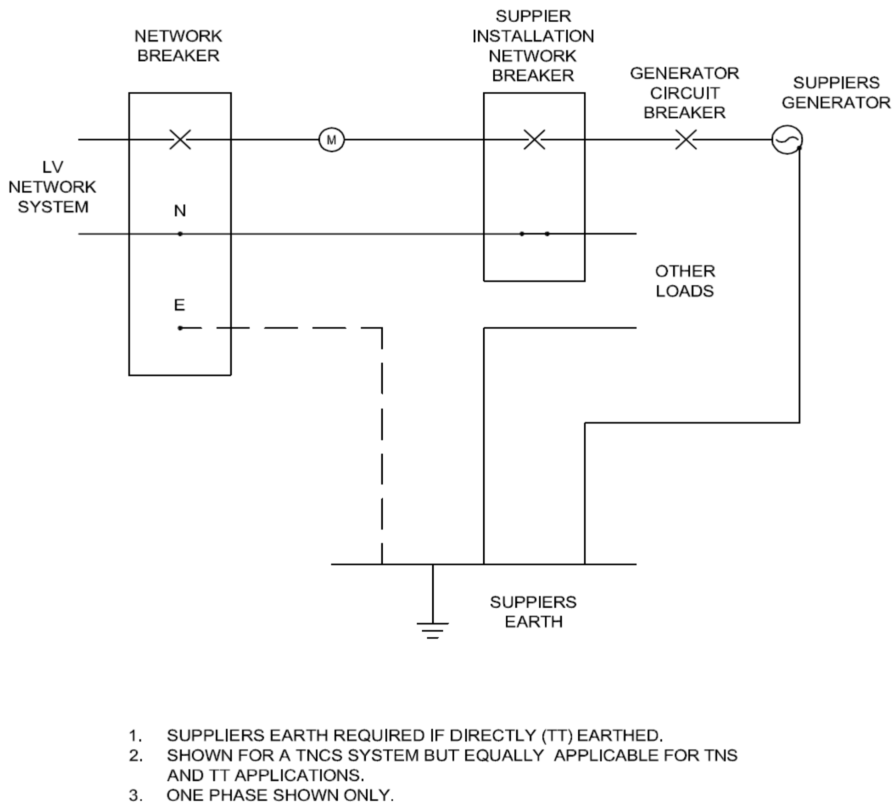
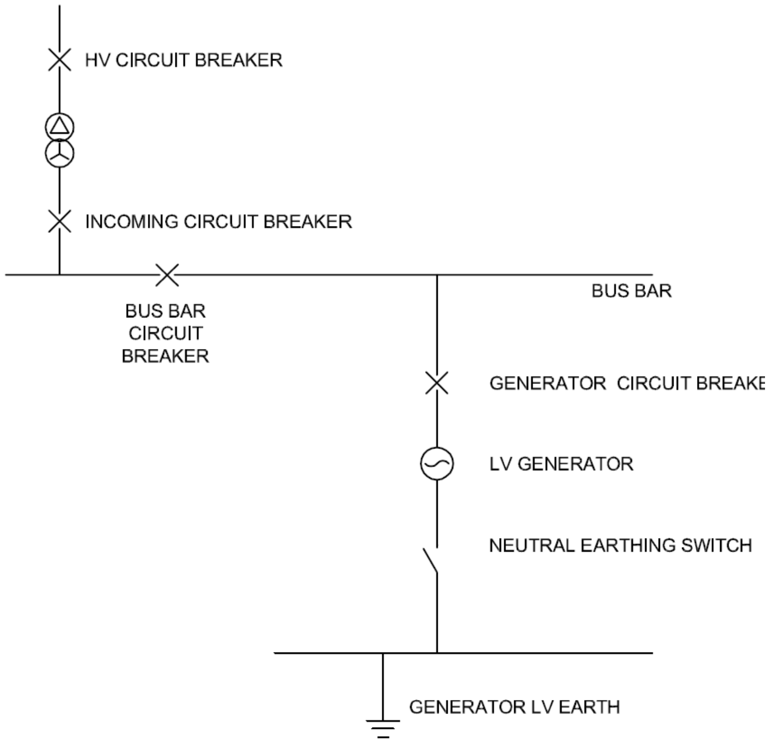


Figure 6: Typical Earthing Arrangement for LV Connected Generator Configured for Parallel Operation Only



NOTES
1. NETWORK OPERATOR HV EARTH NOT SHOWN.
2. SYSTEM OPERATES SO THAT BUSBAR CIRCUIT BREAKER OPENS WHEN GENERATOR IS OPERATED INDEPENDANTLY AND NEUTRAL EARTHING SWITCH IS CLOSED.
3. IN PARALLEL OPERATION BUSBAR CIRCUIT BREAKER IS CLOSED AND NEUTRAL EARTHING SWITCH IS OPEN.

Figure 7: Typical Earthing Arrangement for an LV Generator Connected to an MV Network Configured for both Standby and Parallel Operation

10. INSTALLATION, OPERATION AND CONTROL INTERFACE

1. General

    1. Installations should be carried out by competent persons, who have sufficient skills and training to apply safe methods of work to install the Generating Plant. Ideally they should have recognised and approved qualifications relating to the fuel /energy sources and general electrical installations.

    2. The installation should be carried out to the standards required in the manufacturer's installation instructions.

    3. The Generator and host network operator must ensure that all personnel are competent in that they have adequate knowledge and sufficient judgement to take the correct action when dealing with an emergency. Failure to take correct action may jeopardise the Generator's equipment or the Distribution System and give rise to danger.

    4. No parameter relating to the electrical connection or setting that is subject to type verification certification shall be modified as part of or after the installation process unless previously agreed in writing between the host network operator and the Generator. User access to change such parameters shall be prevented by the use of sealing plugs/paper seals etc. where possible.

    5. The host network operator and the Generator must agree in writing the salient technical requirements of the interface between their two systems. These requirements will generally be contained in the Site Responsibility Schedule and/or the Connection Agreement. In particular it is expected that the agreement will include:

        a. the means of synchronisation between the Generator's system and the

           Distribution System, where appropriate;

        b. the responsibility for plant, equipment and protection systems maintenance, and recording failures;

        c. the means of connection and disconnection between the host network operators and Generator's systems;

d. key technical data e.g. import and export capacities, operating power factor range, interface protection settings;

e. the competency of all persons carrying out operations on their systems;

f. details of arrangements that will ensure an adequate and reliable means of communication between the host network operator and Generator;

g. the obligation to inform each other of any condition, occurrence or incident which could affect the safety of the other's personnel, or the maintenance of equipment and to keep records of the communication of such information;

h. the names of designated persons with authority to act and communicate on their behalf and their appropriate contact details.

6. The Generators should be aware that host network operators apply auto-reclose systems to MV overhead line circuits. This may affect the operations of directly connected MV Generating Plants and also Generating Plants connected to LV Distribution Systems supplied indirectly by MV overhead lines.

2. Isolation and Safety Labelling

1. Every installation or system which includes Generating Plant operating in parallel with the Distribution System must include a means of isolation capable of disconnecting the whole of the Generating Plant in-feed to the Distribution System. This equipment will normally be owned by the Generator, but may by agreement be owned by the host network operator.

2. The Generator must grant the host network operator rights of access to the means of isolation.

3. To ensure that host network operator staff and that of the Customer and their contractors are aware of the presence of Generating Plant, appropriate warning labels should be used.

4. Where the installation is connected to the Low Voltage Distribution System the Generator should generally provide labelling at the Point of Supply (Fused Cut-Out), meter position, consumer unit and at all points of isolation within the Customer’s premises to indicate the presence of Generating Plant. The labelling

should be sufficiently robust and if necessary fixed in place to ensure that it remains legible and secure for the lifetime of the installation.

5. Where the installation is connected to the MV Distribution System the Generator should give consideration to the labelling requirements. In some installations e.g. a complex CHP installation, extensive labelling may be required, but in others e.g. a wind farm connection, it is likely to be clear that Generating Units are installed on site and labelling may not be required. Any labels should comply with safety regulations.

3. Site Responsibility Schedule

1. A Site Responsibility Schedule (SRS) should be prepared by the host network operator in conjunction with the Generator. The SRS should clearly indicate the ownership, operational and maintenance responsibility of each item of equipment at the interface between the Distribution System and the Generating Plant, and should include an operational diagram so that all persons working at the interface have sufficient information so that they can undertake their duties safely and to minimise the risk of inadvertently interrupting supplies. The SRS should also record the agreed method of communication between the host network operator and the Generator.

2. The operational diagram should be readily available to those persons requiring access to the information contained on it. For example, this could be achieved by displaying a paper copy at the Point of Supply, or alternatively provided as part of a computer based information system to which all site staff has access. The most appropriate form for this information to be made available should be agreed as part of the connection application process.

3. In the case of a LV connected Generating Plant, a simple diagram located at the Point of Supply may be sufficient. The scope of the diagram should cover the Distribution System, Customer's installation and the Generating Plant; however the location of any metering devices, consumer unit and circuit protective devices (together with their settings) within the Customer's installation should also be shown. In the case of an MV connected Generating Plant the diagram is likely to be more complex and contain more detailed information.

4. In addition to preparing the diagram as part of the connection process, there are obligations on the host network operator and the Generator to ensure that the

Site Responsibility Schedule including the operational diagram are updated to reflect any changes on site. To facilitate this, the Generator must contact the host network operator when any relevant changes are being considered.

4. Operational and Safety Aspects

1. Where the Point of Supply provided by the host network operator for parallel operation is at MV, the Generator must ensure:

    a. that a person with authority, or his staff, is available at all times to receive communications from the host network operator Control Engineer so that emergencies, requiring urgent action by the Generator, can be dealt with adequately. Where required by the host network operator, it will also be a duty of the Generator's staff to advise the host network operator Control Engineer of any abnormalities that occur on the Generating Plant which have caused, or might cause, disturbance to the Distribution System, for example earth faults;

    b. Where in the case that it is necessary for the Generator's staff to operate the host network operators equipment, they must first have been appropriately trained and designated as a host network operator 'Authorised Person' for this purpose. The names of the Generators authorised persons should be included on the Site Responsibility Schedule. All operation of host network operator equipment must be carried out to the specific instructions of the host network operator Control Engineer in accordance with the host network operator's safety rules.

2. For certain Generating Plant connections to an MV Point of Supply, the Generator and the host network operator may have mutually agreed to schedule the real and/or reactive power outputs to the Distribution System to ensure stability of the local Distribution System. The host network operator may require agreement on specific written procedures to control the bringing on and taking off of such Generating Plant. The action within these procedures will normally be controlled by the host network operators Control Engineer.

3. Where the Point of Supply provided by the host network operator for parallel operation is at LV, the host network operator, depending upon local circumstances, may require a similar communications procedure as for MV connections (see 10.4.1).

5. Synchronizing and Operational Control

1. Before connecting two energised electrical systems, for example a Distribution System and Generating Plant, it is necessary to synchronise them by minimising their voltage, frequency and phase differences.

2. Operational switching, for example synchronising, needs to take account of Step Voltage Changes as detailed in Section 7.5.

3. Automatic synchronising equipment will be the norm which, by control of the Generating Unit's field system (Automatic Voltage Regulator) and governor, brings the incoming unit within the acceptable operating conditions of voltage and speed (frequency), and closes the synchronising circuit breaker.

4. The facility to use the host network operator’s circuit breaker manually for synchronizing can only be used with the specific agreement of the host network operator.

5. The synchronising voltage supply may, with host network operator agreement, be provided from a host network operator owned voltage transformer. Where so provided, the voltage supplies should be separately fused at the voltage transformer.

6. Where the Generator's system comprises ring connections with normal open points, it may not be economic to provide synchronising at all such locations. In such cases mechanical key interlocking may be applied to prevent closure unless one side of the ring is electrically dead. A circuit breaker or breakers will still, however, require synchronising facilities to achieve paralleling between the Generator and the host network operator supply.

7. The conditions to be met in order to allow automatic reconnection when the host network operator supply is restored are defined in Section 10. Where a Generator requires his Generating Plant to continue to supply a temporarily disconnected section of the Distribution System in island mode, the special arrangements necessary will need to be discussed with the host network operator.

11. TESTING AND COMMISSIONING

Connection Guidelines for Small-Scale Renewable Generating Plant

1. General

    1. The exact testing and commissioning requirements will be determined by the network operator. The following is intended as a brief summary of generic requirements. Details of international standards can be found using the references given in Appendix 1.

2. Generating Units rated up to and including 16A per phase

    In satisfying the Type Verification tests, a Generating Unit can be considered as being 'approved' for connection to a public LV Distribution System and so the requirements for on-site commissioning tests are minimal.

    1. The Interface Protection and protection functionality are normally provided by Type Verified and tested equipment with protection settings that have been factory set so there is no requirement for the protection setting to be confirmed during the on-site commissioning tests.

    2. It is the responsibility of the Generator to ensure that the relevant information is forwarded to the host network operator in accordance with the requirements of a single unit or multiple unit installation. The Generator self-certifies that not only a type approved Generating Unit is installed, but that it has been installed compliant with the type approval.

    3. A Type Verification test sheet should be submitted to the host network operator as part of the commissioning notification, but the host network operator does not need to witness the tests. However, the host network operator will have a right to inspect an installation, if only to verify that the Generating Unit installed relates to the information that has been provided.

3. Generating Units >16A per Phase but <50kW 3 Phase (or 17kW single Phase)

    1. Generating Plant may either comprise 'type approved Generating Plant' where the Generating Unit(s) and the protection function are 'type approved' or Generating Units and/or interface equipment that has not been specifically type approved, and where individually certified equipment (e.g. protection relays) will be used.

2. The Generator should discuss the generation project with the local host network operator during the initial stages of the connection process with a view to establishing whether the proposed installation will comprise 'type approved Generating Plant' or whether individual equipment that has not been specifically type approved will be used. Information relating to the approval status of the equipment being proposed should be included in the initial application form where possible; however the agreed information relating to testing and commissioning should be provided at least 15 working days before the proposed commissioning date. This will provide time for the host network operator to confirm whether the Generating Plant can be considered to be 'type approved Generating Plant', and to establish any requirement to witness the commissioning tests and to ensure that staff are available to witness commissioning tests where this is required.

3. In the case of 'type approved Generating Plant':

   a. The type testing procedures should be developed by the manufacturer to describe a methodology for testing the particular type of Generating Plant. The protection settings must follow those given in Sections 7.6 and 8 of these guidelines.

   b. The type verification test sheet confirming that the Generating Plant has been type tested to satisfy the network operator's requirements should be made available to the Generator.

   c. It is the responsibility of the Generator to ensure that the relevant information, including the type verification test sheet is forwarded to the host network operator and that the scope, date and time of the commissioning tests is agreed in advance of the commissioning the Generating Plant. The host network operator should have the opportunity to witness the commissioning tests undertaken by the Generator and inspect the installation.

   d. The Interface Protection and protection functionality is performed by type tested equipment with protection settings that have been factory set so there is no requirement for the protection setting to be confirmed during the on-site commissioning tests.

   e. The Generator should self-certify that only type approved Generating Plant is installed and that it has been installed correctly.

   f. Within 30 days of completing the commissioning tests, the Generator should send the commissioning test results form to the host network operator. Where the commissioning tests have not been witnessed by the host network operator, the completed form should be reviewed by the host network operator and any comments, including any requirements for further tests or remedial works, provided to the Generator.

4. In the case where the Generating Plant is not 'type approved Generating Plant':

   a. It is the responsibility of the Generator to ensure that the relevant information is forwarded to the host network operator and that the scope, date and time of the commissioning tests is agreed in advance of the commissioning the Generating Plant. The host network operator should have the opportunity to witness the commissioning tests undertaken by the Generator and inspect the installation.

   b. The Interface Protection and protection functionality will be performed by individual certified protection relays with settings that can be changed by the Generator on site. The types of relays used and the proposed settings should be submitted to the host network operator 20 days in advance of the agreed commissioning date.

   c. The Generator must self-certify that the Generating Plant has been installed correctly, including that the appropriate safety labels have been fitted properly.

   d. Within 30 days of completing the commissioning tests, the Generator should send the commissioning test results form to the host network operator. Where the commissioning tests have not been witnessed by the host network operator, the completed form should be reviewed by the host network operator and any comments, including any requirements for further tests or remedial works, provided to the Generator.

4. Generating Units Larger Than 50 kW 3 Phase (or 17 kW Single Phase)

   1. Generating Units in this category are not normally 'type approved' and usually some of the Interface Protection function will be performed by either individual protection relays or a combined protection and control system. Protection equipment and protection functions installed within or forming part of the Generator's control equipment should be consistent with the requirements set out in Section. The settings on relays installed on the Generator's equipment will need to be set by the Generator on site and hence full commissioning tests will be required.

   2. The Generator should discuss the generation project with the local host network operator during the initial stages of the connection with a view to establishing the commissioning tests that need to be undertaken. Detailed information relating to

testing and commissioning, including the date of the commissioning tests should be provided by the Generator at least 25 working days before the proposed commissioning date. This will provide time for the host network operator to establish any requirement to witness the commissioning tests or inspect the installation and to ensure that staff are available to witness commissioning tests where this is required. It is the responsibility of the Generator to undertake these tests and make appropriate arrangements for them to be witnessed.

3. Where the installation is connected to the MV Distribution System, the tests must be witnessed by a representative of the host network operator.

4. Where the installation is connected to the LV Distribution System the host network operator should be invited to witness the commissioning tests undertaken by the Generator and inspect the installation.

5. The tests must be carried out on site; tests performed before delivery and installation should not be accepted.

6. Within 30 days of completing the commissioning tests, the Generator should send the commissioning test results form to the host network operator. Where the commissioning tests have not been witnessed by the host network operator, the completed form should be reviewed by the host network operator and any comments, including any requirements for further tests or remedial works, provided to the Generator.

7. The Generator must make a written record of all protection settings and test results. A copy of the record must be provided to the host network operator. The Generator should retain a copy of the record to make available for inspection as required by the host network operator or other legitimately interested party.

8. Periodic testing of the Interface Protection should be carried out by the Generator at intervals to be agreed in discussion with the host network operator. In addition it may be necessary to undertake ad-hoc testing to' determine for example:

    - the voltage dip on synchronising;

- the harmonic voltage distortion;
- the voltage levels as a result of the connection of the Generating Plant and to confirm that they remain within the statutory limits.

9. Periodic testing of the Generating Plant is recommended at intervals prescribed by the manufacturer. This information shall be included in the documentation provided by the Generator. The method of testing and/or servicing should be included in the servicing instructions/documentation.

5. Changes in the Installation

1. If during the lifetime of the Generating Plant it is necessary to replace a major component of a Generating Unit or its protection system, it is only necessary to notify the host network operator if the operating characteristics of the Generating Plant or the protection have been altered when compared against that which was originally commissioned.

2. In the event that Generating Plant is to be decommissioned and will no longer operate as a source of electrical energy in parallel with the Distribution System, the Generator should notify the host network operator. Where the presence of Generating Plant is indicated in a bespoke Connection Agreement, it will be necessary to amend the Connection Agreement appropriately.

12. SAFETY ASPECTS

12.1. The Generator shall take precautions to prevent, so far as is reasonably practicable, danger due to the influx of water or any noxious or explosive liquid or gas into any enclosed space containing its apparatus.

12.1.1. Where apparatus can or does emit noxious or explosive liquids or gasses (for example batteries or oil tanks) then the Generator shall ensure that there is adequate ventilation, that appropriate notices of danger are posted, and that when work must be done on the apparatus all doors shall be locked open.

12.1.2. Where the apparatus in an enclosed space is protected by inert gas (COs, N2) fire suppression then the Generator shall ensure that whenever work takes place within the enclosed space the fire suppression is locked of.

12.1.3. All of the Generator's rotating equipment and equipment with other moving parts shall be constructed, installed, protected and maintained in such a manner as to prevent danger to humans, animals and property. When work must take place on such apparatus then adequate precautions must be taken to ensure that it is mechanically isolated including electrically isolating associated motors and the locking off of inlets of steam or water or other physical sources of danger.

12.2. The following shall also apply to Generating Plant connected at medium voltage:

12.2.1. The Generator or host network operator shall enclose any part of a ground-mounted transformer in the open air, containing live apparatus which is not encased, by a fence not less than 2.4 metres high to prevent, so far as is reasonably practicable, danger or unauthorised access.

12.2.2. The Generator shall ensure that, so far as is reasonably practicable, there are at all times displayed in a conspicuous position a danger notice in English, and the local language bearing a sign of a skull and crossbones and a notice giving the name of the Generator and an address or telephone number where a person appointed by the Generator shall be in constant attendance.

12.3. The Generator shall take all reasonable precautions to minimise the risk of fire.

12.3.1. At ground-mounted transformers the Generator shall provide fire buckets filled with clean dry sand, fire extinguishers and first aid boxes or cupboards. In addition, an adequate number of gas masks shall be kept conspicuously at accessible locations.

12.3.2. At ground mounted transformers, instructions in English and the local language of the area, for the restoration of persons suffering from electric shock shall be affixed by the Generator in a conspicuous place.

12.4. Where Generating Plant and equipment is exposed as to be liable to damage from lightning, adequate means for diverting to earth any such electrical surges must be provided.

12.5. The Generator shall apply protective devices to every system which will so far as is reasonably practicable, prevent any current, including leakage to earth, from flowing in any part of a system for such a period that part of the system can no longer carry that current without danger.

12.6. The host network operator shall ensure that its entire works on a Customer's premises which are not under the control of the Customer (whether forming part of the Customer's Installation or not) are:

a) suitable for their respective purposes

b) installed and, so far as is reasonably practicable, maintained so as to prevent danger, and

c) protected, so far as is reasonably practicable, by a suitable fusible cut-out or automatic switching device as close as reasonably practicable to the supply terminals, provided that no such fusible cut-out or automatic switching device shall be inserted in any conductor connected with earth.

12.7. The host network operator shall ensure that every cut-out or automatic switching device not within a Distribution compound shall be enclosed in a locked or sealed container.

12.8. The host network operator shall ensure that any electric line which forms part of the Distribution System and which is taken into a building at a point below the level of the ground shall be so installed as to prevent, so far as is reasonably practicable, the influx of any noxious or explosive liquid or gas at the point of entry.

12.9. The host network operator shall mark permanently the separate conductors of electric lines connected to supply terminals as close as practicable to those terminals to show the phase of each conductor including neutral and earth conductors and, where appropriate, phase rotation.

12.10. The Customer shall, so far as is reasonably practicable, take precautions for the safe custody of the equipment in its premises belonging to the host network operator.

12.11. If any accident occurs at the Generating Plant resulting in serious injury to or loss of life of a human being or serious damage to a property the Generator shall send to the Energy Regulatory Commission a report of the accident within 24 hours of its knowledge of the occurrence. In this context serious injury means injury that requires the person to become a hospital in-patient, and serious damage to a property means that a significant part of the property has been damaged or destroyed.

APPENDIX 1 – REFERENCE STANDARDS

A number of British and European Standards exist which are applicable to the connection of Generating Units. These may offer useful reference:

A. Health and Safety at Work etc. Act (HASWA): 1974
The primary piece of legislation covering occupational health and safety in the UK.

B. Electricity Safety, Quality and Continuity Regulations (ESQCR): 2002
Statutory Instrument Number 2665 -HMSO ISBN 0-11-042920-6.

C. Electricity at Work Regulations (EaWR): 1989

D. BS 7671: 2008 Requirements for Electrical Installations
IEE Wiring Regulations: Seventeenth Edition.

E. BS 7430: 1999 Code of Practice for Earthing.

F. BS 7354 Code of Practice for Design of Open Terminal Stations.

G. BS EN 61000 series Electromagnetic Compatibility (EMC).

H. BS EN 61508 series Functional safety of electrical/ electronic/ programmable electronic safety related systems.

I. BS EN 60255 series Measuring relays and protection equipment.

J. BS EN 61810 series Electromechanical Elementary Relays.

K. BS EN 60947 series Low Voltage Switchgear and Controlgear.

L. BS EN 60044-1: 1999 Instrument Transformers. Current Transformers.

M. BS EN 60034-4:2008 Methods for determining synchronous machine quantities from tests.

N. BS EN 61400-21:2008 Wind turbines. Measurement and assessment of power quality characteristics of grid connected wind turbines.

O. IEC 60909 series Short-circuit currents in three-phase a.c. systems. Calculation of currents.

P. **IEC TS 61000-6-5: 2001** Electromagnetic Immunity Part 6.5 Generic Standards. Immunity for Power Station and Substation Environments.

Q. **IEC 60364-7-712: 2002** Electrical installations of buildings - Special installations or locations - Solar photovoltaic (PV) power supply systems.

R. **ENA Engineering Recommendation G5/4 -1 (2005)** Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission and distribution networks in the United Kingdom.

S. **ENA Engineering Recommendation G59/2-1 (2011)** Recommendations for connection of generating plant to the distribution systems of licensed distribution network operators.

T. **ENA Engineering Recommendation G74 (1992)** Procedure to meet the requirements of IEC 909 for the calculation of short-circuit currents in three-phase AC power systems.

U. **ENA Engineering Recommendation G83/1-1 (2008)** Recommendations for connection of small-scale embedded Generators (up to 16A per phase) in parallel with public low voltage distribution networks.

V. **ENA Engineering Recommendation P2/6 (2006)** Security of Supply.

W. **ENA Engineering Recommendation P18 (1978)** Complexity of 132kV circuits.

X. **ENA Engineering Recommendation P28 (1989)** Planning limits for voltage fluctuations caused by industrial, commercial and domestic equipment in the United Kingdom.

Y. **ENA Engineering Recommendation P29 (1990)** Planning limits for voltage unbalance in the UK for 132 kV and below.

Z. **ENA Technical Specification 41-24 (1992)** Guidelines for the design, installation, testing and maintenance of main earthing systems in substations.

AA. **ENA Engineering Technical Report ETR 124 (2004)** Guidelines for actively managing power flows associated with the connection of a single distributed generation plant.

AB. **ENA Engineering Technical report ETR 126 (2004)** Guidelines for actively managing voltage levels associated with the connection of a single distributed generation plant.

AC. **ENA Engineering Technical report ETR 130 (2006)** The application guide for assessing the capacity of networks containing distributed generation.