IMP/001/007 – Code of Practice for the Economic Development of Distribution Systems with Distributed Generation

1. Purpose

The purpose of this document is to state Northern Powergrid's policy for the economic development of systems containing distributed generation. This document states the requirements, in addition to those described in the suite of Economic Development Codes of Practices,[1] that shall be adopted where there is existing distributed generation connected to the system or where the connection of new distributed generation is being considered. The document states the requirements to achieve a robust, economical and efficient distribution system, taking into account the initial capital investment, system losses and the maintenance and operation costs over the life of the assets forming the system. It also takes into account the continuing commitment to improve the quality and reliability of supply to customers. In order to facilitate the connection of distributed generation to the distribution system, this document introduces additional flexibility at the design stage associated with the provision of flexible connection solutions.

This Code of Practice also helps to ensure the company achieves its requirements with respect to the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004), The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002 (as amended[2]), the Health and Safety at Work Act 1974, the Electricity Distribution Licences, The Distribution Code, The Grid Code and Commission Regulation (EU) 2016/613, 14 April 2016, establishing a network code on requirements for grid connection of generation.

This document supersedes the following document, all copies of which should be withdrawn from circulation.

Document Reference	Document Title	Version	Published Date
IMP/001/007	Code of Practice for the Economic Development of Distribution Systems with Distributed Generation	6.0	November 2019

2. Scope

This document applies to:

- The distribution systems of Northern Powergrid Northeast and Northern Powergrid Yorkshire; and
- All distribution system developments including new connections,[3] system reinforcement and asset replacement where there is existing distributed generation connected to that part of the system or where the connection of new or additional distributed generation to that part of the system is being considered.

For the purposes of this document, electricity storage systems are considered to be distributed generation.

It is not intended to apply this Code of Practice retrospectively, but when work is being done on the system, the opportunity shall be taken to improve sections of system to comply with the Code of Practice when it is practicable and economic to do so.

[1] IMP/001/914 Code of Practice for the Economic Development of the 132kV System, IMP/001/913 Code of Practice for the Economic Development of the EHV System, IMP/001/912 Code of Practice for the Economic Development of the HV System, IMP/001/911 Code of Practice for the Economic Development of the LV System.

[2] This includes The ESQC (Amendment) Regulations 2006 (No. 1521, 1st October 2006) and The ESQC (Amendment) Regulations 2009 (No. 639, 6th April 2009).

[3] Including connections to IDNO networks and Private Wire networks.

The document provides guidance on the design issues that are associated with the connection of distributed generation in addition to those associated with the connection of passive demand of an equivalent size. It should be read in conjunction with the design policy appropriate to the voltage at which the distributed generation is or will be connected, IMP/001/010 - Code of Practice for Standard Arrangements for Customer Connections, IMP/001/007/001 – Battery Energy Storage System Guidance Document, IMP/001/007/003 - Application Guide on Flexible Connection Solutions and the relevant Engineering Recommendations.[4]

[4] See section 3.1.7 and 3.3.2.

2.1. Table of Contents

3. Policy

3.1. Assessment of Relevant Drivers

The key internal business drivers relating to the economic development of the systems with distributed generation are:

- Employee commitment - achieved by developing a safe system to ensure that employees are not exposed to risks to their health as far as reasonably practicable;
- Financial strength - achieved by developing an integrated distribution system having minimum lifetime cost;
- Customer service - achieved by reducing the potential number of customer interruptions and customer minutes lost;
- Regulatory integrity - achieved by designing a robust system that meets mandatory and recommended standards;
- Environmental respect - achieved through due consideration being given to the environmental impact of new developments; and
- Operational excellence - achieved through improving the quality and reliability of supply.

The external business drivers relating to the development of systems with distributed generation are detailed in the following sections.

3.1.1. Requirements of the Electricity Safety, Quality and Continuity Regulations (ESQC Regulations)

The ESQC Regulations 2002 (No. 2665, 31st January 2003) and its amendments[5] impose a number of obligations on the business, mainly relating to quality of supply and safety. All the general requirements of the ESQC Regulations that are applicable to the design of the distribution systems shall be complied with. In addition, Regulation 22 imposes specific obligations on a customer wishing to operate generation in parallel with Northern Powergrid's distribution systems, including the requirement for the customer to agree any specific requirements with Northern Powergrid.

3.1.2. Requirements of the Electricity Act 1989 (as amended)

Section 9 (1) of the Electricity Act 1989 (as amended) places an obligation on Distribution Network Operators (DNOs) to develop and maintain an efficient, co-ordinated and economical system of electricity distribution and to facilitate competition in the supply and generation of electricity.

3.1.3. Requirements of the Electricity at Work Regulations 1989

The Electricity at Work Regulations 1989 (No. 635) place obligations on the business relating to the safety of plant and equipment used on the distribution system. It requires that plant and equipment is designed, constructed and operated such that it is operated within the limits of its capability.

3.1.4. Other Safety Related Requirements

In addition to the requirements of the ESQC Regulations and the Electricity at Work Regulations, all other relevant statutory legislation including Health and Safety at Work Act 1974 etc. shall be complied with.

3.1.5. Requirements of Northern Powergrid's Distribution Licences

Northern Powergrid's Distribution Licences contain a number of standard conditions to be complied with which are relevant to system design generally and to the connection of distributed generation. Standard Licence Condition 20 (Compliance with Core Industry Documents) requires the licensee to comply with some of the core industry documents relevant to distributed generation:

- Standard Licence Condition 20.1 requires the licensee to comply with the Grid Code;

[5] This includes The ESQC (Amendment) Regulations 2006 (No. 1521, 1st October 2006) and The ESQC (Amendment) Regulations 2009 (No. 639, 6th April 2009).

- Standard Licence Condition 20.2 requires the licensee to at all times have in force, implement, and comply with the Distribution Code;
- Standard Licence Condition 20.3 requires the licensee to be a party to and comply with the Connection and Use of System Code (CUSC); and
- Standard Licence Condition 20.3 requires the licensee to be a party to and comply with the Distribution Connection and Use of System Agreement (DCUSA).

Standard Licence Condition 49[6] (Electricity Distribution Losses Management Obligation and Distribution Losses Strategy) requires the licensee to ensure that distribution losses from its distribution system are as low as reasonably practicable, and to maintain and act in accordance with its Distribution Losses Strategy.[7] In particular:

- Standard Licence Condition 49.2 requires the licensee to design, build, and operate its distribution system in a manner that can reasonably be expected to ensure that distribution losses are as low as reasonably practicable; and
- Standard Licence Condition 49.3 requires that in designing, building and operating its distribution system the licensee must act in accordance with its Distribution Losses Strategy, having regard to the following:
    a) the distribution losses characteristics of new assets to be introduced to its distribution system;
    b) whether and when assets that form part of its distribution system should be replaced or repaired;
    c) the way that its distribution system is operated under normal operating conditions; and
    d) any relevant legislation that may impact on its investment decisions.

3.1.6. The Grid Code

The Grid Code places specific requirements on Generators with a registered capacity of 50MW or more, for example, in relation to the provision of information regarding distributed generation output as well as setting out certain requirements for the performance, control and maintenance of their distributed generation plant. When designing the connection of distributed generation which is subject to the Grid Code, care should be taken to ensure that Generator informs Northern Powergrid of any specific obligations that they need to comply with so that the connection can be designed such that they can meet their obligations under the Grid Code.

3.1.7. Requirements of the Distribution Code

As a distribution licence holder, Northern Powergrid is required to hold, maintain and comply with the Distribution Code of Licensed Distribution Network Operators of Great Britain.

The Distribution Code covers all material technical aspects relating to connections to and the operation and use of the distribution systems of the Distribution Network Operators. The Distribution Code is prepared by The Distribution Code Review Panel and is specifically designed to:

- permit the development, maintenance and operation of an efficient co-ordinated and economic system for the distribution of electricity;
- facilitate competition in the generation and supply of electricity; and
- efficiently discharge the obligations imposed upon DNOs by the distribution licence and comply with the Regulation (where Regulation has the meaning defined in the distribution licence) and any relevant legally binding decision of the European Commission and/or Agency for the Co-operation of Energy Regulators. This objective is particularly relevant given the introduction of a suite of European Network Codes which will place additional obligations on Generators and DNOs.

---

[6] Came into force in April 2015.

[7] Strategy for Losses, February 2018. https://www.northernpowergrid.com/losses.

The Distribution Code defines the technical aspects of the working relationship between the operators of a distribution system and those who use it. Generators who have distributed generation that can operate in parallel with a DNO's distribution system are bound by the conditions of the Distribution Code. There are a number of Distribution Code obligations that specifically relate to distributed generation including:

- Distribution Planning and Connection Code (DPC) 7 which describes the specific requirements that need to be met by existing and prospective Generators; and
- Distribution Data Registration Code (DDRC) 5, which describes the mechanism for data exchange and update between DNOs and Users including Generators. The ENA standard application form for the 'Connection of Power Generating Modules to DNO Distribution Networks in accordance with EREC G99'[8] sets out the information that needs to be provided to the DNO and the process for providing it prior to any Power Generating Module being operated commercially.

The Distribution Code also gives force to the following Engineering Recommendations specifically related to distributed generation:

- Engineering Recommendation G83: Recommendations for the connection of type tested small-scale embedded generators (up to 16 A per phase) in parallel with low-voltage distribution systems;
- Engineering Recommendation G59: Recommendation for the connection of generating plant to the distribution systems of licensed distribution network operators;
- Engineering Recommendation G98: Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public low-voltage distribution networks on or after 27 April 2019; and
- Engineering Recommendation G99: Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019.

Although not forming part of the Distribution Code, the Distribution Code Review Panel prepares and governs a suite of Guidance Documents[9] related to the connection and operation of distributed generation. These documents provide significant background information on the connection process, licencing regime, power purchase arrangements etc. They are in the public domain and are a useful source of reference material.

3.1.8. Connection and Use of System Code

The Connection and Use of System Code (CUSC) defines the contractual framework for connection to and use of Great Britain's high voltage transmission system. Northern Powergrid is a signatory to CUSC and needs to comply with it.

Under CUSC 6.5.1, there is a requirement that Northern Powergrid shall not energise a connection between any distributed generation and its distribution systems or allow a Generator to use its distribution systems until the Generator has entered into the relevant agreements with National Grid Electricity System Operator (NGESO). The type of agreement that the Generator will require depends on the registered capacity of the distributed generation and will be confirmed by NGESO as part of the Statement of Works process.

CUSC 6.5.5 sets out the obligation on Northern Powergrid to advise NGESO if the connection of distributed generation to the distribution system might have material impact on the transmission system. If the generation plant being assessed has a registered capacity of 50MW or greater, a Modification Application will need to be submitted to NGESO as there will be a need to modify the Bilateral Connection Agreement between NGESO and Northern Powergrid.

A Statement of Works application may be needed where the aggregated registered capacity of generation plant planned to be installed in one or more Power Generating Facilities supplied from the same Grid Supply

[8] Downloadable from the ENA website, https://www.energynetworks.org/assets/files/SAF%20v6%20May%202020.pdf

[9] http://www.energynetworks.org/electricity/engineering/distributed-generation/distributed-generation.html

Point substation exceeds the Grid Supply Point substation specific threshold.[10] NGESO will undertake system studies and establish if remedial work on the transmission system is required to facilitate the connection of the distributed generation. The commercial arrangements, including the requirement for the Generator to enter into formal agreements with NGESO, or for Northern Powergrid to agree a revised Bilateral Connection Agreement, will depend upon the registered capacity of the distributed generation plant.

A revised Bilateral Connection Agreement between NGESO and Northern Powergrid may contain, in the Appendices, conditions for example relating to the disconnection of generation plant or impose site specific conditions referenced in the Statement of Works response from NGESO. Guidance on the acceptability of any such agreement should be sought from the System Planning Manager and the System Design Manager.

Generators with distributed generation plant that has a registered capacity of 100MW or greater, are required to obtain a Generation Licence from the Department for Business Energy and Industrial Strategy (BEIS), become party to The Balancing and Settlement Code (BSC) and enter into a Bilateral Embedded Generation Agreement (BEGA) with NGESO. As a consequence they will also need to comply with the Grid Code.

Generators seeking to connect generation plant that has a registered capacity of 50MW or greater and less than 100MW may obtain a Generation Licence from BEIS by exemption[11]. In such cases NGESO may require Northern Powergrid to agree a revised Bilateral Connection Agreement for the relevant Grid Supply Point to capture any specific technical requirement that the Generator may need to comply with. Such obligations should be reflected in the Connection Agreement between Northern Powergrid and the Generator. An example of a technical requirement is the provision of operational signals. NGESO have advised us that the operational signals required include half hourly indications of the output from the distributed generation plant in terms of MW and MVAr together with the generator circuit breaker status in order that they have sufficient information to manage their system efficiently. The Generator shall make their own arrangements to provide this information directly to NGESO.

3.1.9. Distribution Connection and Use of System Agreement

The Distribution Connection and Use of System Agreement (DCUSA) is a multi-party contract between the DNOs, Suppliers and Generators that deals with the use of distribution system to transport electricity.

3.2. Key Policy Requirements

The general objective in developing the distribution system is to obtain a simple and robust system having minimum lifetime cost taking into account the initial capital investment, system losses and the maintainability and operability over the life of the asset.

This Code of Practice is written to help ensure that the development of systems containing distributed generating is made in such a way as to:

- ensure that new and existing distributed generation is connected in such a way as to prevent danger to the public and Northern Powergrid staff;
- ensure that new and existing distributed generation is connected in such a way that minimises, as far as reasonably practicable, any adverse impact on quality of supply to customers;
- ensure that new and existing distributed generation is connected in such a way that minimises, as far as reasonably practicable, any adverse impact of the power quality experienced by other connected customers; and
- provide new connections that will facilitate, as far as reasonably practicable, the realisation of potential benefits provided by distributed generation plant to the distribution system and Northern Powergrid's customers.

[10] The threshold above which distributed generation plant, either individually or collectively, becomes subject to the Statement of Works process is dependent on the Grid Supply Point substation to which it is connected. Many Grid Supply Point substations have a Statement of Works trigger threshold less than 50MW. Guidance on the thresholds is contained in the Generation Heat Maps which are available from System Planning.

[11] Generators connecting plant rated between 50 MW and 100 MW may be given an exemption from the requirement to hold a Generation Licence, subject to applying to the Secretary of State for BEIS for an exemption, and being granted one.

3.3. Initial Design Considerations

3.3.1. General

Distributed generation can be connected to any part of the distribution system provided that:

- all the conditions laid down in the distribution licence and relevant Engineering Recommendations are satisfied;
- the requirements of the Distribution Code and, where appropriate, the Grid Code are met;
- the requirements of the CUSC are met;
- the connection is designed to meet the appropriate Northern Powergrid technical standards and policies;
- all plant and equipment on the distribution system operates within its rating;
- operation of the distribution system is not unreasonably compromised;
- the quality and security of the supply to other customers is not unreasonably compromised; and
- appropriate Commercial Agreements are in place.

3.3.2. Compliance with Engineering Recommendations

There are Engineering Recommendations specifically related to the connection of distributed generation that shall be complied with. These are:

- Engineering Recommendation G5: Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom;
- Engineering Recommendation G74: Procedure to meet the requirements of IEC 60909 for the calculation of short-circuit currents in three-phase AC power systems;
- Engineering Recommendation G83: Recommendations for the connection of type tested small-scale embedded generators (up to 16 A per phase) in parallel with low-voltage distribution systems;
- Engineering Recommendation G59: Recommendation for the connection of generating plant to the distribution systems of licensed distribution network operators;
- Engineering Recommendation G98: Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public low-voltage distribution networks on or after 27 April 2019;
- Engineering Recommendation G99: Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019;
- Engineering Recommendation P28: Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom; and
- Engineering Recommendation P29: Planning limits for voltage unbalance in the United Kingdom for 132kV and below.

In order to implement the EU Network Code, Requirements for Generation, two Engineering Recommendations are now referenced in the Distribution Code; EREC G98 and EREC G99.

Subject to a small number of exceptions[12] all new Power Generating Modules must comply with the requirements of EREC G98 or EREC G99, as applicable. Further guidance on selecting the applicable document is provided in EREC G98 and EREC G99.

EREC G83 and EREC G59 continue to apply to Generators connected before 27 April 2019.

[12] See clause 2.1 or EREC G99.

EREC G98 and EREC G99 introduce new terminology that aligns with the EU Network Code Requirement for Generators. The following new terms which are defined in EREC G99 are used in this Code of Practice. The definitions of these terms are replicated in Section 5:

- Power Generating Facility;
- Power Generating Module. Power Generation Modules are categorised by their Type;
  - Type A. A Power Generating Module with a Connection Point below 110kV and a Registered Capacity of 0.8kW or greater but less than 1MW;
  - Type B. A Power Generating Module with a Connection Point below 110kV and Registered Capacity of 1MW or greater but less than 10MW; and
  - Type C. A Power Generating Module with a Connection Point below 110kV and a Registered Capacity of 10MW or greater but less than 50MW;
  - Type D. A Power Generating Module with a Connection Point at, or greater than, 110kV; or with a Connection Point below 110kV and with Registered Capacity of 50MW or greater;
- Synchronous Power Generating Module;
- Power Park Module;
- Generating Unit;
- Micro-generator;
- Installation Document;
- Power Generating Module Document;
- Final Operational Notice;
- Energisation Operational Notification;[13] and
- Interim Operational Notification.[14]

The requirements for the connection of fully type tested Micro-generators (up to and including 16A per phase) in parallel with public low voltage distribution networks on or after 27 April 2019 are laid down in Engineering Recommendation EREC G98.

The requirements for the connection of Power Generating Modules greater than 16A per phase in parallel with public distribution networks on or after 27 April 2019 are laid down in Engineering Recommendation EREC G99.[15] For the connection of type tested distributed generation units under 17kW per phase or 50kW three phase, or for the connection of multiple generating units with a maximum aggregate capacity of less than 17kW per phase or 50kW three phase per customer installation, EREC G99 describes a simplified connection procedure.

Synchronous and asynchronous distributed generation generally produce negligible harmonic currents; however harmonic currents can be an issue where power electronic equipment is used in the installation, for example in the case of Double Fed Induction Generation plant or inverter connected generation plant. Any harmonic producing equipment connected to the distribution system as part of the Generator's installation must not produce harmonic currents that exceed the limits stated in Engineering Recommendation G5.

3.3.3. Connection Voltage

Distributed generation can be connected at any voltage level on the distribution system depending upon the Generator's export requirements, import requirements and the distributed generation plant characteristics.

[13] Only applicable for a Type D PGM.
[14] Only applicable for a Type D PGM.
[15] The expectation is that all Power Generating Modules less than or equal to 16A per phase will all be Fully Type Tested, hence EREC G99 (unlike G59) only applies to Power Generating Modules > 16 A per phase.

3.3.4. Connection Arrangement

The design of systems containing distributed generation will depend on many factors including the:

- operating voltage;
- magnitude of the load supplied by the system;
- magnitude of new and existing generation plant connected to the system;
- existing and proposed network topology;
- composition of existing and new circuits i.e. overhead line and cables; and
- requirements of the protection system.

The design of 132kV systems, taking into account the above factors and in accordance with IMP/001/914 – Code of Practice for the Economic Development of the 132kV System is likely to result in one of the generic system topologies shown in Appendix 1.

The design of EHV systems, taking into account the above factors and in accordance with IMP/001/913 – Code of Practice for the Economic Development of the EHV System is likely to result in one of the generic system topologies shown in Appendix 2.

The design of HV systems, taking into account the above factors and in accordance with IMP/001/912 – Code of Practice for the Economic Development of the HV System is likely to result in one of the generic system topologies shown in Appendix 3.

The design of LV systems, taking into account the above factors and in accordance with IMP/001/911 – Code of Practice for the Economic Development of the LV System is likely to result in one of the generic system topologies shown in Appendix 4.

It is important to note that the protection requirements can materially influence the most economic system design and the design of the protection scheme should be considered as an integral part of the design of the system. The protection scheme should comply with the requirements of IMP/001/014 – Policy for the Protection of Distribution Networks.

The general principles relating to the provision of connections to customers as set out in IMP/001/010 – Code of Practice for Standard Arrangements for Customer Connections, also apply to the provision of connections to customers with generating plant.

The connection between the distribution system and the Generator's system should be designed to meet the agreed security requirements of the Generator for both the import and export. The provision of a single circuit connection will mean that there will be periods, for example during an outage on that circuit, when the distributed generation will be disconnected and hence be unable to export to the system.[16] The provision of a double circuit, switched firm, connection would reduce these periods to switching time, whilst an automatic firm connection would minimise such periods.

3.3.5. Engineering Recommendation P2

Where a Generator has an import as well as export requirement, the connection to the Generator's installation should be designed such that it can:

- secure their import requirements with the level of security prescribed in Engineering Recommendation P2, unless specifically agreed otherwise with the Generator; and
- secure their export requirements with the level of security agreed with the Generator.

The distribution system should be designed to accommodate the Generator's import requirement such that compliance with Engineering Recommendation P2 is maintained.

[16] During such periods the Generator will be unable to import from the system unless alternative arrangements have been made. Multiple Points of Supply are permitted as described in IMP/001/010 – Code of Practice for Standard Arrangements for Customer Connections, which may allow import supplies to be provided to the site in such a scenario.

Engineering Recommendation P2 sets out the normal level of security required for distribution systems classified by the group demand. It also provides deterministic values that allow assessment of system security contribution by distributed generation. If necessary, more detailed assessment to determine the security contribution from particular distributed generation can be carried out in accordance with ENA Engineering Report 130 and ENA Engineering Report 131. Guidance on the application of Engineering Recommendation P2 is given in Code of Practice IMP/001/206 – Guidance for assessing Security of Supply in accordance with Engineering Recommendation P2/6.

3.3.6. Flexible Connection Solutions

Systems containing distributed generation should generally be designed such that neither the connection to the distributed generation site nor the wider system, under system intact conditions, imposes any operational constraint on the output of the distributed generation, on any other customer or the system itself. However it is recognised that it may be economically viable, when designing connections for new distributed generation installations, for the Generator to accept a lower cost connection design where, even under system intact conditions, operational constraints need to be imposed under certain network conditions. Such arrangements are often referred to as flexible connection solutions. Active Network Management is a flexible connection solution which manages the output of multiple Power Generating Facilities.

There is a range of flexible connection solutions that can be implemented to facilitate the connection of distributed generation plant. At present Northern Powergrid can offer different flexible connection solutions depending on the number of Power Generating Facilities affected and the type of system constraint that needs to be managed. The following table summarises the flexible connection solutions available; further guidance is provided in Appendix 5.

	Single Power Generating Facility		**Multiple Power Generating Facilities**
Constraint to be Managed	**Export Limitation** [17]	**Event Initiated (HV and above)** [18]	**ANM (HV and above)**
Thermal	✔	✔	✔
Voltage	✔	✔	✔
Tapchanger	✔[19]	✔	✔
Fault level	✘	✔	✘
System connectivity	✘	✔	✘
Infrequently operated generating plant	✘	✔	✘

There may be instances when the primary distribution system infrastructure is intact but the ancillary systems required as part of a flexible connection solution and / or to protect the distribution system effectively are affected by an outage (e.g. unavailability of an intertripping circuit or other communications channel). In such scenarios it may be necessary to restrict the operation of the Power Generating Facility.

The Generator should make their own assessment of the level of constraint associated with an Export Limitation scheme in order to determine the viability of such a connection arrangement. In assessing the viability of an Event Initiated or Active Network Management based flexible connection solution, the Generator should be provided with an estimate of the level of constraint that may be associated with the connection arrangement. It is important to explain to the Generator that the estimate of the constraints is an estimate based on assumptions that might change over a period of time.

[17] Export Limiting Schemes are self-managed by the Generator and may include a reverse power relay installed in the Generator's installation.

[18] Event Managed solutions may be suitable for Generators with an LV Point of Supply provided that the appropriate communications arrangements are in place, although the costs are likely to be prohibitive. 'Event Initiated' flexibility relates to an arrangement that is implemented when a defined undesirable event occurs on the system. See Appendix 5 for further details.

[19] The May 2016 issue of the Code of Practice on the installation of Customer Export Limitation Schemes, IMP/001/015, states that export Limitation schemes can only be used to manage voltage and thermal issues. This Code of Practice will be revised to permit such schemes to be used to manage tap changer constraints.

The provision of connection arrangements involving constraints requires that the constraint is understood by all the relevant departments of Northern Powergrid and the Generator. Hence such arrangements shall be agreed by the System Design Manager, the Northern Powergrid Control Centre and the Generator as being acceptable. Confirmation that the proposed arrangements are acceptable will be captured as an integral part of the formal Investment Appraisal Document associated with the connection design / offer process. A description of the flexible connection solution and the constraint shall be documented in the Connection Agreement.

Where restrictions are imposed by NGESO on the operation of distributed generation plant, there may be a liability for compensation to be paid to the Generator if they are constrained on or off. This is likely to be a consideration for Generators who are party to the Balancing and Settlement Code. Such connections need careful consideration in conjunction with NGESO. Generally, connections should be designed and the Connection Agreement written to eliminate the possibility of Northern Powergrid or NGESO becoming liable for constraint payments.

3.3.7. Future Proofing of the System

The connection of distributed generation should not impose significant restrictions on the way in which the Northern Powergrid distribution system can be developed, operated and maintained. In order to achieve this, consideration should be given to the electrical capacity on the system and the physical capacity at the relevant substation to install additional equipment, taking into account:

- the impact of connecting distributed generation to a lightly loaded substation that would prevent additional load being connected and cause existing assets to be sterilised e.g. through make duty limitations;
- the size of the proposed export compared to the export capability of that part of the distribution system;
- the number of / space for installing additional circuit breakers to accommodate future demand or generation connections;
- whether there is a high probability of further generation plant or demand being connected in the foreseeable future;
- proposed system modifications for the next ten years, including reinforcement, asset replacement and any impact arising from alterations to the transmission system; and
- the costs of any alternative arrangements that are more future proof.

3.3.8. Multiple Connections

When a system containing distributed generation is being designed, the presence of other generation connected to, or which will be connected to, that part of the system shall be considered. Where there are quotations for any connections which have been issued to a demand Customer or a Generator which are still within their validity period it shall be assumed that these connections will be made. The connection designs should take into account all connection interactivity. Interactivity can be associated with issues including thermal, voltage and fault level.[20]

The connection requirements for second and subsequent distributed generation connections to a given part of the distribution system may be more onerous than for the first and may involve modification to earlier connections.[21] Issues associated with power flow, voltage, fault level and stability are likely to be more serious when there is more than one distributed generation installation connected to part of a distribution system.

[20] Further information is provided in the Statement of methodology and charges for connection to the Northern Powergrid (Yorkshire) plc's electricity distribution system and the Statement of methodology and charges for connection to the Northern Powergrid (Northeast) Ltd's electricity distribution system.

[21] Care needs to be taken if the design of a new distributed generation connection is dependent on changes being required at an existing installation, as the existing Generator's agreement to any change is likely to be required.

3.3.9. Synchronising Equipment

Distributed generation plant shall be synchronised to the Northern Powergrid distribution system using circuit breakers fitted with synchronising equipment. Automatic synchronising is the preferred method which shall verify that the voltage and frequency of the Northern Powergrid system is within the range specified in EREC G99 for a minimum of 20 seconds. The Generator must provide their own synchronising plant on their side of the Point of Supply. Synchronising across a Northern Powergrid circuit breaker is not permitted.

Automatic reconnection of Type A Power Generation Modules is permitted as the norm in EREC G99. According to EREC G99, the installation of automatic reconnection systems for Type B, Type C and Type D[22] Power Generating Modules shall be subject to prior authorisation by the DNO. The installation of such systems is permitted for Power Generating Modules connected to Northern Powergrid's system; this permission should be recorded in the Connection Agreement. A Large Power Station (which would be operated by a Generator who is a CUSC party) or a Medium Power Station (which would typically be operated by a Generator with a LEEMPS agreement with the NGESO) is not permitted to resynchronise without permission from the NGESO.[23]

3.3.10. Power Generating Module Data

As part of the connection and commissioning procedure required by EREC G99, before any Power Generating Module is connected to the distribution system the location, connection arrangement and technical parameters, as defined in Distribution Data Registration Code (DDRC) 6 (Schedules 5a, 5b and 5c) of the Distribution Code, shall be provided by the Generator. Prior to commencing normal operation of their Power Generating Module, the Generator shall provide the 'as installed' connection arrangement and the technical data. For Type A Power Generating Modules, this information should be provided as part of the Installation Document. For Type B, Type C and Type D Power Generating Modules, this information should be provided as part of the Power Generating Module Document which is required before a Final Operational Notification can be issued. If a Power Generating Facility comprises a number of Power Generating Modules, information for each Power Generating Module shall be provided. The Power Generating Module Document should be regularly updated by the Generator as the project progresses as information becomes available or previously submitted estimated data can be confirmed. Where possible, information relating generating plant which is not intended to operate in parallel with the Northern Powergrid distribution system should also be recorded.

The Distribution Code and EREC G99 require that validated models of the Power Generation Modules are provided to the DNO by the Generator as part of the connection process. Northern Powergrid's practice was for such models to be provided, under a non-disclosure agreement, to consultants who carry out stability studies on behalf of Northern Powergrid. However, as required by EREC G99, for Type B, Type C and Type D Power Generating Modules, such models shall be made available to Northern Powergrid as part of the Power Generating Module Document. The availability of such models will enable Northern Powergrid to undertake detailed system modelling, including stability modelling, in the future.

3.3.11. Metering

Under the requirements of The Balancing and Settlements Code, where a Generator requires payment for his export, metering that is able to separately measure export and import shall be installed. Half hourly metering is required where the export is greater than 30kW. When specifying the metering circuit breaker, provision for any necessary metering voltage transformers and current transformers should be considered. Section L of The Balancing and Settlements Code and Clause 29 of DCUSA outlines the general requirements for such metering equipment. Specific requirements for metering current and voltage transformers are detailed in the Codes of Practice for Metering numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 that are issued under the Balancing and Settlement Code.

[22] Automatic reconnection is permitted where a Power Generation Module is a Type D PGM by virtue of being connected at 132kV rather than its registered capacity.
[23] Grid Code ECC.6.2.2.9.1.

3.4. System Study Requirements

3.4.1. Connection at Low Voltage

Prior to a Power Generating Module being connected to the Northern Powergrid LV distribution system, a technical assessment of the impact on the system shall be carried out. The exceptions to this requirement are Micro-generators (i.e. Power Generating Modules up to and including 16A per Phase) connecting in a single premises (within a single customer's installation) which are connected under the EREC G98 single connection process and installations that meet the criteria for connection as part of the 'Integrated Micro Generation and Storage Process'.[24] Studies shall take into account the normal operational configuration and credible outage configurations. The studies shall include an assessment of fault levels, load flow, steady state voltage profile, voltage step changes due to generation tripping and protection requirements. Any assumptions made during the design process should be recorded.

3.4.2. Connection at High Voltage and Extra High Voltage

Prior to distributed generation being connected to the Northern Powergrid EHV or HV distribution system, a technical assessment of the impact of the generation on the system shall be carried out. This shall be carried out on a computerised modelling system. Studies shall take into account the normal operational configuration and credible outage configurations. The studies shall include an assessment of fault levels, load flow, reactive power, steady state voltage profile, transient voltages, voltage step change due to generator tripping, generator transformer inrush, harmonic assessment, flicker assessment and protection. As part of the design and commissioning process the relevant Northern Powergrid Control Centre shall be advised which alternative system configurations have been assessed and whether the system design and protection design is such that the distributed generation can safely operate in that alternative operational configuration. The studies may identify opportunities to offer a Generator a flexible connection solution.

A connection at EHV or at HV via dedicated circuits should be designed to meet the Generator's security requirements in terms of being able to operate under the normal operational configuration and defined abnormal operational configurations, such as during an outage of the normal feeder.

A connection embedded in the HV system should be designed to operate under the normal operational configuration and also when connected via the most credible abnormal operational configuration.[25] Where the design and protection studies identify material system design or protection issues which are uneconomic to address when connected via the abnormal operational configuration, the Generator should be advised that their Power Generating Facility will only be permitted to remain connected to the system whist the system is configured normally; in any other system configuration they will be required not to export to, or disconnect from, the system. Depending on the system constraint associated with the alternative operational configuration it may be possible to deploy a flexible connection solution to manage the constraint.

3.4.3. Stability Studies

There are two stability issues relevant to the parallel operation of synchronous distributed generation i.e. steady state and transient stability.

Steady state stability is achieved by ensuring that the distributed generation remains synchronised under normal loading or exciter control. Modern Power Generating Modules are fitted with Automatic Voltage Regulators (AVRs) and rapid acting governors are unlikely to be unstable particularly if they are operated at lagging power factors. Problems may occur if there are two or more electrically close generators with 'weak' connections to the system.

[24] IMP/001/007/001 – Battery Energy Storage System Guidance Document describes a 'fast track' process for connecting battery storage in conjunction with micro- generation and an export limitation scheme provided certain criteria are met. The principles of the 'EREC G59 fast track process' can be applied to generation plant connecting under EREC G99. EREC G99 has been updated to describe this quicker connection process.

[25] The Design Engineer may want to discuss the credible abnormal configurations with Network Management and refer to Network Management's HV pickup plans.

Transient stability is achieved by ensuring that Power Generating Modules remain synchronised without pole slipping during and immediately after faults on the transmission or distribution system to which they are connected. If stability is not achieved there may be damage to the distributed generation plant and power surges resulting in unacceptable voltage fluctuations on the Northern Powergrid system.

The connection of non-synchronous distributed generation (e.g. inverter connected, asynchronous, DFIG)[26] to the system can affect reactive power flow on the system under fault conditions which can affect the stability of synchronous Power Generating Modules.

Where there are existing synchronous Power Generating Modules connected to the EHV or HV system, or the connection of new synchronous or non-synchronous Power Generating Modules is being studied, transient stability studies should be carried out. Where there is only distributed generation connected at HV, rather than undertake stability studies, the Generator should fit pole slip protection. [27]

Where part of a system contains only non-synchronous Power Generating Modules, stability studies are not required.

Distributed generation should be considered to be connected to the same part of the system if it is connected at the same voltage level and supplied from the same source substation.

Where system stability studies are required they should be based on data provided by the Generator as part of the Installation Document or Power Generating Module Document. Provision of this data to the DNO is required by EREC G99.

Stability studies for systems containing synchronous Power Generating Modules should be carried out with the Generating Unit controller included in the system model as this should better assess the stability of synchronous generation plant. Where the system model identifies stability issues the Generator should take all reasonable steps, including those set out in EREC G99, to ensure that their generation plant remains both connected and stable for the operational scenarios set out in EREC G99.[28] This is in addition to the requirement to fit pole slip protection required by EREC G99 to rapidly disconnect the Power Generating Module in the event of a pole slip arising from an operational scenario other than those set out in EREC G99. The installation of pole slip protection is to reduce the risk of damage to the Generator's assets, Northern Powergrid's distribution system and Customers' assets.

If the costs of ensuring stability in all the operational scenarios set out in EREC G99 is excessive then it may be permissible to ensure stability for as many of these operational scenarios as reasonably practicable, and for Northern Powergrid to accept the risks associated with pole slipping recognising that the Generator's pole slip protection, or preferably predictive pole slip protection should prevent multiple pole slip events.

3.4.4. System Study Data

The extent and accuracy of studies performed by Northern Powergrid is dependent upon the completeness and accuracy of the information provided by the Generator as part of the connection application process described in EREC G99. Where sufficient data is not available from the Generator to perform system studies and it is necessary to make assumptions relating to the technical parameters of the Power Generating Module, these assumptions shall be identified and any connection offer made shall include suitable caveats.[29] Where material assumptions have been made, the appropriate system studies shall be reviewed when the Generator provides the 'as installed' information required by EREC G99. For Type B, Type C and Type D Power Generating Modules 'as installed' data, including that required to undertake stability studies, shall be submitted by the Generator in the Power Generating Module Document that is required before a Final Operational Notification can be issued. The review of system studies based on the 'as installed' technical data shall be undertaken prior to energisation of the Generator's connection.

[26] Under system fault conditions non-synchronous generation plant can import reactive power from the system causing voltage reduction and potentially voltage collapse.

[27] Northern Powergrid experience is that stability studies for HV connected generation plant confirm that the plant is unstable and that they recommend installing pole slip protection i.e. carrying out stability studies doesn't serve any useful purpose.

[28] Section 9.

[29] DPC1.6.5 refers.

3.5. Technical Considerations

3.5.1. Short Circuit Current

When distributed generation operates in parallel with the distribution system, the short circuit currents imposed on Northern Powergrid distribution plant will increase.

Short circuit currents in the distribution system need to be modelled to ensure that all new and existing switchgear is adequately rated. Fault level studies covering short circuit make and break duties shall be carried out when assessing the impact of distributed generation on the system. HV and EHV system studies shall be carried out using a computer based package based on the requirements of Engineering Recommendation G74. The short circuit assessment shall assess the capability of switchgear taking to account the distribution system X/R ratio, as X/R ratios higher than 14.14 may reduce the capability of switchgear to less than its nameplate rating. Engineering Technical Report 120 and International Electrotechnical Commission (IEC) standard 60909 provide additional guidance regarding the calculation of short circuit levels.

The 20kV and 11kV systems have been designed based on maximum break duties of 350MVA and 250MVA respectively. These are referred to as the design fault levels. The corresponding make duty limits at 20kV and 11kV are 25.3kA and 32.8kA respectively. The low voltage systems have been designed based on maximum break duties of 18.75MVA and 25MVA in Northern Powergrid Northeast and Northern Powergrid Yorkshire respectively. There is no quoted make rating value for LV plant.

Because of the volume of plant connected to the system, the fault level duties on the LV system shall not exceed these figures, even when new, more highly rated equipment, is present at the point of connection.

It is permissible for the duty on HV equipment to exceed these design fault levels provided that the calculated make and break duties imposed on any piece of existing or proposed equipment does not exceed its capability. Where the duty exceeds the design fault level a bespoke assessment will be required to confirm that all equipment will operate within its capability for all operational scenarios. This will include establishing the short circuit capability of all equipment, including switchgear, cables, overhead lines, transformers, CTs etc.

Similarly it is permissible for the duty on EHV equipment to exceed the design fault levels;[30] provided that the calculated break and make duties imposed on any piece of existing or proposed equipment does not exceed its capability. Studies shall assess the impact of fault levels at other voltage levels in the same system and other systems capable of being connected to it.

Where there is an existing Operational Restriction[31] in place at a substation to manage a prospective fault level duty in excess of the capability of the equipment, further generation plant can be connected to the system even if it increases the fault level at that substation provided that:

- the increase in fault level can be accommodated within the existing Operational Restriction;
- the fault level issue can be resolved by the implementation of a standard Northern Powergrid design solution e.g. the replacement of transformers with standard higher impedance units or the replacement of an EHV or 132kV switchboard with standard higher rated equipment;[32] and
- The increase in fault level does not cause any issues at any other points of the system.

Where these conditions aren’t satisfied guidance should be sought from the System Planning Manager.

The introduction of a new Operational Restriction as part of a connection design is not permitted.[33]

[30] As set out in IMP/001/909 Code of Practice for Distribution System Parameters.

[31] e.g. OR12 or OR14.

[32] Such remedial works may or may not be included in the Investment Plan. Guidance should be sought from the System Planning Manager where the additional fault level contribution would prevent the implementation of a standard solution to address the issue.

[33] New operational restrictions may be permissible where they apply to HV overhead line equipment remote from the source HV substation e.g. expulsion fuses, automatic sectionalising link.

3.5.2. Fault Current Limiting Devices

Fault current limiting devices are designed to reduce the short circuit current imposed on electricity system equipment under fault conditions to within its rating. Given the safety related implications arising from short circuit current flowing through equipment which is greater than the capability of that equipment, it is essential that any devices used to limit short circuit current are:

- modelled correctly as part of the design process to ensure that it has the required performance; and
- of a 'fail-safe' design i.e. designed to limit the short circuit current to a safe level in the event that some or all of the components forming the device, including any associated control equipment, fails.

3.5.2.1. Fail-safe Fault Current Limiting Devices

Transformers and reactors are traditional devices that can be used to manage short circuit current and are considered to be fail-safe as the short circuit current is restricted by the inherent nature of the equipment.

Other fail-safe devices to limit short circuit current are available, including:

i. Superconducting Resistive Fault Current Limiters. Superconducting Resistive Fault Current Limiters comprise a resistive element made from superconducting material that is cooled to an extremely low temperature such that its resistance reduces to near zero. As the resistive element heats due to the passage of short circuit current, the resistance increases thus limiting the short circuit current. Such devices are generally considered to be fail-safe because the resistance of the supercooled resistor is designed to increase rapidly to a value that limits the short circuit current to a safe level if the cryogenic equipment fails. Northern Powergrid and Western Power Distribution have conducted trials of Superconducting Resistive Fault Current Limiters.[34]

ii. Pre-Saturated Core Fault Current Limiters. Pre-Saturated Core Fault Current Limiters comprise two AC winding and a DC winding round an iron core. The DC coil is used to magnetically saturate the iron core to provide a low impedance during normal operation. When the current through the device increases the AC flux in the iron core increases and the core can no longer remain saturated by the DC contribution resulting in the iron core being brought out of saturation such that the impedance of the device increases, hence restricting the short circuit current. In the event that the DC coil system fails the pre-saturation is lost and the device reverts to becoming a high impedance device. Hence such devices are generally considered to be fail-safe. WPD have conducted trials of Pre-Saturated Core Fault Current Limiters.[35]

iii. Back to Back AC-DC-AC converters. AC-DC-AC converters are considered to be fail-safe because, as in the case of an inverter connected asynchronous wind generator or PV system, the manufacturer will make sure that the short circuit current does not exceed the manufacturer's stated maximum short circuit current to prevent damage to the electronic components in the inverter.

3.5.2.2. Non Fail-safe Fault Current Limiting Devices

Is Limiters are products designed to limit short circuit currents presently manufactured by ABB[36] and G&W Electric;[37] such devices are considered to be non-fail-safe devices. Hence, as detailed in 3.5.2.3, the use of an Is Limiter to manage the short circuit current on the Northern Powergrid system **is not permitted**.

The ABB Is Limiter comprises a main current carrying conductor / contact with a parallel HRC fuse. A current transformer driven triggering device detects when the short circuit current and the rate of rise of

[34] Further information can be found on the following links: NPg 11kV Superconducting Fault Current limiter at Station Lane, Scunthorpe, NPg 33kV Superconducting Fault Current limiter at Jordanthorpe, and Western Power Distribution FlexDGrid project.

[35] Western Power Distribution FlexDGrid project.

[36] ABB manufacture the Is-Limiter.

[37] G&W Electric manufacture the CLiP Current Limiting Protector. Whilst the term 'Is limiter' strictly relates to the ABB device, it is typically used to describe fault current devices using a small explosive charge as part of the current limiting process.

short circuit current exceeds a predetermine threshold. When this threshold is breached, a small explosive charge opens the main current carrying contacts commuting the short circuit current to the parallel connected HRC fuse, where it is limited within 0.5ms and then finally interrupted at the next voltage zero passage.

The G&W Electric CLiP Current Limiting Protector comprises a segmented copper main current carrying conductor with a parallel fuse. A current transformer driven triggering device detects when the short circuit current and the rate of rise of short circuit current exceeds a predetermine threshold. When this threshold is breached, a small explosive charge breaks and bends upwards copper spanning multiple weak points in the segmented copper conductor causing gaps to form and arcs to form across the gaps. This results in the transfer of the short circuit current to the parallel fuse. The fuse melts and operates and current extinction occurs in the first voltage zero passage.

There are industry concerns associated with the use of these devices associated with:[38]

- Their intrinsic safety;
- Testing their operation;
- The integrity of the triggering system;
- The lack of an associated 'backup system';
- The possibility of legal constraints[39] preventing their use; and
- The possibility that a failure if the device to operate could overstress switchgear.

3.5.2.3. Application of Fault Current Limiting Devices

Fail-safe fault current limiting devices can be used to manage short circuit current on the Northern Powergrid 132kV, EHV or HV system. Where there is a need to restrict short circuit current, traditional equipment such as transformers and reactors, and network reconfiguration can be used, however other fail-safe fault current limiting devices, such as Superconducting Resistive Fault Current Limiters, Pre-Saturated Core Fault Current Limiters and Back to Back AC-DC-AC converters can also be considered, if they are a more economical solution. Where such non-traditional solutions are considered guidance should be sought from the Head of Smart Grid Implementation and the Policy and Standards Manager to ensure that equipment is suitable for the proposed application and is approved for use on the Northern Powergrid system.

Where a fail-safe non-traditional solution is proposed to be installed on a customer's system or IDNO system to manage a short circuit current on the Northern Powergrid system, guidance should be sought from the Head of Smart Grid Implementation to ensure that the customer or IDNO provides evidence that the device is fail-safe and will limit the short circuit current from their system such that all Northern Powergrid equipment operates within its capability.

Non fail-safe devices, including the ABB Is Limiter and the G&W Electric CliP Current Limiting Protector, cannot be used to manage short circuit current on the Northern Powergrid system. This prohibition applies to the installation of such devices on:

- the Northern Powergrid system to manage short circuit current on the Northern Powergrid system;
- an IDNO's system to manage short circuit current on the Northern Powergrid system; or
- a customer's installation to manage the short circuit current on the Northern Powergrid system.

[38] These concerns are described in more detail in a PB Power report, DG/CG/0022/REP Development of a safety case for the use of current limiting devices to manage short circuit currents on electrical distribution network, 2004. This report was produced by a work group comprising PB Power, DTI, HSE and Industry.

[39] Several legal concerns are raised in the PB Power report, the principle concerns relate: The Management of Health and Safety at Work Regulations 1992: Regulations 3 (1) (b), The Electricity at Work Regulations 1989: Regulations 5 and 29, The Electricity Safety, Quality and Continuity Regulations 2002: Regulations 3 (1) and 6.

Where an IDNO or a customer is seeking to manage short circuit current on their own system and there would be no issues for the Northern Powergrid system if the device was to fail, the selection and use of fault current limiting devices is a decision for the IDNO or customer, rather than Northern Powergrid. In this case, the Northern Powergrid system shall be designed as though the fault current limiting device was not installed i.e. based on the full, unrestricted short circuit current contribution from the IDNO or customer's installation.

3.5.3. Voltage Control

The systems employed by Northern Powergrid for maintaining the voltage provided to connected customers within statutory limits were developed in an environment when there was very little distributed generation connected to the system. Consequently, when the export from distributed generation exceeds the local load requirements, careful consideration must be given to the effect of 'reverse' power flow through the system as this will influence the voltage control systems.

When the registered capacity and operation of a distributed generation plant is such that the exported power exceeds the local load on the distribution system, power will be exported against transformer and circuit impedance to a higher voltage level, increasing system voltages. The connection and operation of generation plant shall be such that:

- The voltage at any point on the system where other customers are, or could be, connected, is within statutory limits set out in the ESQC Regulations. These are:

System Voltage	Voltage Range
230/400V	+10/-6%
6kV	+6/-6%
11kV	+6/-6%
20kV	+6/-6%
33/66kV	+6/-6%
132kV	+10/-10%

- The voltage at any part of the distribution system does not exceed the voltage rating of the plant forming part of the distribution system. These are:

System Voltage	Plant Rating
230/400V	1000V
6kV	7.2kV
11kV	12kV
20kV	22kV
33/66kV	36/72.5kV
132kV	145kV

Where the export from distributed generation is such that these two requirements are not met, the connection design will need to include one or more mitigation measures. Mitigation measures that should be considered are described briefly in the following sections and are discussed in more detail in IMP/001/915, Code of Practice for Managing Voltages on the Distribution System.

3.5.3.1. Connection at a Higher Voltage Level

Where a transformer has a de-energised tapchanger, at times of light load when the system voltage tends to be high, reverse power flows could cause the busbar voltage on the LV side of the transformer to go outside statutory limits quoted in the ESQC Regulations. Connecting the distributed generation plant at a higher voltage level could address the issue.

When distributed generation exports onto the distribution system at a position remote from the source substation, care should be taken to ensure that the consequent voltage rise on the feeder does not result in voltages outside the statutory limits quoted in the ESQC Regulations being imposed on other customers. Connecting the generation plant at a higher voltage level could address the issue.

3.5.3.2. Enhancing the Existing Voltage Control

When a transformer is equipped with an on-load tapchanger there may be limits to its reverse power capability and the voltage control scheme may not function correctly if the power factor as seen by the transformer is lower than approximately 0.7. Such a situation could occur where the real power output from a generation plant, operating at unity power factor, matches the real power requirements of the network and the reactive power requirements of the network is provided by the transformer. Where the reverse power capability is limited by the capability of the voltage control scheme, it may be possible to increase this capability by installing a modern voltage control scheme. There is currently a programme to install modern voltage control schemes in most substations; where required to support a customer connection it may be possible to advance the replacement of the voltage control scheme at a particular substation.

3.5.3.3. Changing the Voltage Control Set Point

It may be possible to reduce the set point voltage of an AVC control scheme to ensure that system voltage remains within the required limits. When considering this option system studies are required to ensure that voltages remain within the required limits under credible scenarios of demand and generation on the entire downstream system. It may be possible to mitigate the effects of lower voltages (e.g. when the generator is not operating) through the use of one or more of the following:

- HV and LV in line voltage regulators. Further guidance is provided in IMP/001/915/001 – An application guide for modelling and selecting HV voltage regulators;
- HV and LV shunt capacitors;
- Distribution transformer with an on-load tapchanger (OLTC); or
- Application of load drop compensation (LDC). Further guidance is provided in IMP/001/915/002 – An Application Guide for using Load Drop Compensation on HV Systems.

When considering such techniques, consideration should be given to developing a holistic solution that caters for the generation that is known or expected to be connected to that part of the system. The use of distribution transformers with an OLTC and the application of LDC should be considered on a case by case basis and further guidance may be sought from the Head of Smart Grid Implementation.

In order to comply with the Grid Code OC6 requirement to implement demand control via voltage reduction care should be taken to ensure that under normal operational conditions there are sufficient transformer taps to implement a 6% voltage reduction.

3.5.3.4. Constrained Connection

Where a voltage issue occurs in a scenario that is expected to occur infrequently it may be possible to offer the Generator a flexible connection solution that restricts the export under certain system conditions. Further details are provided in section 3.3.6 and Appendix 5.

3.5.4. Voltage Fluctuations

Voltages at the Point of Supply to customers' premises shall remain within statutory limits at all times. Under normal operation of distributed generation plant any voltage fluctuations shall be within the limits stated in Engineering Recommendation P28[40]. Normal operation includes synchronising, increasing output to the maximum and taking the generation plant off line. Limits on the generation plant ramp up and ramp down rates may need to be imposed to ensure that system transformer tapchangers have time to operate if required. For unplanned outages such as faults it will generally be acceptable to design to a step voltage

[40] Guidance on the application or EREC P28 when assessing the connection of battery storage systems is provided in IMP/001/007/001 – Battery Energy Storage System Guidance Document.

change of 10% of nominal voltage.[41] Where a Power Generating Facility comprises a number of Power Generating Modules, the step voltage change considered shall be that under the most onerous condition. This is likely to be operation of the metering circuit breaker.

Voltage fluctuations should be assessed:

- under full and minimum system loading conditions. The minimum load used when undertaking analysis should be based on a realistic minimum demand[42] rather than an absolute minimum; and
- at the extremes of the power factor operating ranges stated in section 3.5.6.

The most onerous voltage fluctuation is likely to arise as a result of the metering circuit breaker opening.

3.5.5. Power Flow

When the registered capacity and operation of a Power Generating Facility is such that the exported power exceeds the local load on the distribution system, power will be exported through the system in the 'reverse' direction.

Any reverse power flow must be within the capabilities of the equipment on the distribution system, taking due account of the profile of the power flow. The rating of overhead lines and underground cables is not related to the direction of the power flow, but where the power flow is dominated by the output from the Power Generating Facility, the profile is likely to be different than that associated with demand customers. The use of continuous, rather than cyclic, ratings will therefore generally be appropriate, although generic or bespoke cyclic ratings can be applied where there is a high degree of confidence of the future profile of the current flowing through a cable or transformer.[43]

Where a substation is equipped with two transformers normally operating in parallel, the export through the substation should normally be limited to the Summer Typical Bespoke Static Continuous Oil Forced Air Forced (OFAF) rating of one transformer,[44] taking into account an assessment of the realistic minimum demand supplied from the substation. The export used in this assessment should be the aggregate of the contracted export capacity of generation plant with a registered capacity of 100kW[45] or greater connected to the substation.

The same requirement applies where a substation is equipped with a single transformer, such that the export through the substation should normally[46] be limited to the Summer Typical Bespoke Static Continuous Oil Natural Air Natural (ONAN) rating, although it may be possible to utilise the OFAF rating provided that there is thermal monitoring of the transformer as set out below is installed. In this case when the transformer is out of service, it is probable that the Generator will not be able to export.

Transformers used on the EHV system generally have ratings which recognise that they are normally operated in parallel with a similar transformer. Supplementary cooling, facilitated by fans and oil pumps is generally provided to increase the current carrying capability under outage conditions. This auxiliary equipment is not designed for continuous operation and where the generation results in power flows in excess of the Summer Oil Natural Air Natural (ONAN) rating of a transformer for extended periods (whilst remaining less than the OFAF rating), consideration should be given to installing a scheme to either i) detect a failure of the fans and pumps, or ii) to detect when the Winding Temperature Alarm level has been reached to indicate a problem with this ancillary equipment. Such a scheme would send an alarm and subsequent trip signal to the Generator rather than relying on the Winding Temperature Alarm to indicate a problem to a Control Engineer which would require manual intervention.

---

[41] EREC G59/3: para 9.5.7. EREC G99 refers to EREC P28.

[42] Further guidance is provided in section 3.5.5.

[43] For example the export from PV generation will have an inherent daily profile, unlike that of wind generation.

[44] The principle is that i) under normal operating conditions the power flow through the transformer will be within its Summer Typical Bespoke Static Continuous ONAN rating and ii) for a transformer outage, load on the remaining transformer will be within its Summer Typical Bespoke Static Continuous Rating OFAF rating. The capability of a transformer should be based on a summer ambient temperature of 25°C. Further guidance on transformer ratings is given in IMP/001/918 - Code of Practice for Transformer Ratings.

[45] 100kW is the de-minimis value in ETR130.

[46] Export up to the Summer OFAF rating may be acceptable where an alarm and trip scheme is installed as set out below.

A further detail on transformer ratings is given in IMP/001/918 – Code of Practice for Transformer Ratings. When assessing the capability of a transformer to cater for the power flows from Power Generating Facilities, it is permissible for the transformer hotspot temperature to exceed 98°C provided that it does not exceed 140°C and the daily transformer relative ageing rate is unity or less. Where the operation of fans and or pumps is required to ensure that these temperatures aren't breached, a scheme to detect failure of such equipment shall be installed.

In addition to being within the thermal capability of a transformer, the reverse power flow must be within the reverse power capability of the transformer tapchanger. Not all on-load tapchangers fitted to system transformers have the same capability to cater for reverse power flow as for forward power flow; the capability depends on the type and design of the tapchanger. Guidance of the reverse power capability of transformers installed on the EHV system is given in NSP/003/012 – Guidance Document for Reverse Power Flow Capabilities of On-Load Tapchangers. When assessing the potential reverse power flow an assessment of the realistic minimum demand supplied from the substation and the contracted export capacity as per the thermal assessment should be carried out.

When assessing whether the duty on a transformer is within the thermal capability and the capability of its tapchanger, a view of the realistic minimum network demand should be made taking into account the:

- gross network demand after having taken the demand directly supplied by generation into account. This will require an assessment of the half hourly export from generation plant which, for power generating facilities of 30kW and above is available via the settlement metering system;[47]
- likelihood of network demand materially reducing if known e.g. as a result of the closure of a commercial or industrial customer site; and
- time of day e.g. assessing the minimum demand during daylight hours when considering export from PV generation plant.

Where cost-effective, it may be appropriate to carry out a bespoke thermal rating study using wind speed measuring/modelling for overhead lines,[48] soil thermal resistivity measurements for cables[49] and thermal modelling for transformers.[50] Using such data and modelling it is possible to calculate circuit specific ratings which may release latent thermal headroom. The use of real time thermal ratings as an input into an Active Network Management system or other flexible connection solution can also be considered.

A flexible connection solution can be considered when the reverse power capability of a transformer and / or its tapchanger does not provide sufficient export capacity to meet the Generator's requirements.

3.5.6. Power Generating Module Power Factor

3.5.6.1. Background

Voltage control and power factor control systems used by Power Generating Modules are linked. Controllers operate in one of three modes:

- Voltage Control. In this mode the reactive power is varied to maintain a constant target voltage; at a given level of export MW, the real power remains constant and power factor is variable. This is typically referred to as PV mode;
- Power Factor Control: In this mode the reactive power is varied so that the ratio between real and reactive power is constant, i.e. fixed power factor. This is typically referred to as PQ mode; and
- Reactive Power Control: In this mode the reactive power is held constant to maintain a constant target level of reactive power; real power and power factor are variable.

[47] This is available in the new PI system.

[48] Further details are provided in IMP/001/011 - Code of Practice for Overhead Line Ratings and Parameters.

[49] Further details are provided in IMP/001/013 - Code of Practice for Underground Cable Ratings and Parameters.

[50] Further details are provided in IMP/001/918 - Code of Practice for Transformer Ratings.

Power Generating Modules should normally be set to operate in Power Factor Control (PQ) mode. Further guidance on these operating modes is provided in IMP/001/007/002 – Application guide for modelling generator reactive power control modes.

3.5.6.2. Power Generating Module Capability

EREC G99 sets out the power factor operating range throughout which Power Generating Modules should be capable of operating. There are slightly different requirements for the different types of Power Generating Modules i.e. Types A, B, C and D. Generally, the requirement is for the Power Generating Module to be capable of operating throughout the range 0.95 lagging to 0.95 leading, assessed at the Point of Supply, although for Type C and D Synchronous Power Generating Modules, the required operating range is 0.92 lagging to 0.92 leading. This capability should be demonstrated by the Generator in the Information Document or Power Generating Module Document provided by the Generator as part of the connection process.

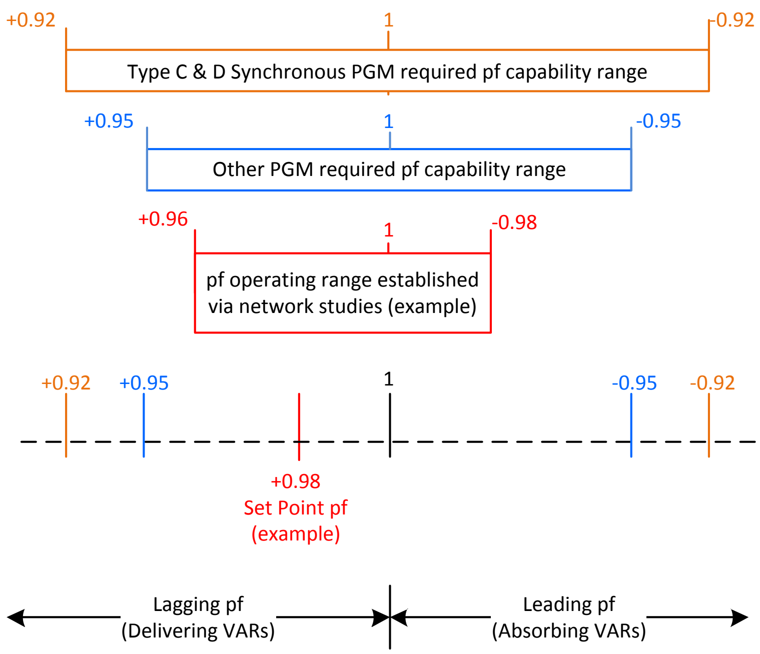
When connected to the Northern Powergrid system, the Power Generating Module may not be able to operate across the whole of its capability range, for example, operation at leading power factors may cause stability issues. The system studies carried out as part of the connection design shall:

- establish the power factor range within which the Power Generating Module can operate whilst complying with the thermal and voltage, requirements of the relevant Economic Development Codes of Practice; and
- where system stability studies are carried out as part of the connection design, establish the power factor operating range within which stability can be maintained by varying the power factor used in the studies between 0.95 lagging to 0.95 leading (or 0.92 lagging to 0.92 leading for Type C and D Synchronous Power Generating Modules).

The power factor range from thermal and voltage assessment and from the stability assessment should be amalgamated to establish the power factor range within which thermal, voltage and stability issues will not be incurred. This range, which may be smaller than the capability range set out in EREC G99, shall be recorded in the Investment Appraisal Document or Scheme Release Document, as appropriate, and the Connection Agreement.

Where a Power Generating Module cannot achieve compliance with Northern Powergrid's Economic Development Codes of Practice across the power factor range capability range set out in EREC G99, for example where there is excessive voltage rise when operating at a power factor of 0.95 lagging, or where the Power Generating Module would become unstable when operating at a leading power factor, Northern Powergrid will be flexible on requiring compliance throughout the operating range provided that the Generator acknowledges the right for Northern Powergrid to require operation within the full power factor operating range set out in EREC G99 in the future and that this may require the Generator to change their operational behaviour e.g. constrain their output to a level at which issues on the distribution system cease, or potentially install additional equipment to ensure system stability.

The EREC G99 capability ranges, the operating range established via network studies and the power factor set point are illustrated in the diagram below:



In order to retain this future flexibility, the Connection Agreement shall state the requirement for the Power Generating Module to operate across the full power factor operating range set out in EREC G99. It is important to note that Northern Powergrid will not require a Power Generating Module to operate at a power factor that could result in Power Generating Module or system instability.

Whilst demonstration of compliance with the power factor requirements would normally be assessed at the Generator's Point of Supply,[51] there is the option to assess the compliance at the Generating Unit terminals. It may be reasonable to do this where the Generation Unit is deeply embedded in a Customers installation. In this case, modelling would need to be carried out to reflect the demonstrated capability at the Generating Unit terminals to the performance at the Point of Supply which is where compliance with EREC G99 is required.

Whilst the Power Generating Module Performance Chart should normally be provided at the Point of Supply there is the option for this to relate to the Generating Unit terminals.

3.5.6.3. Establishing the Power Factor Set Point

For Power Generating Modules connected to the Northern Powergrid distribution system at EHV or at HV via a dedicated HV circuit to an EHV to HV substation, Northern Powergrid will establish the operating power factor that the Power Generating Module should operate at during the connection design study in accordance with IMP/001/007/002 – Application guide for modelling generator reactive power control modes. The exception to this is where the Power Generating Module is connected to a part of the system where new Power Generating Facilities above 1MW fall within the scope of the CUSC Statement of Works process. In this case, it is likely that the Power Generating Module will need to be set in Power Factor Control mode with a set point power factor of unity, or in Reactive Power Control mode with a setting to offset any significant cable susceptance associated with the new connection.[52] This is to avoid exacerbating the issues associated with reactive power export onto the transmission system. The aim of IMP/001/007/002 – Application guide for modelling generator reactive power control modes is to establish the optimum power factor that reduces reactive power flow on the system and hence reduces system losses. Typically the power factor set point would be the power factor at the part of the system where the

[51] Referred to as the Connection Point in EREC G98 and G99.

[52] Under the Statement of Works process NGESO may expect Northern Powergrid to not increase the reactive power export at the GSP as a result of connecting a new Power Generating Module, so the Generator may need to operate their plant to absorb the reactive power associated with any significant new cable added to the Northern Powergrid network as part of the new Generator's connection.

Power Generating Module is connected. If the Power Generating Module is connected to a part of the system where the power factor is low, for example in a ring system, the power factor set point would normally be a minimum of 0.95 lagging.

For Power Generating Modules connected at HV (other than via a dedicated HV circuit to an EHV to HV substation) or at LV, Northern Powergrid will normally agree with the operating power factor proposed by the Generator, provided that it is in the range 0.95 lagging to Unity.

For Power Generating Modules connected at EHV or at HV, operation at a leading power factor may also be acceptable where there is reasonable justification.

Generators with connections at EHV and HV may be required to change the power factor set point of their Power Generating Modules periodically to a value within the range set out in the Connection Agreement, for example where the power factor of the system changes, as required by Northern Powergrid.

The agreed fixed power factor should normally refer to the Generator's Point of Supply to the distribution system. Where a Power Generating Facility is supplied via a long circuit, consideration should be given to the reactive characteristics of the circuit[53] when establishing the power factor set point of the Power Generating Module. This may result in the Power Generating Module operating at a leading power factor at the Point of Supply.[54]

The initial and any revised power factor set point shall be recorded in the Connection Agreement.[55]

3.5.7. Monitoring and Control

Facilities shall be provided at Power Generating Facilities connected to EHV, HV and to LV systems when the Power Generating Facility is subject to half hourly metering to monitor and record operational information in accordance with IMP/001/017 – Standard for the Application of System Monitoring.

IMP/001/014, Policy for the Protection of Distribution Networks, requires the installation of power quality logging equipment at sites where the aggregate installed Power Generating Module capacity exceeds 200kVA. It is Northern Powergrid's preference to supply and install the equipment that provides both power quality monitoring and fault disturbance information as part of the generation connection project; however there may be instances in which the Generator wishes to supply and install the equipment and provide Northern Powergrid with this information. In these circumstances Northern Powergrid shall provide the customer with the functional specification for such monitoring equipment, the data items to be provided and the means of transferring the data to Northern Powergrid e.g. measurement values, accuracy, sensitivity, sampling rates, communications protocols, error handling, security arrangements etc. Power quality and fault disturbance information, whether sourced from Northern Powergrid's or the Generator's equipment, shall be stored in the Northern Powergrid iHost system or another approved standard company database for use in the investigation of system disturbances.

In addition to providing these monitoring facilities the following control functionally should be provided:

- Remotely control the operation of the metering circuit breaker;[56]and
- Provide a signal that the Generator can use to trip their synchronising circuit breaker.

In addition consideration should be given to facilitate the future requirement to regulate the output from a Generator's Power Generating Module.

These requirements are likely to be required in the future to manage the export from generation as DNOs take a more proactive role in managing power flows on distribution systems.

[53] Typically this should be considered where the new connection involves the installation of more than 5km of 11kV cable, 3km of EHV cable or any length of 132kV cable.

[54] Where more than one Power Generating Facility is connected to a circuit care needs to be taken to ensure that any differences between their controls coordinate with rather than 'fight' against each other.

[55] Normally via a schedule in the Connection Agreement.

[56] This functionality is currently provided via SCADA where the connection is provided at EHV or at HV via a dedicated HV cable to an EHV to HV substation.

3.5.8. Protection

The protection requirements of EREC G99 are designed to ensure that a Power Generating Module is disconnected if the voltage or frequency at the point of supply deviates outside acceptable limits or if the incoming supply fails. This protection shall be generally installed on the Generator's system on the synchronising circuit breaker.

The Northern Powergrid interface protection is designed to ensure the safety of the distribution system and shall be installed on the Northern Powergrid circuit breaker at the point of supply. This is generally the metering circuit breaker.

In designing the protection scheme, consideration should be given to the Generator's requirements to operate in island mode and to resynchronise following a failure of the Northern Powergrid supply.

Protection for systems comprising distribution generation shall be in accordance with IMP/001/014 – Policy for the Protection of Distribution Networks.

3.5.9. Auto Reclose Equipment

The design of a generator connection, and in particular the associated protection scheme, shall ensure that synchronisation shall not take place across Northern Powergrid equipment. This is particularly important where auto-reclose schemes, either substation or pole mounted, are installed.

3.5.10. Earthing

The Generator's earthing system shall meet the requirements of British Standard BS 7430:2011. LV networks and HV distribution substations should be designed to meet the requirements of IMP/010/011 – Code of Practice for Earthing LV Networks and HV Distribution Substations. The HV system is designed to have only one point of earth on a given system. When HV connected distribution plant operates in parallel with the HV system it should utilise the Northern Powergrid HV system earth. The low voltage distribution system is a multipoint earth system, and there are several earthing options described in EREC G99. The rise in earth potential in the Northern Powergrid substation should be calculated in accordance with Engineering Recommendation S34. Substation earthing arrangements shall be designed in accordance with ENA Technical Specification 41-24.

3.5.11. Connections via Long Cables

In order to avoid issues associated with securing the permissions required to construct new overhead lines to connect new generators in remote rural locations, typically such connections are made using long lengths of 132kV, EHV or HV cables. Depending on the length of such cables there can be issues associated with capability of switchgear to cater for the capacitive charging currents when the cable is energised and the ability to carry out fault location and pressure testing using standard test equipment. Present practice is to install intermediate isolation / switching points such that the maximum section length of 132kV and EHV cable is 10km and the maximum section length of HV cable is 7km.[57]

3.5.12. PV Installations on Domestic Premises

The peak output from PV arrays typically installed on the roofs of domestic premises is likely to be higher than the nominal rated capacity stated in the EREC G98 commissioning certificate. The maximum output is typically 110% of the rated capacity although this can be up to 130%.

Analysis of the output from 100 PV distributed generation installations across the country shows that the diversified maximum output per unit varies between 1.1 and 0.9 times the nominal rated capacity.[58] This analysis took into account the diversity across PV arrays from a variety of manufacturers, installation orientation and geographic location as well as the finding that PV output is typically greater than the nominal rating.

[57] Further background information can be found in EATL STP Report S5243_1: AC Cable Connections: Practical and Electrical Limits to Their Length.
58 CLNR L095 Solar Photovoltaic (PV) Installations: Technical Note and Appendix 7 refer.

When assessing the effect of PV installations on the distribution system, a diversity factor should be applied to the nominal rated capacity of each PV installation. The diversity to be applied depends on the number of PVs connected to the part of the network being assessed and whether the PV arrays are randomly oriented (as might be the case in a new housing development) or aligned (as might be the case where PV arrays are installed on south facing roofs of a row of refurbished terraced housing).

PV installations where the arrays are randomly orientated:

Number of Premises Equipped with a PV Array (per phase)	Diversity Factor
Greater than 30	0.9
Between 5 and 30	0.95
Less than 5	1.0

PV installations where the arrays are aligned:

Number of Premises Equipped with a PV Array (per phase)	Diversity Factor
Greater than 30	0.95
Between 5 and 30	1.0
Less than 5	1.1

Further information is given in Appendix 7.

4. References

4.1. External Documentation

Reference	Title	Version and/or Date
BS 7430:2011	Code of Practice for Protective Earthing of Electrical Installations.	2011
Distribution Connection and Use of System Agreement (DCUSA)	The Distribution Connection and Use of System Agreement is a multi-party contract between the licensed electricity distributors, suppliers, and generators of Great Britain.	Nov 2019
EATL STP Report S5234_1	AC Cable Connections: Practical and Electrical Limits to Their Length.	Jan 2015
Electricity Act 1989	Electricity Act 1989.	1989 (as amended)
ENA Engineering Report 124	Guidelines for Actively Managing Power Flows Associated with the Connection of a Single Distributed Generation Plant.	2012
ENA Engineering Report 126	Guidelines for Actively Managing Voltage Levels Associated with the Connection of a Single Distributed generation Plant.	2012
ENA Engineering Report 130	Guidance on the Application of Engineering Recommendation P2, Security of Supply	Aug 2019
ENA Engineering Report 131	Analysis Package for Assessing Generation Security Capability – Users' Guide.	2012
ENA Technical Specification 41-24	Guidelines for the Design, Installation, Testing and Maintenance of Main Earthing Systems in Substations.	2009
Engineering Recommendation G100	Technical Requirements for Customer Export Limiting Schemes.	May 2018
Engineering Recommendation G5	Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom.	Issue 5 Jun 2020
Engineering Recommendation G59	Recommendations for the Connection of Generating Plant to the Distribution Systems of Licensed Distribution Network Operators.	Issue 3-7 Sep 2019
Engineering Recommendation G74	Procedure to Meet the Requirements of IEC 60909 for the Calculation of Short-circuit Currents in Three-phase AC Power Systems.	1992
Engineering Recommendation G83	Recommendations for the Connection of Type Tested Small-scale Embedded Generators (up to 16A Per Phase) in Parallel with Low-voltage Distribution Systems.	Issue 2-3 Jun 2019
Engineering Recommendation G98	Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public low-voltage distribution networks on or after 27 April 2019	Issue 1-4 Jun 2019
Engineering Recommendation G99	Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019.	Issue 1-6 Mar 2020
Engineering Recommendation P2	Security of Supply.	Issue 7 Aug 2019
Engineering Recommendation P28	Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom.	Issue 2, May 2019
Engineering Recommendation P29	Engineering Recommendation P29: Planning Limits for Voltage unbalance in the United Kingdom for 132kV and below.	1990
Engineering Recommendation S34	A Guide For Assessing the Rise of Earth Potential at Substation Sites.	Nov 2018

Reference	Title	Version and/or Date
Engineering Technical Report 120	Calculation of Fault Currents in Three-phase AC Power Systems (Application Guide to Engineering Recommendation G74).	1995
Health and Safety at Work	Health and Safety at Work etc. Act 1974.	1974
IEC 60909	Short-circuit Currents in Three-phase a.c. Systems.	2001
Requirements for Generation (RfG)	Commission Regulation (EU) 2016/613 of 14 April 2016 establishing a network code on requirements for grid connection of generation.	Apr 2016
Standard Licence Conditions (SLC)	Standard conditions of the Electricity Distribution Licence.	Apr 2015
Statutory Instruments 1989 No. 635	The Electricity at Work Regulations 1989.	1989
Statutory Instruments 2002 No. 2665	The Electricity Safety, Quality and Continuity Regulations 2002.	2002 (as amended)
The Balancing and Settlement Code (BSC)	The code that contains the rules and governance arrangements for the electricity balancing and settlement arrangements in England, Wales and Scotland.	Nov 2019
The Connection & Use of System Code (CUSC)	The Connection & Use of System Code constitutes the contractual framework for connection to, and use of the Great Britain's (GB) high voltage transmission system.	Apr 2020
The Distribution Code	The Distribution Code and The Guide to the Distribution code of Licensed Distribution Network Operators of Great Britain.	Issue 45, Jun 2020
The Grid Code	The Grid Code sets out the operating procedures and principles governing the relationship between NGESO and all Users of the National Electricity Transmission System, be they Generators, DC Converter owners, Suppliers or Non-Embedded Customers.	Issue 5, Revision 43, Jun 2020

4.2. Internal Documentation

Reference	Title	Version and/or Date
IMP/001/007/001	Battery Energy Storage System Guidance Document	Apr 2018
IMP/001/007/002	Application guide for modelling generator reactive power control modes	Jun 2018
IMP/001/010	Code of Practice for Standard Arrangements for Customer Connections.	Nov 2018
IMP/001/011	Code of Practice for Overhead Line Ratings and Parameters	Dec 2017
IMP/001/013	Code of Practice for Underground Cable Ratings and Parameters	Nov 2019
IMP/001/014	Policy for the Protection of Distribution Networks	Jul 2016
IMP/001/017	Standard for the Application of System Monitoring	Apr 2019
IMP/001/206	Guidance for assessing Security of Supply in accordance with Engineering Recommendation P2/6.	Jul 2019
IMP/001/911	Code of Practice for the Economic Development of the LV System.	Nov 2018
IMP/001/912	Code of Practice for the Economic Development of the HV System.	Jul 2018
IMP/001/913	Code of Practice for the Economic Development of the EHV System.	Jun 2020
IMP/001/914	Code of Practice for the Economic Development of the 132kV System.	Jun 2020
IMP/001/915	Code of Practice for Managing Voltages on the Distribution System	Feb 2017
IMP/001/915/001	An application guide for modelling and selecting HV voltage regulators	Aug 2017
IMP/001/915/002	An Application Guide for using Load Drop Compensation on HV Systems.	Jan 2018
IMP/001/918	Code of Practice for Transformer Ratings	Jun 2017
NSP/003/012	Guidance Document for Reverse Power Flow Capabilities of On-Load Tapchangers.	Jun 2018

4.3. Amendments from Previous Version

4.3.1. Changes between version 6.0 to 7.0

Section	Amendment
3.1.8	Reference updated to current EA Standard Application Form.
3.1.7	Title of EREC G83 corrected.
3.3.2	Title of EREC G83 corrected.
3.5.1	Fault current corrected from 23.5kA to 25.3kA
3.5.2	Section expanded to clarify the policy relating to fault current limiting devices.
4.1	Minor updates.
Appendix 6	Updated reference from G83 to G98.
General	Titles of EREC P29 and G5 updated.

4.3.2. Changes between version 5.0 to 6.0

Section	Amendment
3.3.2	Clarification of application of EREC G98 & G99 now that their implementation date (27 April 2019) has passed.
3.3.2	Clarification of the application of EREC P2 to generation connections.
3.5.6.1	Description of the three PGM control modes added.
3.5.6.2	Section (previously) 3.5.6.3 substantially rewritten to: • Clarify the PGM capability range as set out in G99 • Include a new requirement for stability studies to establish the leading power factor at which instability occurs • Include a requirement to establish and record the operating power factor range • Include an explanatory diagram
3.5.6.3	Section (previously) 3.5.6.2 rewritten to provide guidance on establishing the set point where a PGF is covered by a Statement of Works requirement
All	Minor typographical changes

4.3.3. Changes between version 4.0 to 5.0

Section	Amendment
1	Clarification that this CoP provides guidance on flexible connection solutions.
1	Reference added to EU Network Code Requirements for Generators.
2	Clarification that this CoP applies to when designing connections to IDNO networks.
2	Clarification that this CoP applies when designing connections to electricity storage systems.
2	Reference to the following documents added: IMP/001/010 - Code of Practice for Standard Arrangements for Customer Connections, IMP/001/007/001 – Battery Energy Storage System Guidance Document; IMP/001/007/003 - Application Guide on Flexible Connection Solutions
3.1.5	Reference to the Losses Strategy updated.
3.1.7	Clarification of the data required from Generators prior to commercial operation.
3.1.7	Reference added to the new generation connection ENA standard application form.
3.1.7	Reference added to the new Engineering Recommendations G98 and G99.
3.1.8	Clarification of the Statement of Works process, and the introduction of the NCET Bilateral Connection Agreement Appendix G site specific requirements.

Section	Amendment
3.1.8	Reference to the generation heat maps.
3.3.10	Clarification of the data required from Generators prior to commercial operation and the provision of this data via the Installation Document / Power Generating Module Document.
3.3.2	Reference added to Engineering Recommendations G98, G99 and G100.
3.3.2	Explanation provided re the applicability of EREC G83, G59, G98 and G99.
3.3.2	New terminology added to reflect RfG terminology.
3.3.4	Typical 132kV connection arrangement drawings included in new Appendix 1. Other appendices have been renumbered accordingly
3.3.4	Clarification added that the requirements of IMP/001/010 apply to generation connections.
3.3.4	Reference to IMP/001/014 – Policy for the Protection of Distribution Networks added.
3.3.4	Reference to the Network Unavailability scheme removed as it is included in the Charging Methodology statements.
3.3.6	Section rewritten to describe flexible connection solutions.
3.3.6	Clarification added that for an Export Limitation flexible connection solution the Generator should make their own assessment of the impact of the constraint. For other flexible connection solutions Northern Powergrid should provide an estimate of the constraint.
3.3.7	Further guidance added re the issues to consider where a connection might sterilise part of the Northern Powergrid system.
3.3.7	Clarification added that planning period is ten years.
3.3.8	Clarification that interactive connections can relate to thermal, voltage and fault level issues.
3.3.9	New paragraph added to set out the requirements in EREC G99 relating to the installation and use of automatic reconnection / resynchronisation equipment.
3.4.1	Clarification that system studies are not expected where a Generator is seeking connection under the ‘G59 fast-track’ or new ‘G99 Integrated Micro generation and Storage’ process.
3.4.2	Clarification of the requirement to advise Network Management of operational restrictions associated with any new connection.
3.4.2	Clarification that a flexible connection solution may be used to manage a constraint where distribution generation is connected via an alternative feeding arrangement.
3.4.3	Clarification of the DCode, G59 and G99 requirements re the operational scenarios when stability is required and the scenarios when pole slip / predictive pole slip protection should be installed.
3.4.4	Clarification of the data required from Generators prior to commercial operation and the provision of this data via the Power Generating Module Document before a FON can be issued.
3.5.1	Clarification that the 350MVA and 250MVA legacy HV fault levels are ‘design fault levels’.
3.5.1	Clarification that it is permissible for the duty on EHV and HV equipment to exceed the design fault levels provided that the calculated make and break duties imposed on any piece of existing or proposed equipment does not exceed its capability.
3.5.1	Confirmation of the requirement that the introduction of a new Operational Restriction as part of a connection design is not permitted.
3.5.10	Reference to the new IMP/010/011 - Code of Practice for Earthing LV Networks and HV Distribution Substations.
3.5.3	Reference to IMP/001/915 added.
3.5.3.2	Reference added to the voltage control scheme replacement programme.
3.5.3.3	Reference to guidance documents IMP/001/915/001 and IMP/001/915/002 added.
3.5.3.3	Reference to ANM changed to refer more generally to flexible connection solutions.

Section	Amendment
3.5.5	Reference added to generic and bespoke static ratings in relation to cables and transformers.
3.5.5	Clarification of the capability of transformers to accommodate reverse power flow and reference to IMP/001/918.
3.5.5	Clarification of the functionality of the control scheme to guard against failure of oil pumps and fans.
3.5.6	Reference added to the guidance on generator operating modes, IMP/001/007/002.
3.5.6	Section substantially rewritten to: • clarify the power factor requirements for EHV, HV and LV connected Power Generating Modules • set out the requirement to establish, as part of the design studies, the power factor range within which the generating plant can operate when connected to the NPg system • clarify the flexibility when a Generator is unable to meet the power factor range design requirements • refer to the flexibility in RfG to assess the Generators power factor compliance at the generating unit terminals rather than at the Connection Point • clarify the flexibility when generation plant is supplied via a long circuit
3.5.7	New section to capture the new monitoring requirements and control requirements.
3.5.8	Reference to the new IMP/001/014 – Policy for the Protection of Distribution Networks.
4.1	External document references updated
4.2	Internal document references updated.
5	New definitions added including EU terminology.
All	Minor typographical changes and use of new EU terminology.
Appendix 1	New appendix showing 132kV connection arrangements.
Appendix 2-4	Exiting Appendices renumbered
Appendix 5 (was Appendix 4)	Substantially rewritten to describe the flexible connection solutions that Northern Powergrid can offer.
Appendix 6 (was Appendix 5)	Revised to reference the new ENA standard application form and changes to the DCode

5. Definitions

Reference	Title
ANM	Active Network Management
AVRs	Automatic Voltage Regulators
BEIS	Department for Business Enterprise and Industrial Strategy
BS	British Standard
BSC	The Balancing and Settlement Code
CLNR	Customer Led Network revolution
CUSC	The Connection & Use of System Code
DCUSA	Distribution Connection and Use of System Agreement
DDRC	Distribution Data Registration Code
Distributed Generation	A generating plant connected to the distribution network, where a generating plant is an installation comprising one or more generating units.
DNO	Distribution Network Operator
DPC	Distribution Planning and Connection Code of the Distribution Code
EHV	Extra High Voltage: a voltage at 33,000V and above.
ENA	Energy Network Association
ENA TS	ENA Technical Specification
EREP	ENA Engineering Report
ESQC Regulation	Electricity Safety, Quality and Continuity Regulation
ETR	ENA Engineering Technical Report
Final Operational Notification (FON)	A notification issued by the DNO to a Generator, who complies with the relevant specifications and requirements in this EREC G99, allowing them to operate a Power Generating Module by using the Distribution Network connection.
Flexible Connection Solution	A connection solution offered to a Generator involving some form of operational restriction as a means of managing a system constraint.
GB	Great Britain
Generating Unit	Any apparatus which produces electricity. This includes micro-generators and energy storage devices. Note that although storage is in the scope of EREC G99, some aspects do not apply. The exclusions are noted where they apply in the text.
Generator	A person or a business that generates electricity under licence or exemption from Section 4.1(a) of the Electricity Act 1989 (as amended).
HV	High Voltage: a voltage greater than 1000V, but less than 33,000V.
IEC	International Electrotechnical Commission.
LIFO	Last In First Off
LV	Low Voltage: a voltage up to and including 1000V.
Micro-generator	A source of electrical energy and all associated interface equipment able to be connected to an electric circuit in a Low Voltage electrical installation and designed to operate in parallel with a public Low Voltage Distribution Network with nominal currents up to and including 16 A per phase.
NGESO	National Grid Electricity System Operator Limited
Northern Powergrid	Northern Powergrid (Northeast) Ltd and Northern Powergrid (Yorkshire) plc.
OFAF	Oil Forced Air Forced
ONAN	Oil Natural Air Natural
Point of Supply	The Northern Powergrid ownership boundary and point of isolation from the Customer's equipment.
Power Generating Facility (PGF)	A facility that converts primary energy into electrical energy and which consists of one or more Power Generating Modules connected to a Network at one or more Connection Points.

Power Generating Module (PGM)	Either a Synchronous Power Generating Module or a Power Park Module.
Power Generating Module Document (PGMD)	A document provided by the Generator to the DNO for a Type B or Type C Power Generating Modules which confirms that the Power Generating Module's compliance with the technical criteria set out in this EREC G99 has been demonstrated and provides the necessary data and statements, including a statement of compliance.
Power Park Module (PPM)	A Generating Unit or ensemble of Generating Units (including storage devices) generating electricity, which is either asynchronously connected to the network or connected through power electronics, and that, may be connected through a transformer and that also has a single Connection Point to a Distribution Network.
Synchronous Power Generating Module (SPGM)	Means an indivisible set of Generating Units (i.e. one or more units which cannot operate independently of each other) which can generate electrical energy such that the frequency of the generated voltage, the generator speed and the frequency of network voltage are in a constant ratio and thus in Synchronism. Each set of Generating Units which cannot run independently from each other (such as those Generating Units on a common shaft or as part of an integrated CCGT Module), but can run independent of any other generating equipment, form an individual Synchronous Power Generating Module. Any prime mover and alternator combination that can run as an independent unit (irrespective of normal operating practice) is a Synchronous Power Generating Module.
Type A	A Power Generating Module with a Connection Point below 110 kV and a Registered Capacity of 0.8 kW or greater but less than 1 MW.
Type B	A Power Generating Module with a Connection Point below 110 kV and Registered Capacity of 1 MW or greater but less than 10 MW.
Type C	A Power Generating Module with a Connection Point below 110 kV and a Registered Capacity of 10 MW or greater but less than 50 MW.
Type D	A Power Generating Module with a Connection Point at, or greater than, 110 kV; or with a Connection Point below 110 kV and with Registered Capacity of 50 MW or greater.

6. Authority for issue

6.1. CDS Assurance

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for authorisation.

		Date
Liz Beat	Governance Administrator	08/06/2020

6.2. Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for authorisation.

Review period - This document should be reviewed within the following time period;

Standard CDS Review of 3 years?	Non -Standard Review Period & Reason		
Yes	**Period:** n/a	**Reason:** n/a	
Should this document be displayed on the Northern Powergrid external website?			Yes
			Date
Alan Creighton	Senior Smart Grid Development Engineer		19/06/2020

6.3. Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for authorisation.

		Date
Derek Fairbairn	System Design Manager	19/06/2020

6.4. Authorisation

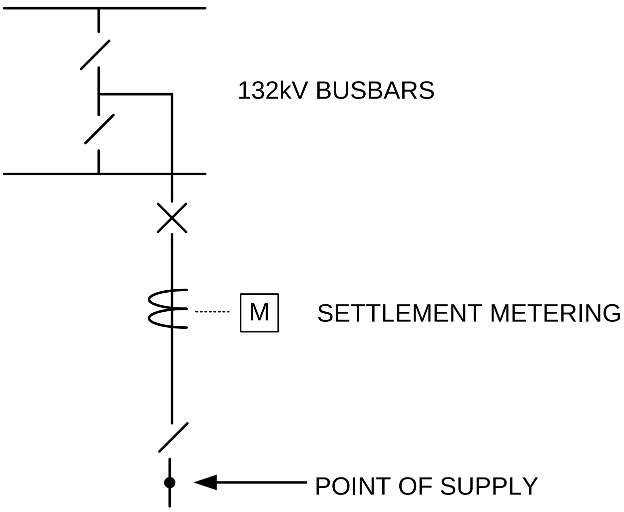
Authorisation is granted for publication of this document.

		Date
Mark Nicholson	Head of Smart Grid Implementation	19/06/2020

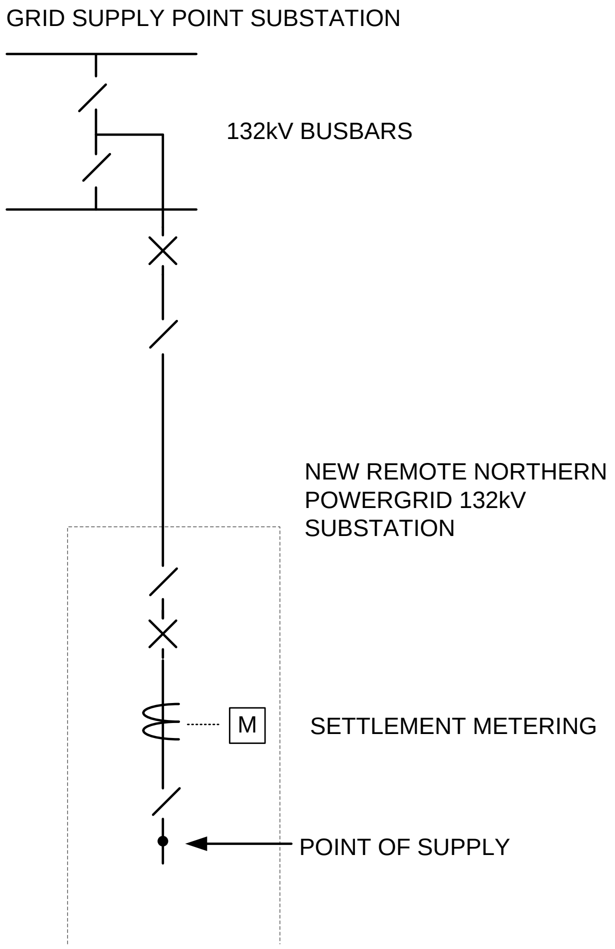
Appendix 1 - Typical 132kV Connection Arrangements

This Appendix illustrates the typical arrangements of 132kV systems containing generation. Each of these single line diagrams align with a more detailed standard Connection and Protection diagram.

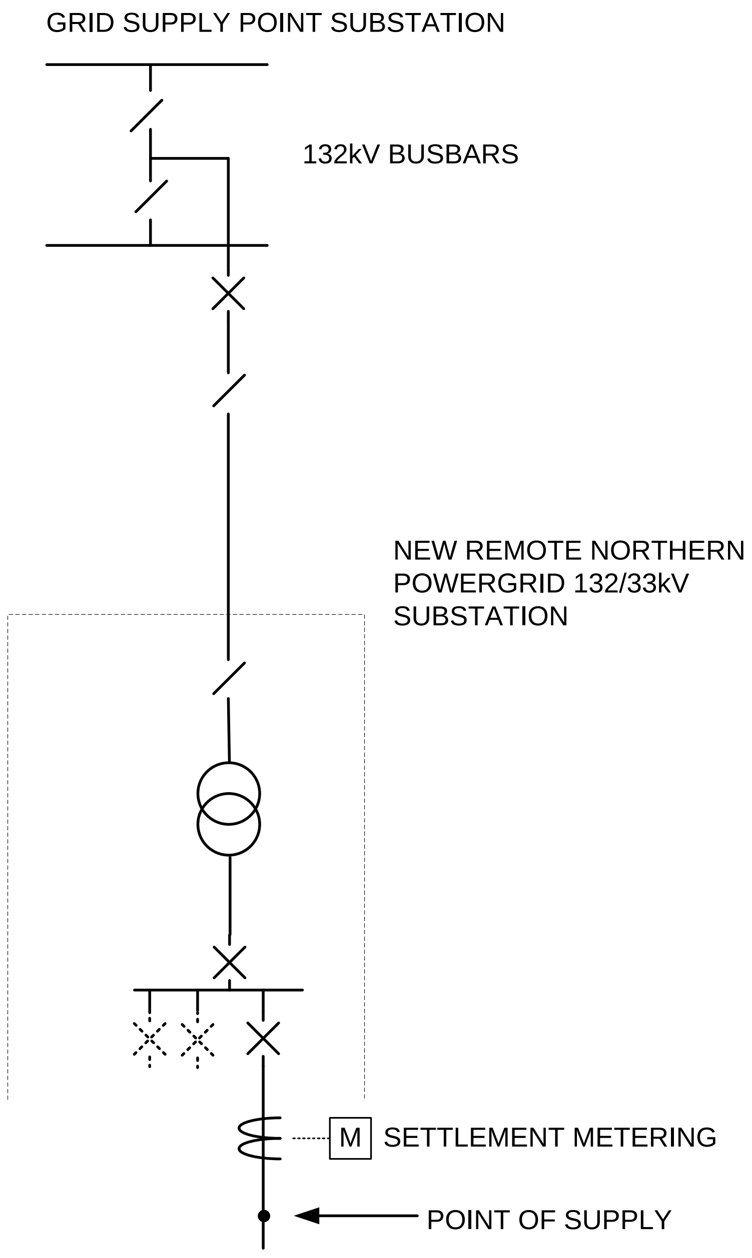
A1.1 132kV Point of Supply at a 132kV Switchboard at a 400/132kV or 275/132kV Substation



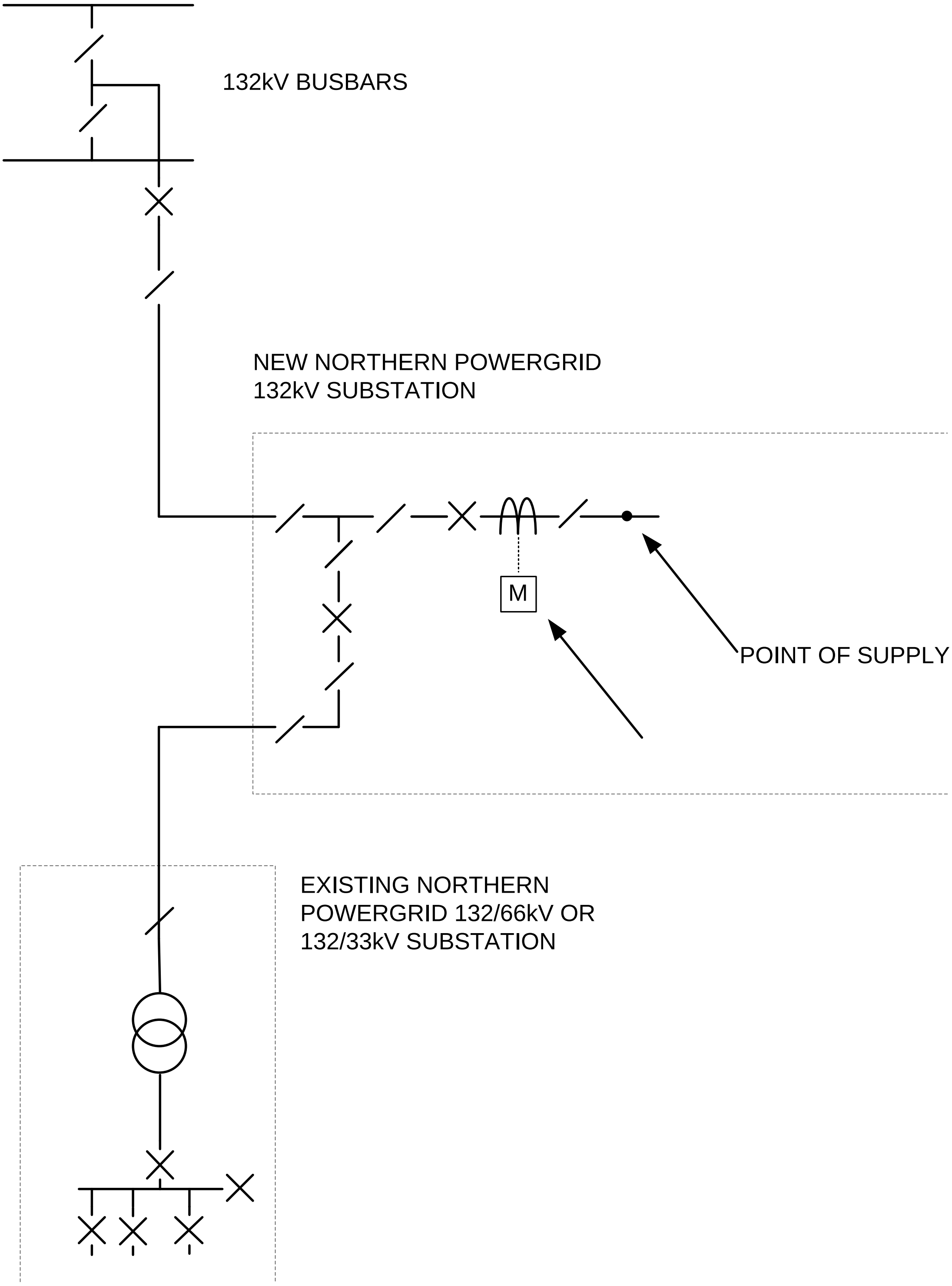
A1.2 132kV Point of Supply at a New 132kV Switchboard Remote from a 400/132kV or 275/132kV Substation (132kV metered)



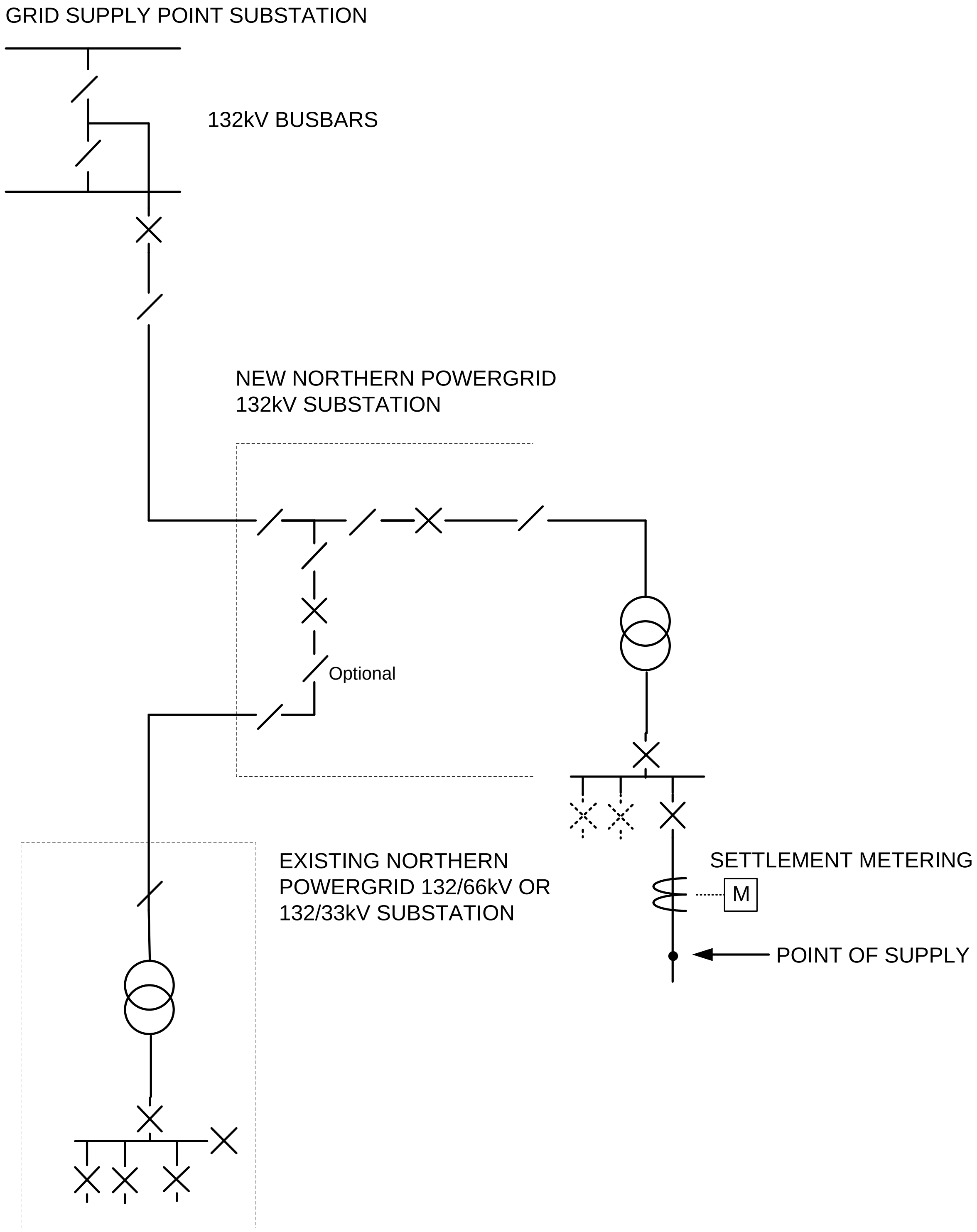
A1.3 33kV Point of Supply at a New 33kV Substation Remote from a 400/132kV or 275/132kV Substation



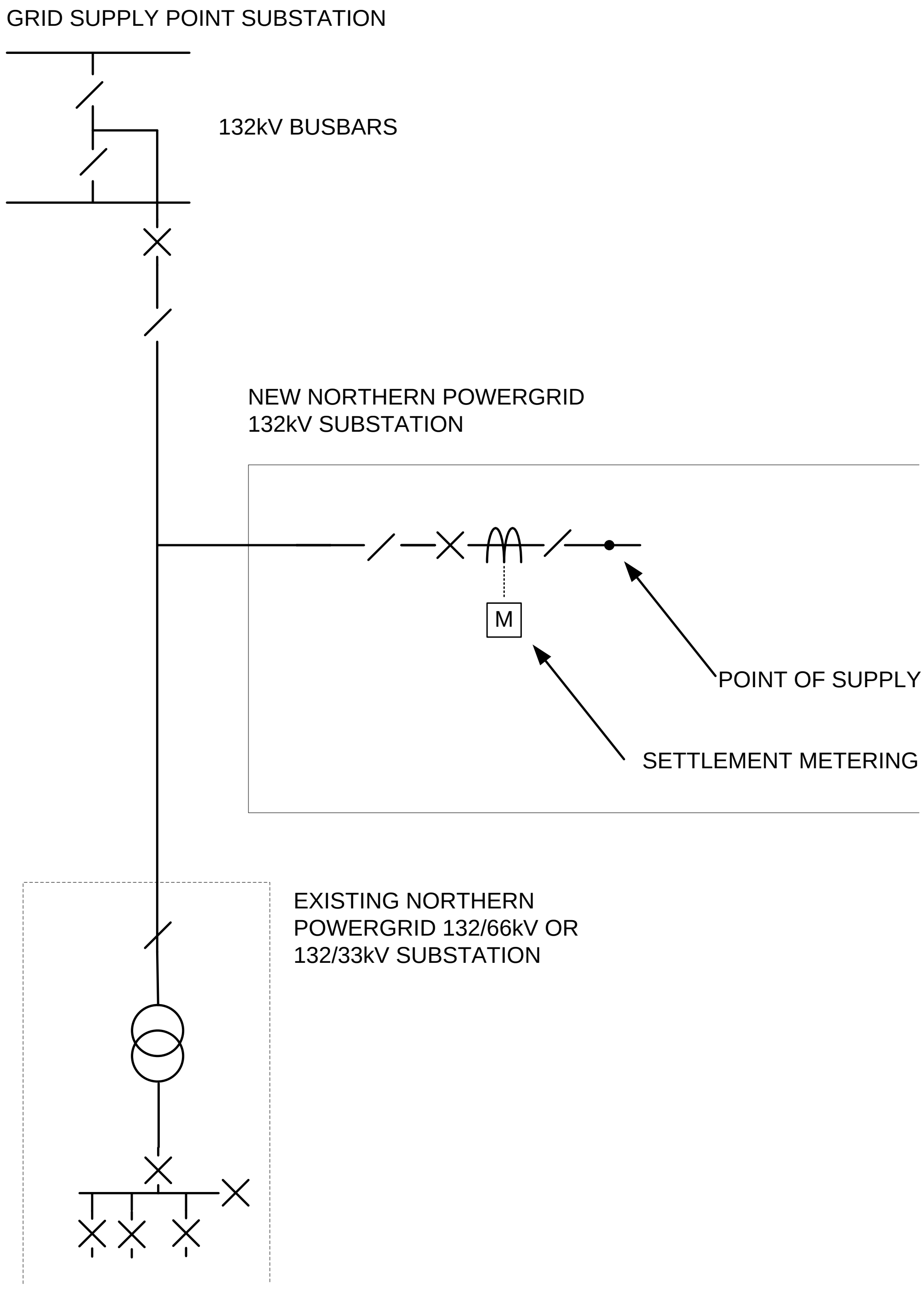
A1.4 132kV Point of Supply at a New 132kV Switchboard Looped into an Existing 132kV Circuit (132kV metered)



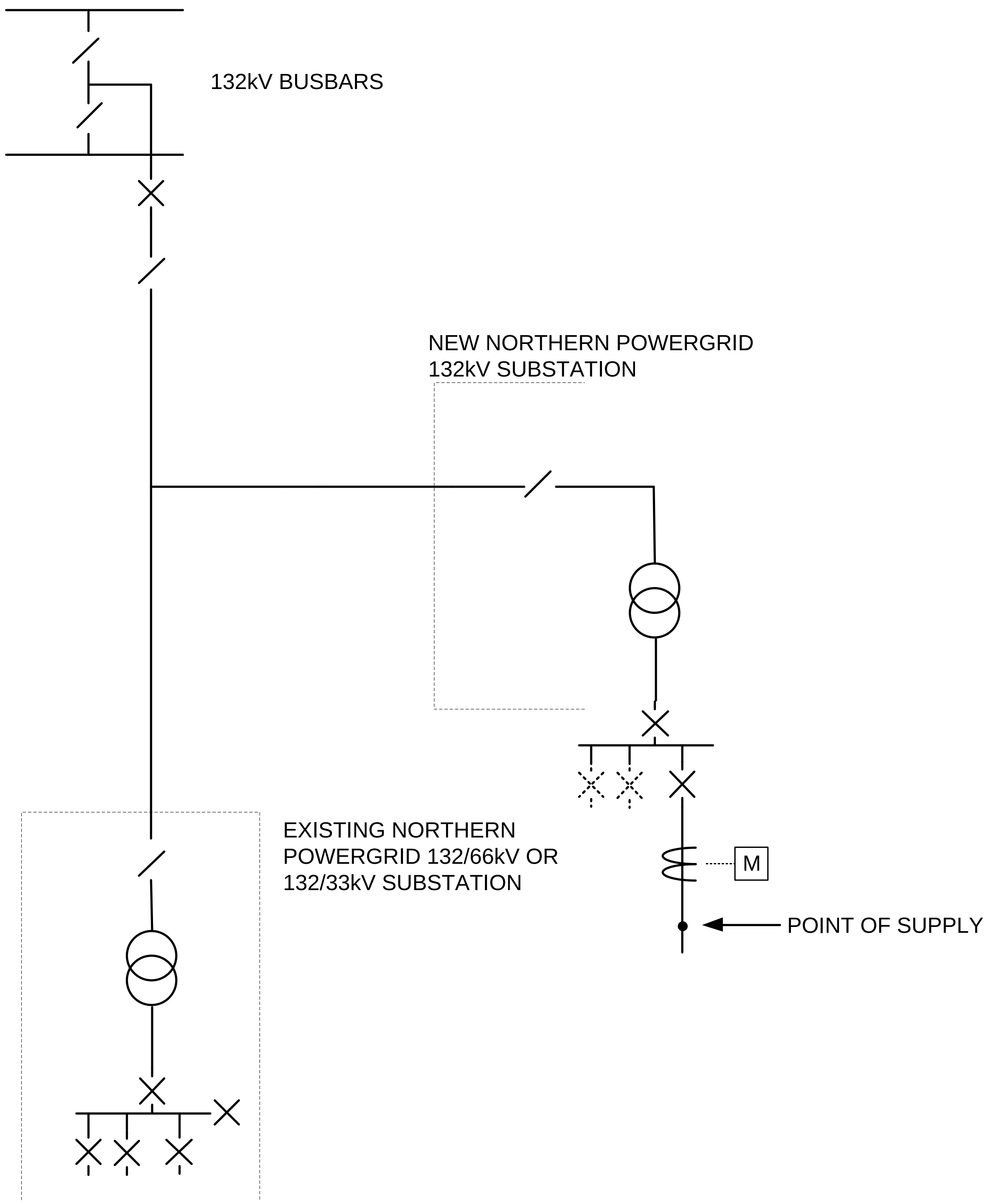
A1.5 33kV Point of Supply at a New 33kV Substation Looped into an Existing 132kV Circuit (33kV metered)



A1.6 132kV Point of Supply at a New 132kV Switchboard teed into an Existing 132kV Circuit (132kV metered)



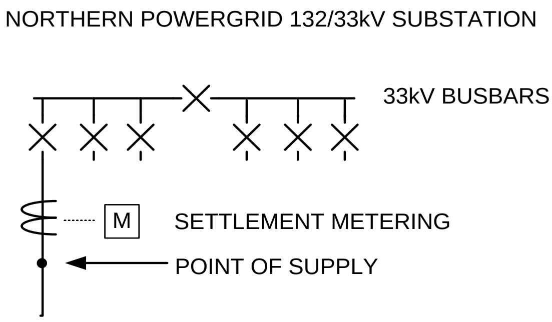
A1.7 33kV Point of Supply at a New 132kV Substation teed into an Existing 132kV Circuit (33kV metered)



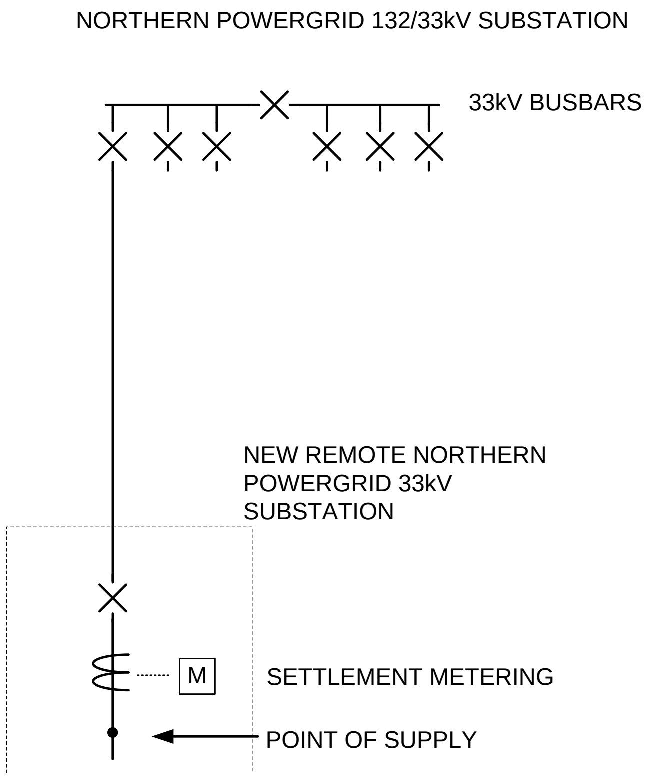
Appendix 2 - Typical EHV Connection Arrangements

This Appendix illustrates the typical arrangements of EHV systems containing generation. Each of these single line diagrams align with a more detailed standard Connection and Protection diagram.

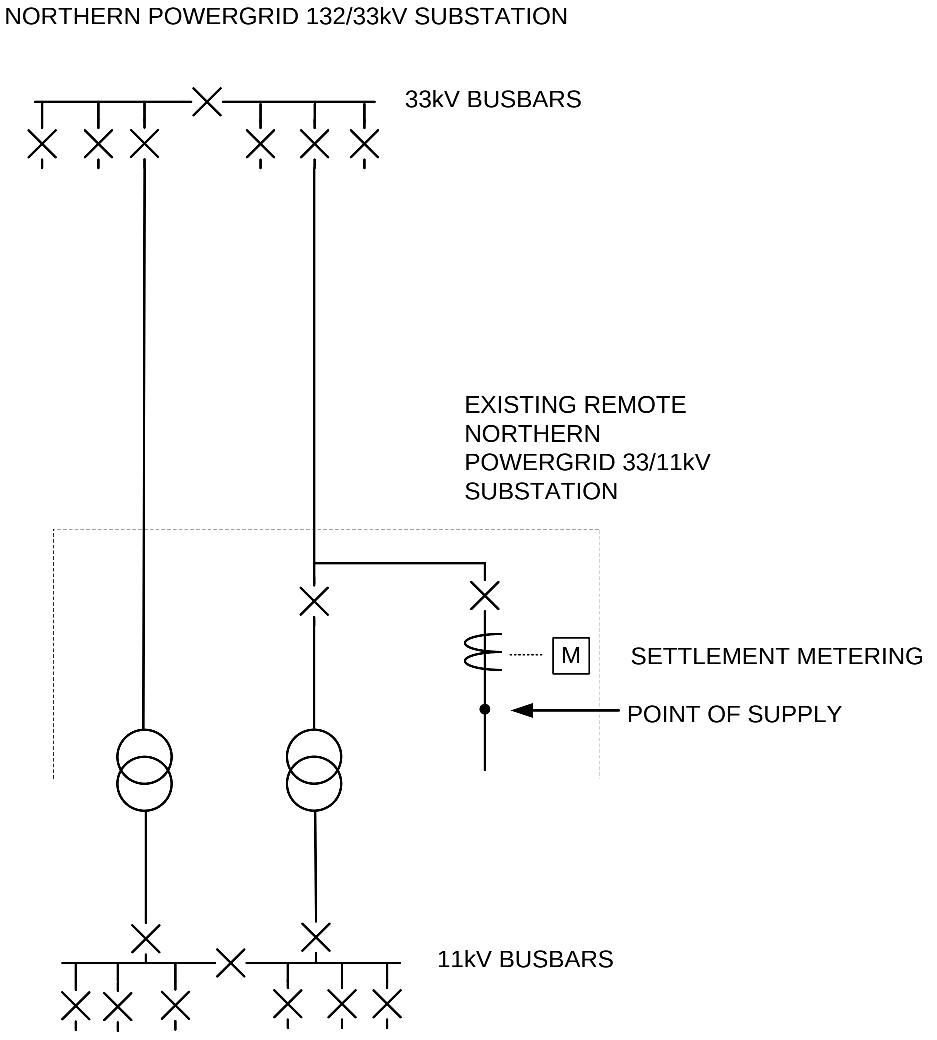
A2.1 33kV Point of Supply at a 33kV Switchboard at a 132/33kV Substation



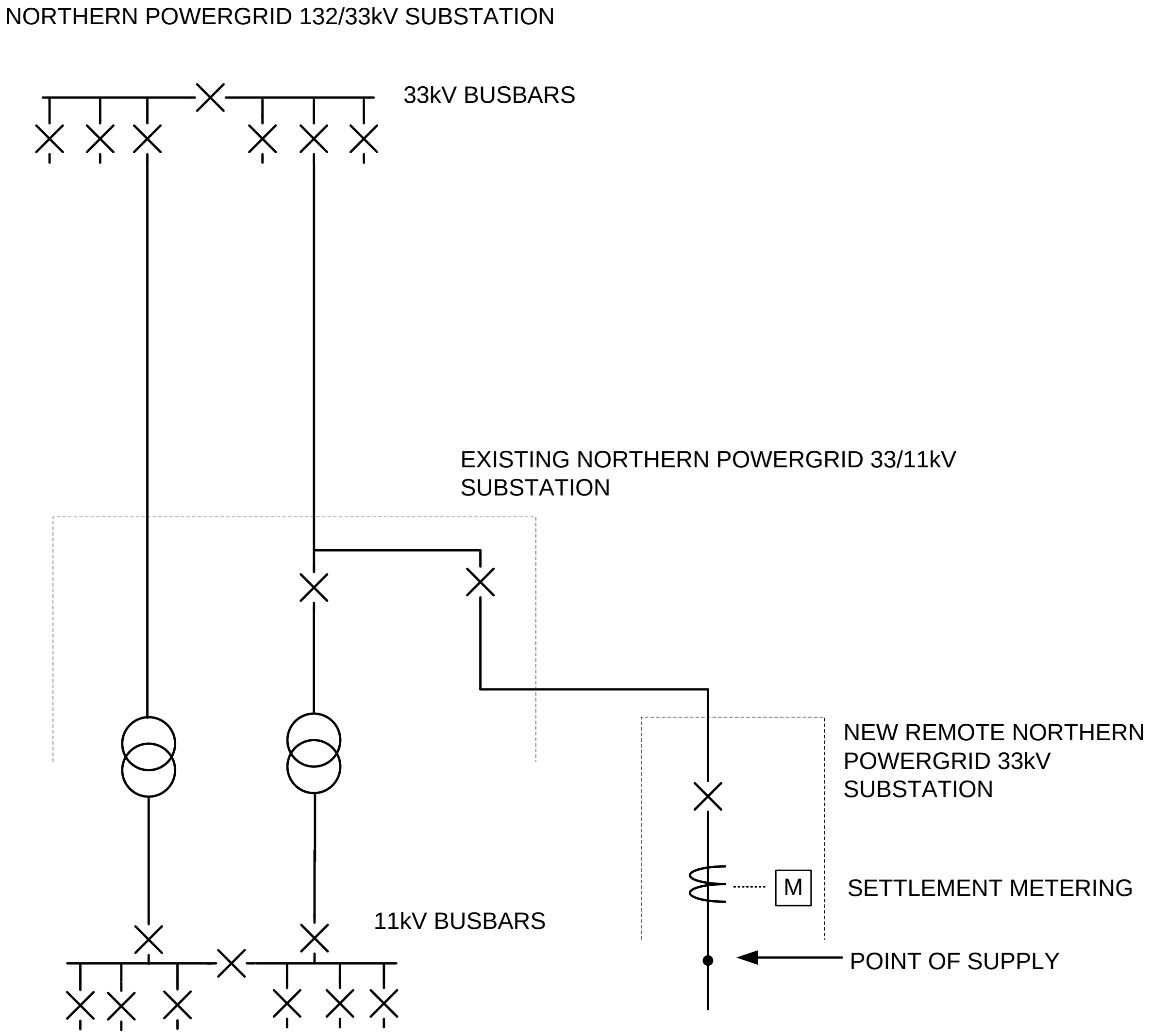
A2.2 33kV Point of Supply at a New 33kV Switchboard Remote from an Existing 132/33kV Substation



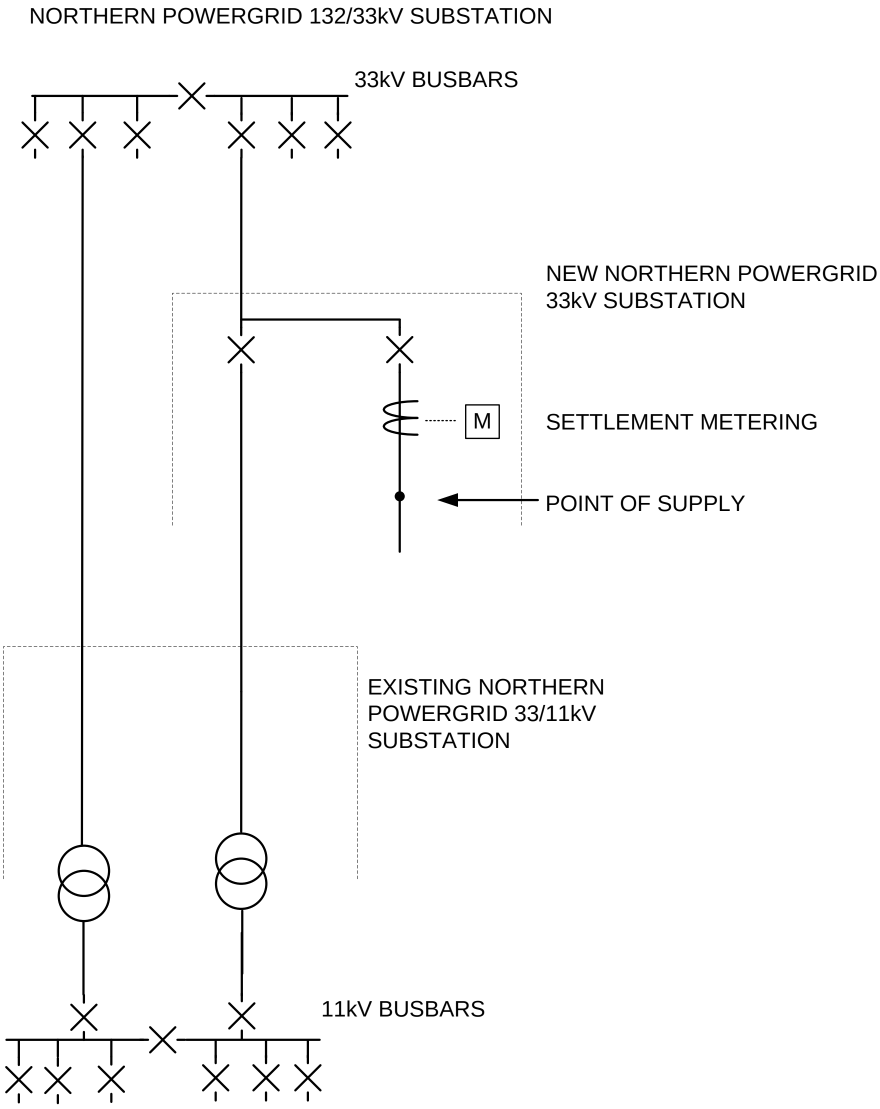
A2.3 33kV Point of Supply at a New 33kV Switchboard at Existing 33/11kV Substation



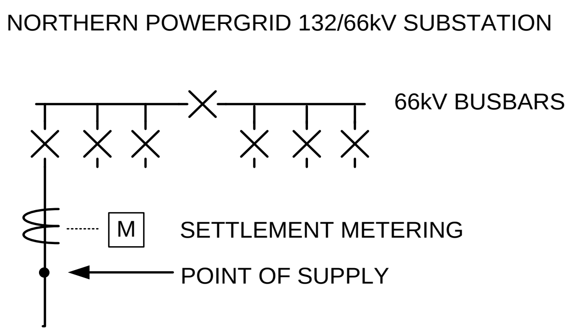
A2.4 33kV Point of Supply at a New 33kV Switchboard Remote from a 33/11kV Substation



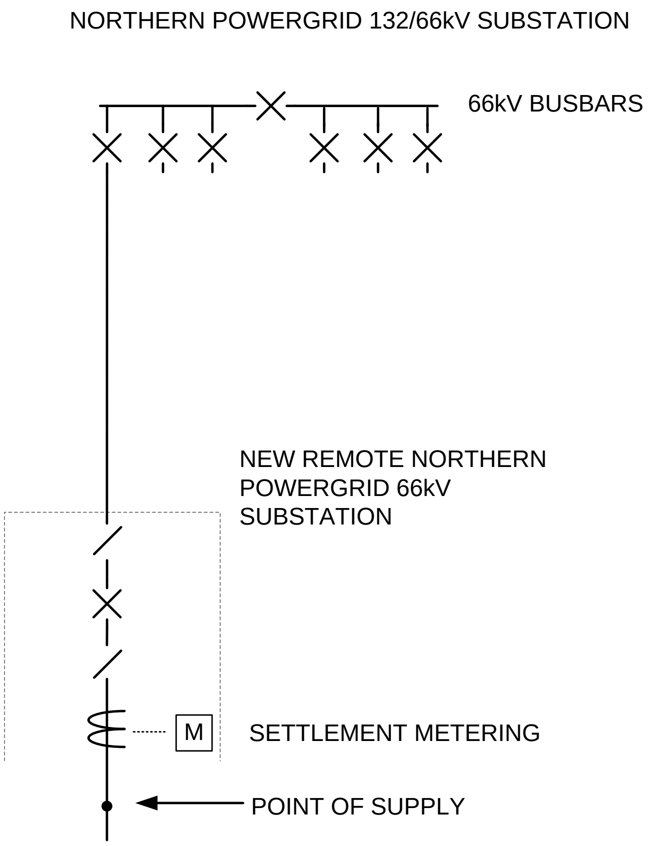
A2.5 33kV Point of Supply at a New 33kV Switchboard located between a 132/33kV Substation and an Existing 33/11kV Substation



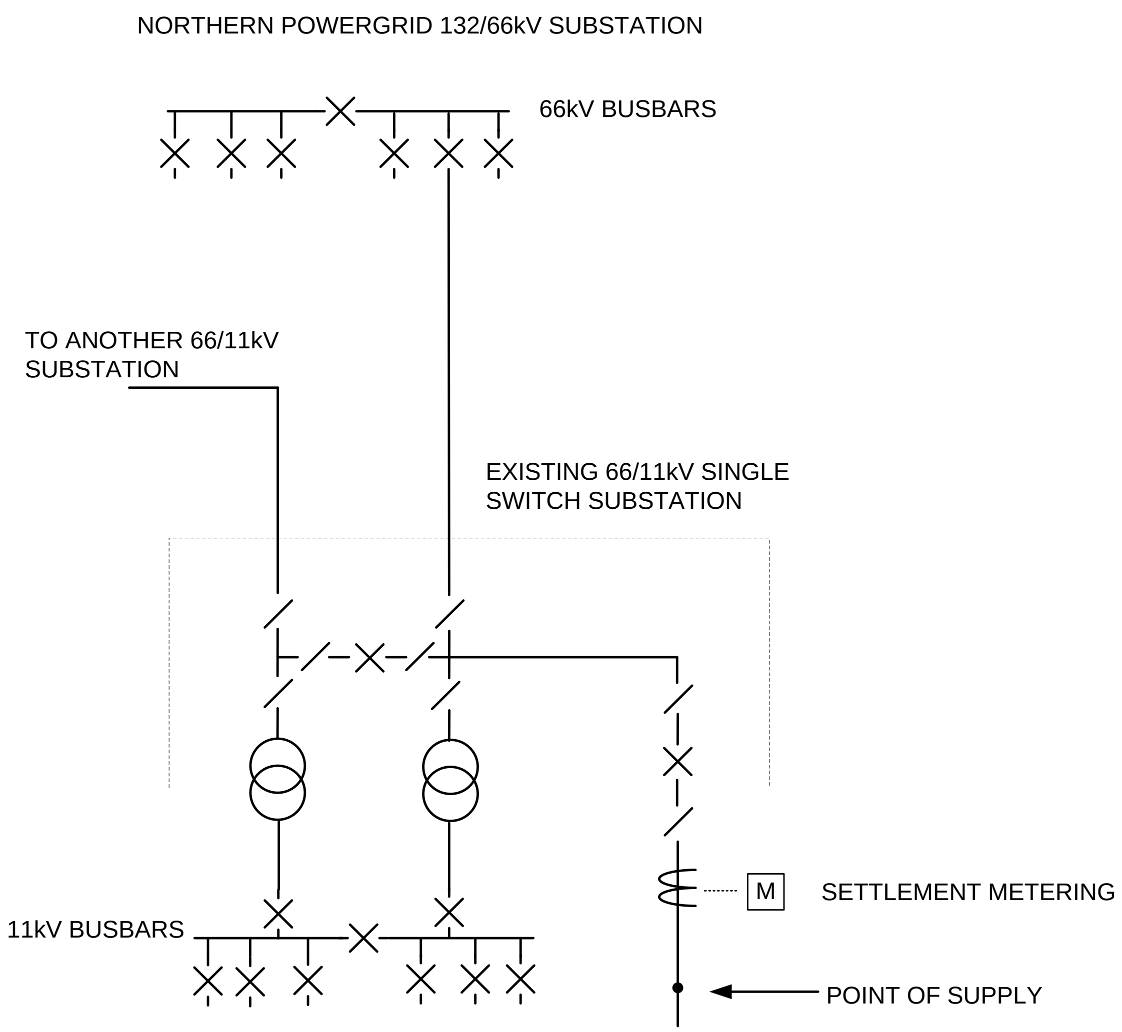
A2.6 66kV Point of Supply at a 66kV Switchboard at a 132/66kV Substation



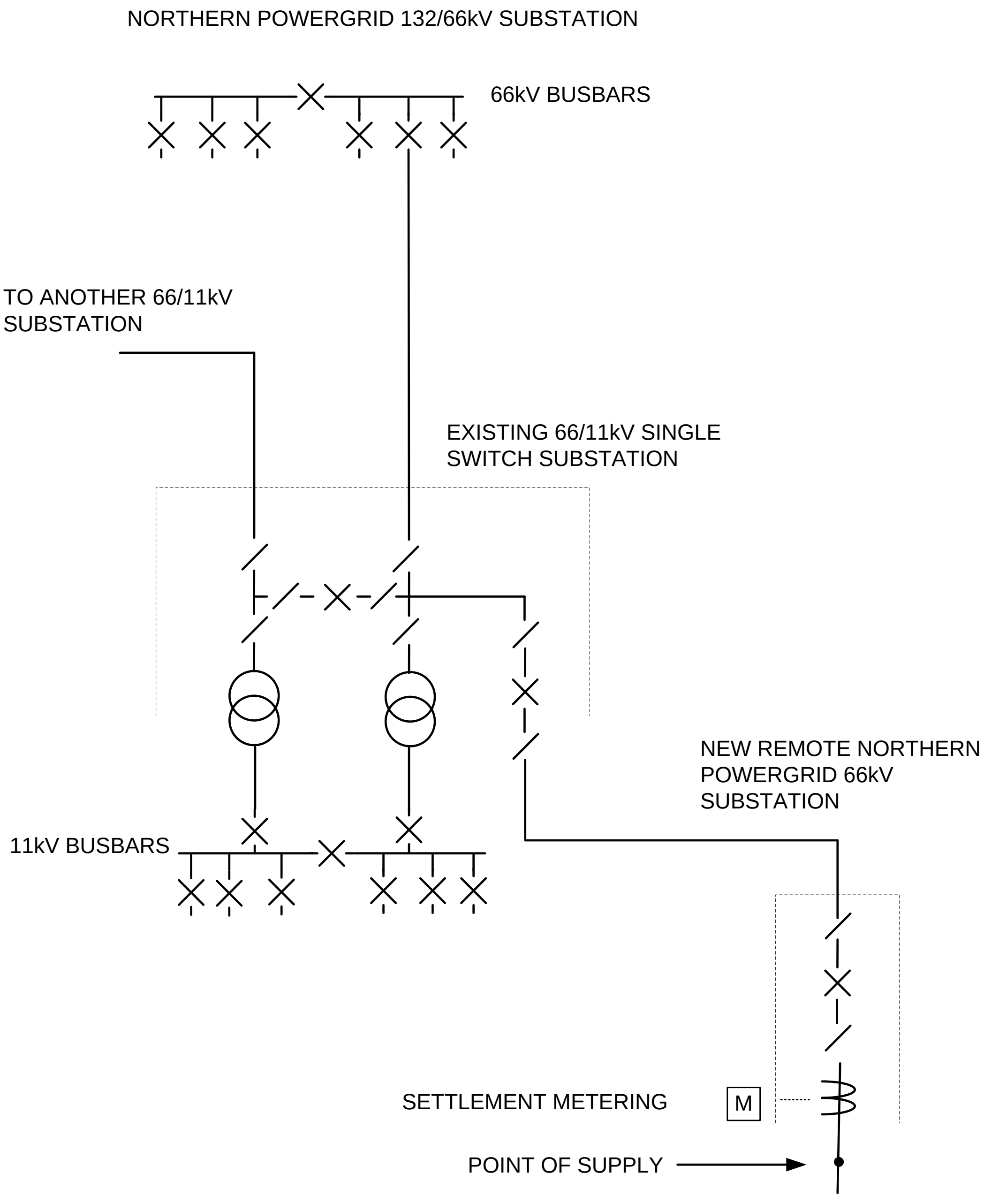
A2.7 66kV Point of Supply at a New 66kV Switchboard Remote from a 132/66kV Substation



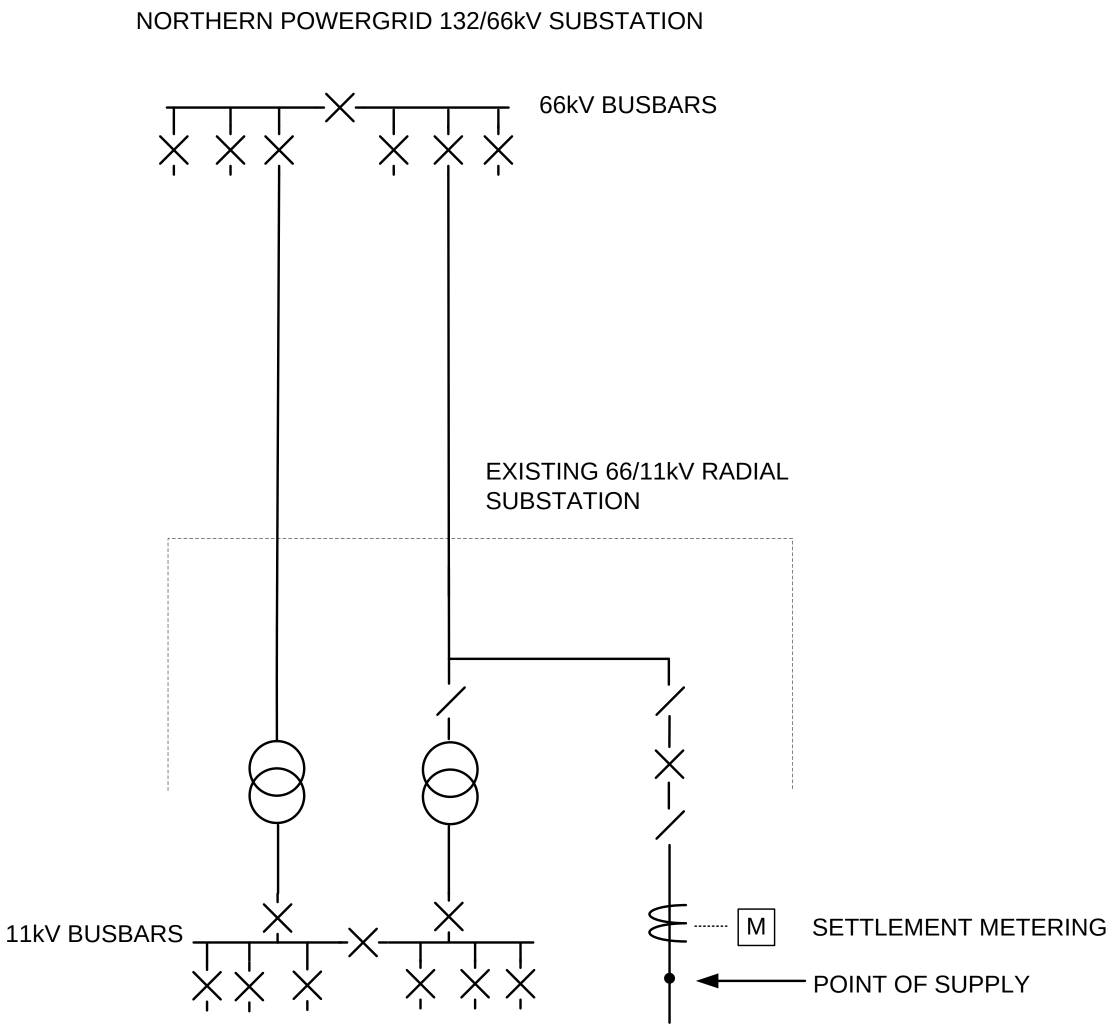
A2.8 66kV Point of Supply at a New 66kV Switchboard at an Existing (single switch) 66/11kV Substation



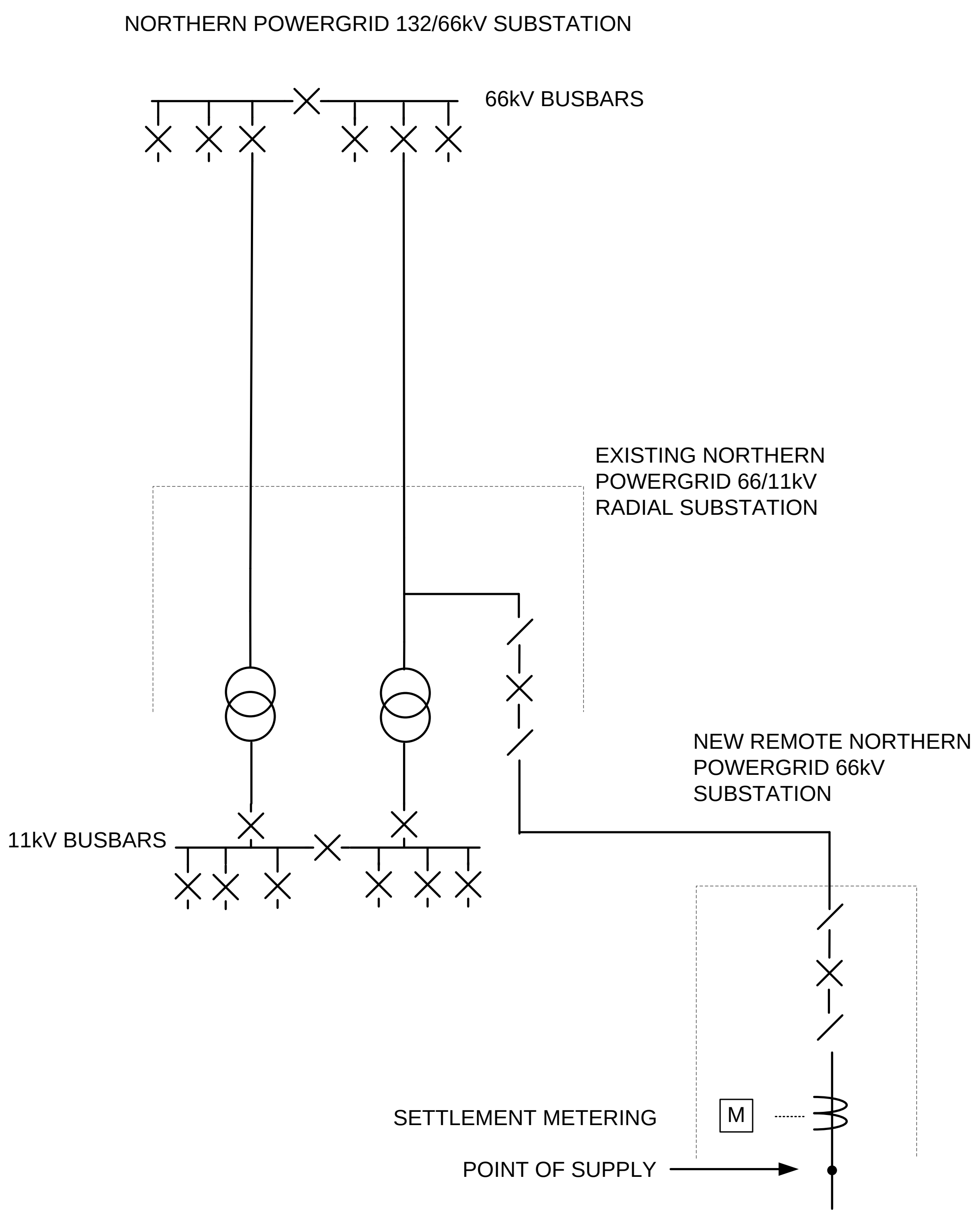
A2.9 66kV Point of Supply at a New 66kV Switchboard Remote from an Existing (single switch) 66/11kV Substation



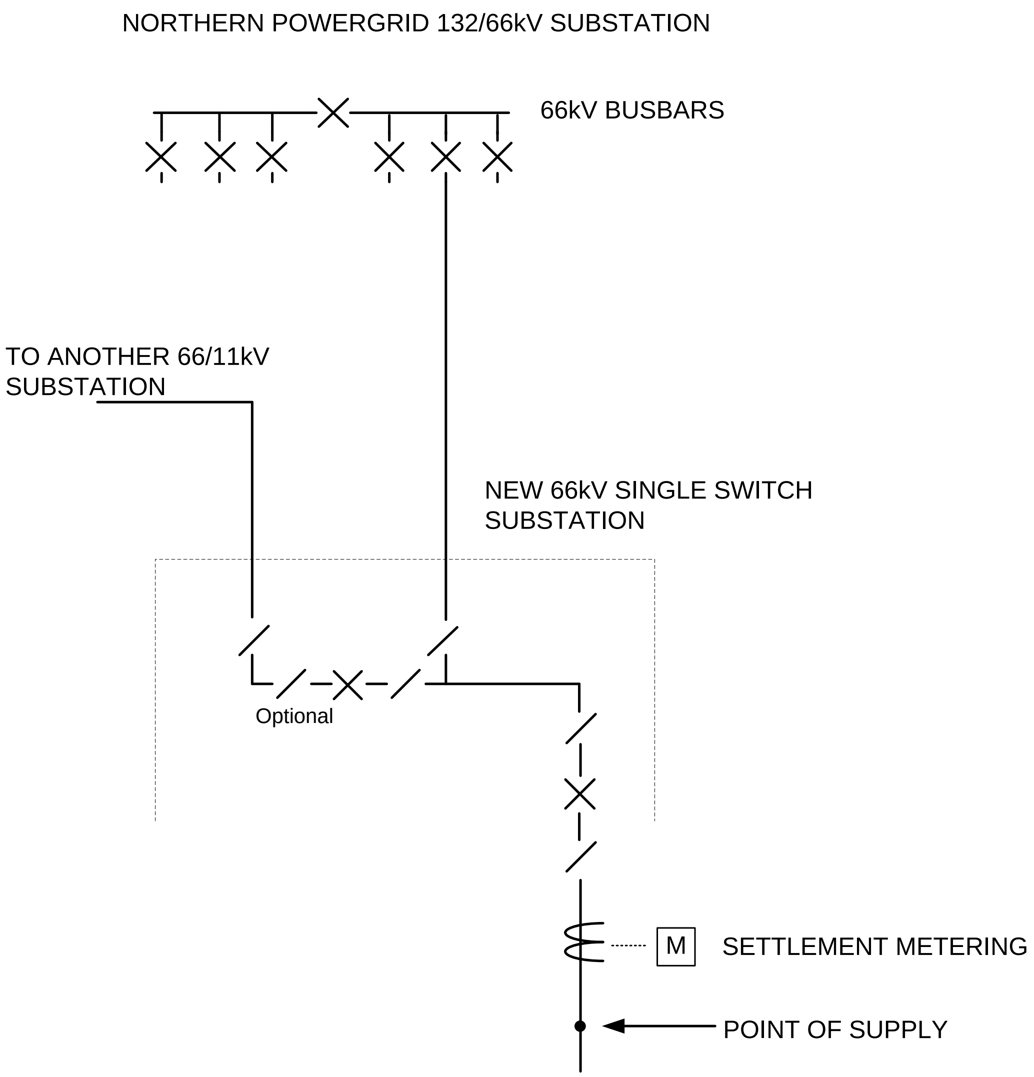
A2.10 66kV Point of Supply at a New 66kV Switchboard at an Existing (radial supplied) 66/11kV Substation



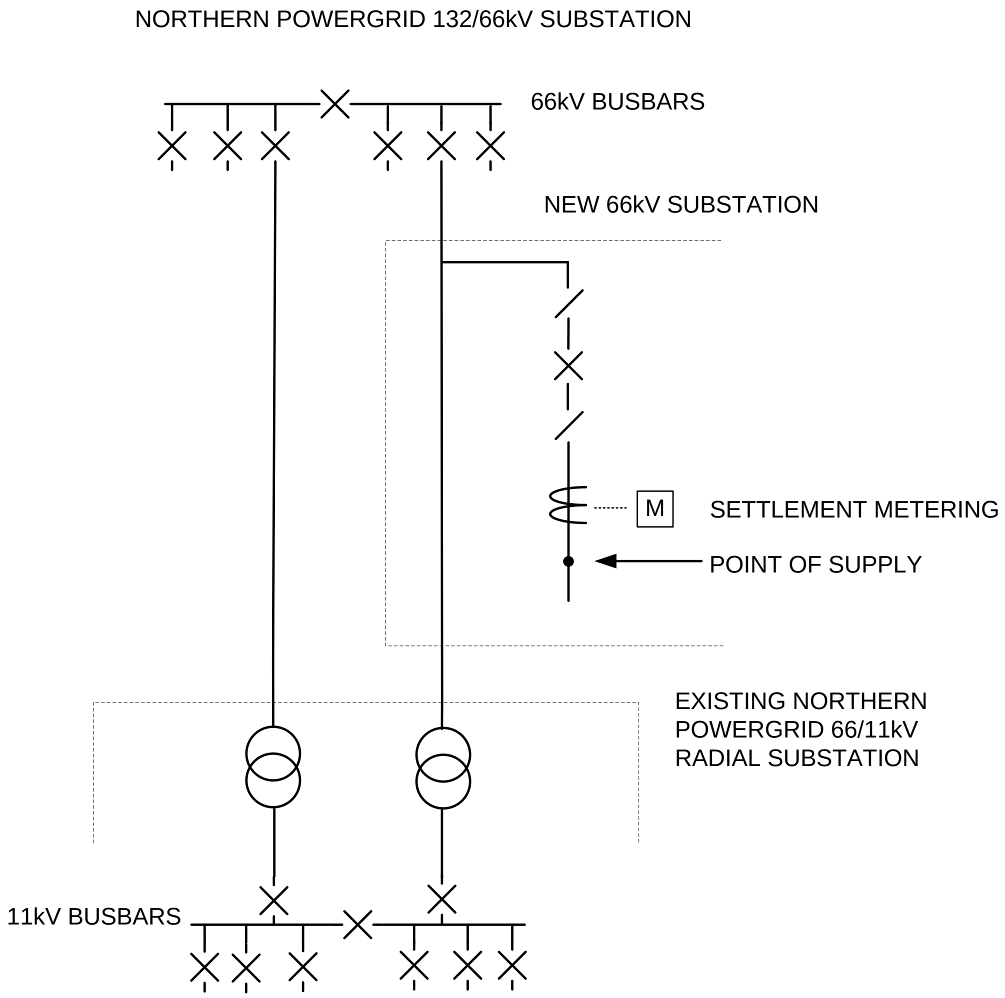
A2.11 66kV Point of Supply at a New 66kV Switchboard Remote from an Existing (radial supplied) 66/11kV Substation



A2.12 66kV Point of Supply at a New 66kV Switchboard Looped into an Existing 66kV Circuit



A2.13 66kV Point of Supply at a New 66kV Switchboard Teed into an Existing 66kV Circuit



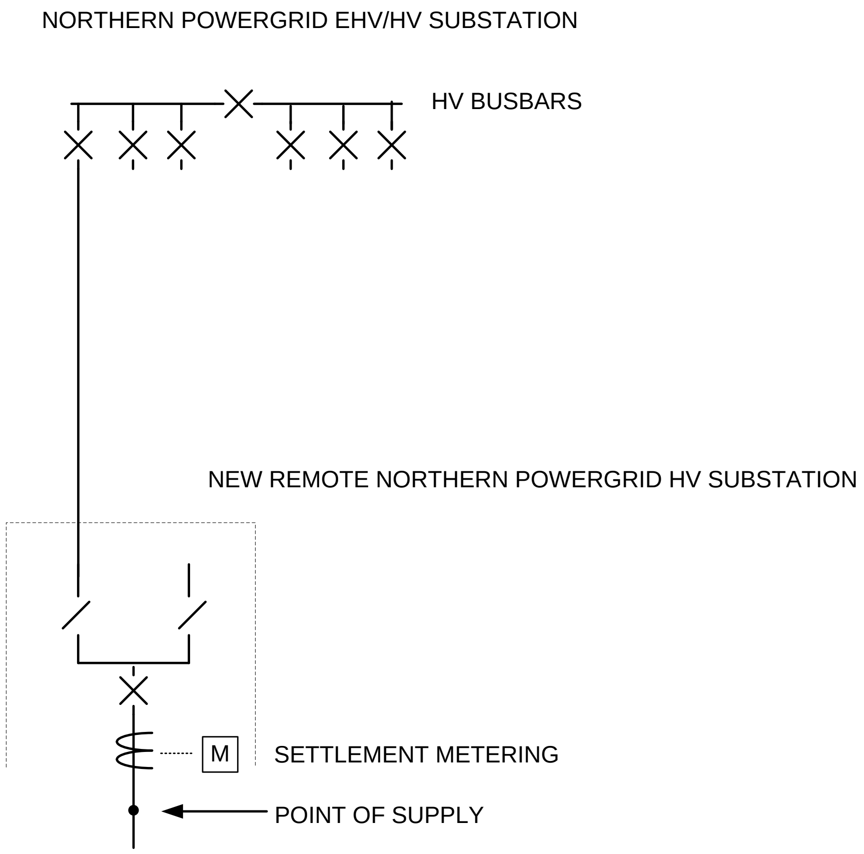
Appendix 3 - Typical HV Connection Arrangements

This Appendix illustrates the typical arrangements of HV systems containing generation. The connection capacities are illustrative only and the connection capacity available at a particular point on the system will be dependent on the results of system design and protection studies.

A3.1 HV Point of Supply via a Dedicated Connection

Typical Power Generating Module connection capacity:

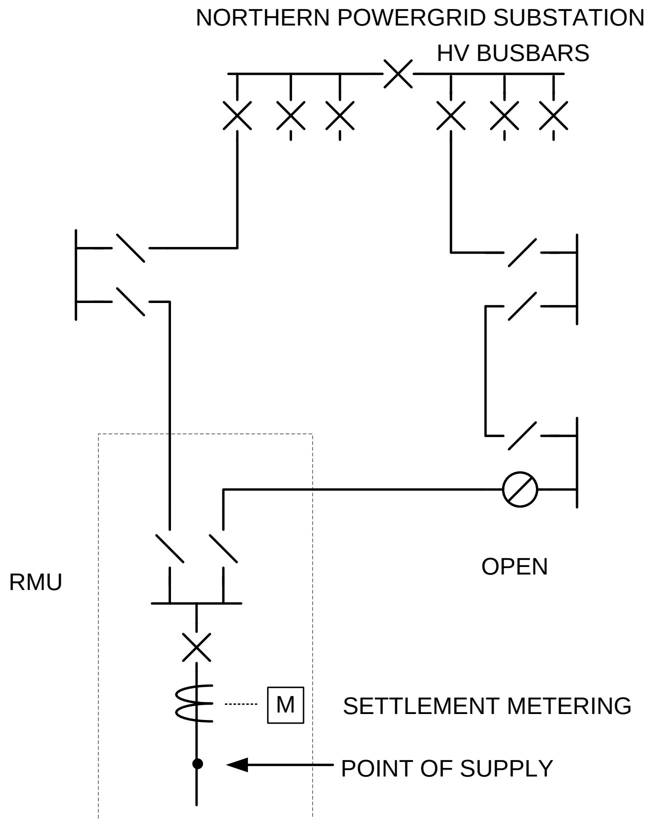
Up to about 7MVA at 11kV
Up to about 10MVA at 20kV



A3.2 HV Point of Supply via a Looped Connection

Typical Power Generating Module connection capacity:

Up to about 1MVA at 11kV
Up to about 2MVA at 20kV



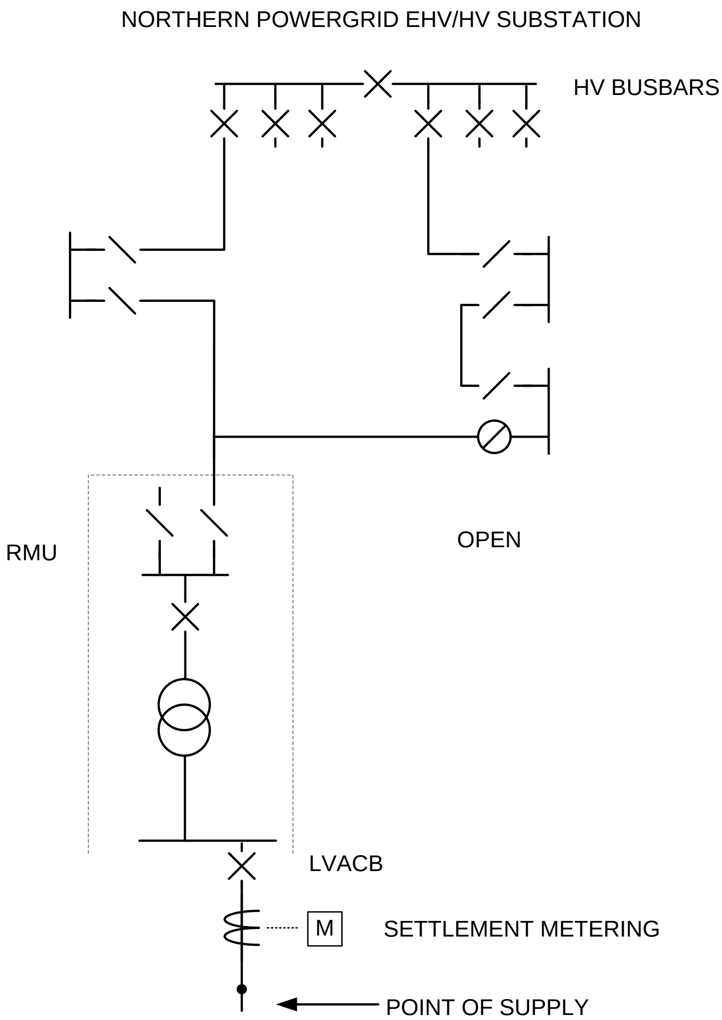
Appendix 4 - Typical LV Connection Arrangements

This Appendix illustrates the typical arrangements of LV systems containing generation. The connection capacities are illustrative only and the connection capacity available at a particular point on the system will be dependent on the results of system design and protection studies.

A4.1 LV Point of Supply via a Dedicated UDE and Transformer

Typical Power Generating Module connection capacity:

Up to about 1.6MVA

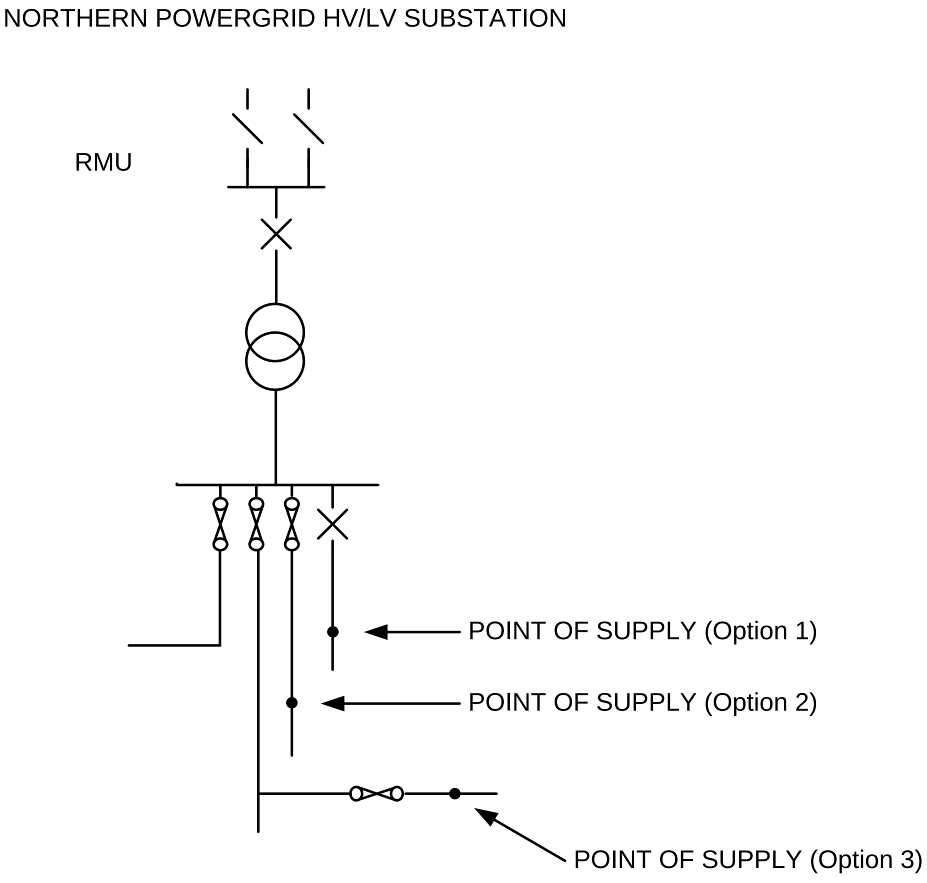


A4.2 LV Point of Supply via a Shared UDE and Transformer

Typical Power Generating Module connection capacity:

Option 1 Up to 1MVA
Option 2 & 3 Up to about 200kVA*

* Larger capacity Power Generating Modules up to about 330kVA can be connected via these options, however consideration of the protection requirements means that an LVABC rather than a fuse is required.



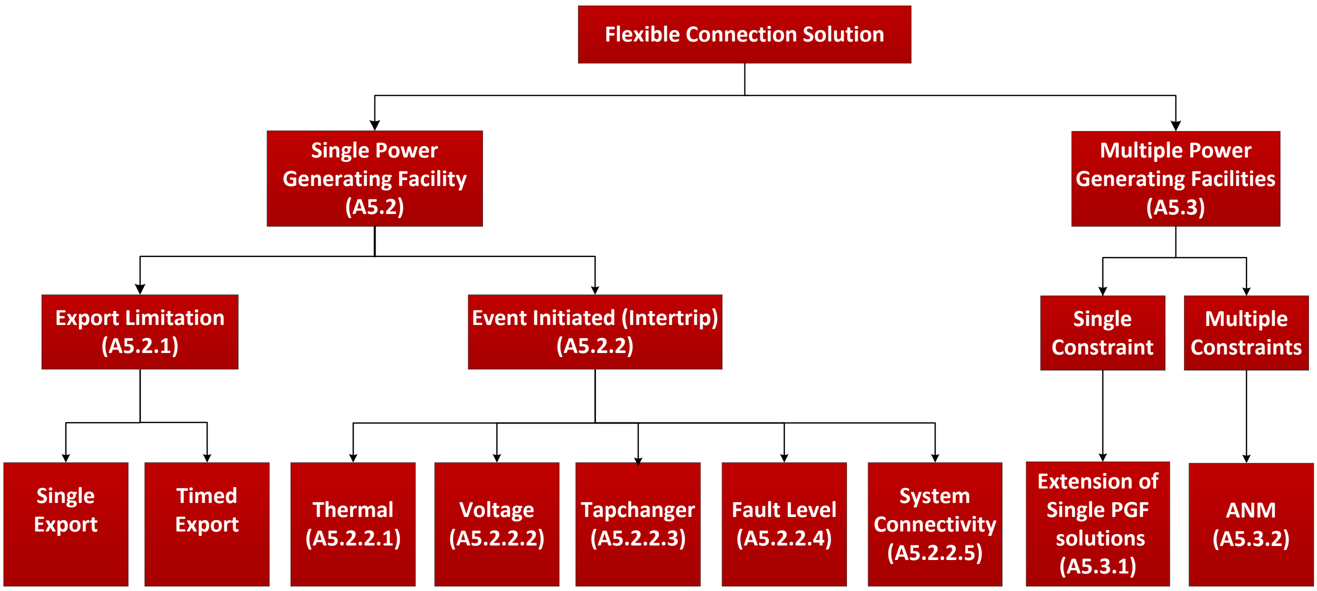
Appendix 5 - Flexible Connection Solutions

A5.1 Introduction

Flexible connection solutions is a generic term given to customer connection solutions that use techniques for managing distribution systems more actively than would have been the case in the past e.g. managing power flow by actively controlling the current flowing through a circuit by controlling customers' demand or the output from generation plant.[59]

Flexible connection solutions can be applied to customer's demand connections, however this Appendix focuses on the application of flexible connection solutions to the connection of new distributed generation plant.

There is a range of flexible connection solutions that can be implemented to facilitate the connection of distributed generation plant. At present Northern Powergrid offer different flexible connection solutions depending on the number of Power Generating Facilities associated with a system constraint and the type of system constraint that needs to be managed. The following diagram and table summarise the flexible connection options available:



[59] Generic guidance on ANM techniques is include within two Engineering Reports: a) ENA Engineering Report 124 provides guidance on the types of connection designs which can be considered when assessing whether there are cost effective solutions to managing power flow issues on the distribution network that may involve operational constraints, and b) ENA Engineering Report 126 provides guidance on the types of connection designs which can be considered when assessing whether there are cost effective solutions to managing voltage issues on the distribution network that may involve operational constraints. This Code of Practice describes the current application on of the principles described in ENA Engineering Report 124 and 126.

	Single Power Generating Facility		Multiple Power Generating Facilities
Constraint to be managed	**Export Limitation** [60]	**Event Initiated (HV and above)** [61]	**ANM (HV and above)**
Thermal	✔	✔	✔
Voltage	✔	✔	✔
Tapchanger	✔ [62]	✔	✔
Fault level	✘	✔	✘
System connectivity	✘	✔	✘
Infrequently operated generating plant	✘	✔	✘

Flexible connection solutions can be offered for connections at all voltages unless otherwise indicated in the table above.

Flexible connection solutions for generation connections involve the detection of an unacceptable condition on the distribution system associated with unconstrained export from distributed generation plant. In such a scenario the Generator needs to either reduce their export to an acceptable level or disconnect from the system. Flexible connection solutions can be considered where the connection or operation of distributed generation plant could, in a credible system scenario, result in:

- a thermal issue on a Northern Powergrid asset;
- customers connected to the Northern Powergrid system receiving a voltage which exceeds statutory voltage limits;
- parts of the Northern Powergrid system, to which a future customer could reasonably be connected, exceeding statutory voltage limits;
- the reverse power capability of a Northern Powergrid transformer tapchanger being exceeded; or
- the fault level duty imposed on a Northern Powergrid asset exceeding its capability.

A flexible connection solution can be used to either i) agree an operational regime that will prevent an issue from arising in all credible system scenarios by limiting the export from the Power Generating Facility as required (i.e. an Export Limitation solution) or ii) implement a constraint when a thermal, or voltage issue is detected or a fault level issue is anticipated (i.e. an Event Initiated solution).

All flexible connection solutions can be implemented either as an interim measure pending the development of a permanent solution that does not require any constraints or as a permanent solution where the Generator is able to accept the constraint risk on an enduring basis.

Where a Generator is looking to connect a Power Generating Facility in an ANM enabled part of the Northern Powergrid system they should normally[63] be offered an ANM solution as it is likely that a single Power Generating Facility solution would adversely interact with the ANM scheme and disadvantage customers already connected to the ANM scheme.

[60] Export Limiting Schemes are where the managed by the Generator.

[61] Event initiated solutions may be suitable for Generators with an LV Point of Supply provided that the appropriate communications arrangements are in place, although the costs are likely to be prohibitive.

[62] The May 2016 issue of the Code of Practice on the installation of Customer Export Limitation Schemes, IMP/001/015, states that export Limitation schemes can only be used to manage voltage and thermal issues. This Code of Practice will be revised to permit such schemes to be used to manage transformer tapchanger constraints.

[63] It is recognised that there may be examples where a standalone flexible connection option would not adversely interact with existing ANM arrangements; such a scenario should be considered on its merits.

A5.2 Single Power Generating Facility

Flexible connection solutions affecting a single Power Generating Facility can be offered where:

- the new Power Generating Facility is the only Power Generating Facility affected by the operational constraint; and
- the connection and operation of the Power Generating Facility creates a single constraint at a single point on the distribution system. This constraint may relate to thermal capability, voltage or tapchanger capability.

In these cases an Export Limitation or Event Initiated flexible connection solution may be offered.

A5.2.1 Export Limitation

Export limitation solutions relate to the self-management of constraints by the Generator installing equipment to ensure that the export from the Generator's installation doesn't exceed the agreed limit. The agreed limit can be a single export scheme where the export is limited to a value applied 24 hours per day, 365 days per year, or a timed export scheme where the export is limited to a different value at different times of the day or year. An export limitation scheme compliant with EREC G100 does not require any additional safeguards to ensure that the export limitation is not breached, however in some situations, as set out below; the Generator should install a reverse power relay in their installation.

Export limitation solutions can be used for connections at all voltage levels to manage constraints associated with:

- Thermal capability;
- Voltage; or
- Tapchanger capability.

Export limitation solutions should be designed to meet the requirements set out in IMP/001/015 - Code of Practice for Customer Export Limitation Schemes. In summary, an export limitation scheme that complies with IMP/001/015 is one where:

- The export is self-managed by the Generator to a predetermined export value established in the design process;
- The connection is at LV;[64] and
    - The Max Installed Capacity is less than 1.25 times the export capacity headroom; and
    - The voltage rise at the point of supply is less than 1% above statutory voltage.
- The Generator installs a reverse power relay if the registered capacity of the Power Generating Modules is >=200kW, or where the Point of Supply is at HV or EHV.

There are two types of Export Limitation flexible connection solutions that can be offered where these conditions are satisfied:

- Single Export Value: These schemes are based on a single value to which export is limited throughout the year.
- Timed Export Value: These schemes are based on different export limits that are applicable at different times of the day or different times of the year. For example the export from an EHV connected wind farm may only need to be constrained in summer to accommodate the reduced summer rating of an overhead line. In such case:
    - The Generator's control system will need to implement and manage the variable export levels; and
    - The Generator's reverse power relay will need to accommodate different settings to cater for the different levels of permitted export.

[64] Where these two conditions are not satisfied, an export limitation scheme may be acceptable if the Generator installs a reverse power relay.

The export limitation scheme performance may be monitored by Northern Powergrid and frequent excursions may lead to a reduction in the agreed maximum export capacity. Exceeding the maximum export capacity may also result in the connection agreement being rescinded or additional monitoring / remote control / protection being installed. If Northern Powergrid has reason to believe that the scheme is not operating correctly, the Generator will be required to supply detailed export data.

A5.2.2 Event Initiated (Intertripping)

Event initiated solutions relate to the management of constraints by the Generator responding to a binary signal provided by Northern Powergrid when an event occurs to ensure that the export from the Generator's installation doesn't exceed the agreed limit.

Event initiated solutions can be used for connections at high voltage and above and where appropriate robust communications channels are available to manage constraints associated with:

- Thermal capability;
- Voltage;
- Tapchanger capability;
- Fault level; or
- System connectivity.

Upon detection of a defined event, a signal is sent to the Generator to either instruct a reduction in export within a pre-determined period of time or trip the Generator's synchronising circuit breaker / metering circuit breaker depending upon specific scheme requirements.

Event initiated solutions may be referred to as intertripping solutions as they are typically implemented using an intertripping arrangement.

Because they deploy control equipment that has been tested, event managed solutions can be used to manage constraints in both system intact and first circuit outage conditions, depending on the scenario where the critical event occurs. Constraints under first circuit outage conditions are likely to be more onerous than those under system intact conditions.

A5.2.2.1 Thermal

Where the export from generation plant at times of low system demand causes an thermal issue on a system asset (including cables, overhead lines, circuit breakers and transformers), it may be possible to install current monitoring at an appropriate point on the system to detect the thermal event which can be used to provide a trip signal to a Generator.

The standard Northern Powergrid scheme is based on the provision of binary signals to the Generator via a suitably robust communications system:

- Stage 1 signal requiring the Generator to reduce their export to a predetermined level within defined period of time;
- Stage 2 signal tripping the Generators synchronising CB where the Generator does not respond appropriately to the Stage 1 signal; and
- Stage 3 signal tripping the Generators metering CB where the Generator does not open their synchronising CB within a prescribed period of receiving the Stage 2 signal.

Where the constraint point is located at the same substation site as the Point of Supply to the Generator, it may be possible to provide the Generator with an analogue signal that provides an indication of the load at the constraint point. The Generator may be able to use this signal to manage their export to minimise the initiation of the trip signals.

Where the distribution system topology is such that the Generator is able to measure the load at the system constraint point, the Generator will be able to measure the current at this point and use this information to reduce their export to minimise the initiation of the trip signals.

In both options a backup protection relay may be required that would trip the Generator's circuit breaker or issue an alarm to the Northern Powergrid control centre for further action in order to manage the risk that the Generator doesn't respond appropriately to the control signal.

Thermal events may be initiated via current (I) and / or thermal (I^2t)[65] measurements.

A5.2.2.2 Voltage

Where the export from generation plant at times of low network demand causes a customer's Point of Supply, or part of the Northern Powergrid network to which a future customer could reasonably be connected, to exceed statutory voltage limits, voltage monitoring can be installed to detect a voltage event which can be used to provide trip signals to the Generator. The sequence of the binary signals sent to the Generator is the same as those for managing thermal constraints.

This solution can also be applied for distributed generation plant connections to HV circuits where the export is acceptable under normal system configurations, but not in alternative, post outage, configurations as an alternative to using auxiliary contacts on distribution system plant to detect the abnormal system configuration. Detecting an abnormal configuration via auxiliary contacts at a single site can be straightforward, but obtaining status indications from multiple pieces of equipment at different sites can become 'too complex'.

A5.2.2.3 Tapchanger

Where the export from generation plant at times of low system demand causes the reverse power capability of a Northern Powergrid transformer tapchanger to be exceeded, it may be possible to install current monitoring at that point to detect the event which can be used to provide trip signals to the Generator. The sequence of the binary signals is the same as those for managing thermal constraints.

A5.2.2.4 Fault Level

Some credible operational configurations can increase system fault levels above the normal 'maximum plant' conditions. If the connection of generation plant is acceptable in the normal system operational configuration, but creates a fault level issue in credible operational scenarios, a flexible connections solution may be installed to manage the issue. There are two options for the required Generator response including:

- disconnection of all the generation plant for the duration of the abnormal feeding arrangement; or
- disconnection of sufficient generation plant to reduce the fault level to an acceptable level for the duration of the abnormal feeding arrangement.

It may be possible to offer a connection without the Generator having to contribute to costly reinforcement if they are willing to reduce their fault-level contribution upon instruction from the Northern Powergrid control centre. Such a scheme can ultimately mean that the Generator is off supply for the duration of the abnormal feeding arrangement to ensure that fault-levels remain within equipment ratings.

This option would be implemented by instructions being issued to the Generator by Northern Powergrid as part of the switching arrangements to implement the operational configuration that gives rise to the fault level issue. Communications would be required so that the Control Engineer is confident that the Generator has responded accordingly within an agreed period of time, so that they can complete the system reconfiguration. This may include the use of signals from auxiliary switches to confirm that an acceptable running arrangement is in place. Confirming acceptable network configurations via auxiliary contacts at a single site can be straightforward, but obtaining status indications from multiple pieces of equipment at different sites can become 'too complex' and the technical complexity requirements set out in A5.2.3 should be considered.

[65] Thermal measurements / modelling can be used to prevent a tripping scheme hunting where a Generator tries to maintain the export at a level that results in the load at the constraint point remaining below the threshold.

In the event that the Generator fails to respond, facilities shall be provided for the Control Engineer to remotely open the Generator's metering circuit breaker.

A5.2.2.5 System Connectivity

Some operational scenarios may result in part of the Northern Powergrid system operating beyond its capability when it is configured in a particular way or when other generation plant is connected to the system. Examples of such scenarios include:

- where a specific system post outage configuration creates an unacceptable condition e.g. generation plant that creates a high voltage when connected via an alternative HV feeding arrangement. Such a scenario could also be managed as a voltage constraint; and
- where a specific system outage creates an unacceptable condition e.g. a connection comprising two circuits normally operating in parallel may have a constrained capacity under first circuit outage conditions. Such a scenario can be managed by detecting the abnormal system configuration, providing a signal to the generation plant and obtaining an appropriate response.

A5.2.2.6 Infrequently Operated Generation Plant

Some of the generation plant connected to the Northern Powergrid system is designed to operate infrequently e.g. generation that operates under National Grid's Short Term Operating Regime (STOR) framework. Under these arrangements the generation plant will typically only operate for a small number of hours per annum, although the connection agreement may not specify this and over a period of time the Generators operational regime may change. When designing a new generation plant connection, Northern Powergrid needs to consider the scenario where all the generation plant connected to a network is operational. If in this scenario there is insufficient system capacity to allow the connection of further generation plant, it is possible to offer a connection that is constrained off (or to a lower level of export) whilst generation plant, that is expected to operate infrequently, is operating. Such generation plant is typically required to operate quickly at short notice, hence a second Generator will need to be prepared to disconnect or reduce the output from their generating plant at very short notice.

The new generation plant could be managed by providing a binary trip / limit export signal to the new distributed generation plant when the infrequently operating generation is operating, such that the new distributed generation plant disconnects or reduces its output. The communication system would need to be appropriately fast,[66] reliable and the new generation plant would not be permitted to operate, or only at a reduced export, when the communication system was unavailable.

A5.2.3 Technical Complexity

Unlike an ANM scheme where considerable work has been done to develop an acceptable system, flexible connection solutions associated with single Power Generating Facilities are typically bespoke schemes. These flexible connection solutions may require the application of standard Northern Powergrid protection, control and communications equipment; however their nature means that each scheme will require a degree of bespoke design. It is therefore important that that the details of a proposed flexible connection solution are discussed with Technical Services at an early stage in the development of a project, as a scheme that initially appears to be simple can become overly complicated and have an adverse impact on the operability of the distribution system. Factors that affect the complexity of a flexible connection scheme include:

- The location of the single point on the distribution system that needs to be monitored;
- The availability, reliability and redundancy of the communication systems;
- The arrangements that need to be in place when the communication system is unavailable;
- Monitoring that the required response from a Generator is obtained when required;

[66] Some of the NGESO Frequency Response and Reserve Services have very short response times. Further information is provided in the Battery Energy Storage System Guidance Document IMP/001/007/001.

- The arrangements required in the event that the required response from a Generator is not observed;
- Integration of the flexible connection with the Generator's Loss of Main scheme; and
- Integration of the flexible connection with the Northern Powergrid main and backup protection scheme.

As a general guide, a system that requires three or fewer signals / indications from one substation site to be transmitted as binary signals to a second site is likely to be acceptable; with other systems being considered to be 'too complex' for single customer flexible connections.

Northern Powergrid's requirement is for flexible connection solutions to be designed to BSEN 61508 (Functional safety of electrical / electronic / programmable electronic safety-related systems). It may be acceptable to develop a flexible connection solution based on devices that do not meet this standard, and in this case the scheme shall be supplemented by ENA assessed (and Northern Powergrid approved) protection relays providing thermal overload protection at the distribution system constraint point. This protection should be arranged to trip a circuit breaker local to the constraint point, or provide a remote trip to the Generator's metering circuit breaker via supervised pilot cables in order to manage the situation safely.

A5.2.4 Connection Agreement

Where a flexible connection solution for a single Power Generating Facility is offered, the contractual and commercial implications associated with each solution shall be recorded in the Connection Agreement.

As a minimum, Connection Agreements for flexible connection solutions shall contain the following information / clauses:

- Identification of the main factors that influence the level of curtailment;
- Northern Powergrid's entitlement to de-energise the Generator's installation and ultimately the Generator's connection point on failure of the Generator to comply with either the level of curtailment required or the time in which it is required to effect such curtailment;
- A statement that Northern Powergrid does not guarantee any availability of access to the system or any level of duration or frequency of curtailment or constraints;
- A statement that Northern Powergrid expects the Generator to have carried out their own assessments of potential curtailments and associated constraints and risks and ultimately financial viability of their connection prior to connection offer acceptance;
- A statement indemnifying Northern Powergrid against liability for loss, damage, cost, expense, claims or compensation arising from or in conjunction with any curtailment of the energy passing through the connection point by Northern Powergrid;
- Details of the Generator's responsibilities in respect of flexible connection solution related assets located at the Generator's installation;
- A statement prohibiting the Generator from disposing of any interest in the premises, Generator's installation or Generator's plant prior to obtaining a deed of covenant acceptable to Northern Powergrid binding the transferee to the connection agreement;
- Site responsibility schedules relating to any flexible connection related equipment; and
- Additional Northern Powergrid connection agreement termination rights relating to a material breach of the above conditions by the Generator.

A5.3 Multiple Power Generating Facilities

Where a flexible connection solution is being considered to manage the export from multiple Power Generating Facilities the type of solution will depend on the number of locations on the Northern Powergrid system where there is a constraint. Where there is a constraint on just one part of the distribution system it may be possible to develop a single Power Generation Facility solution. Where there are constraints at multiple locations, an Active Network Management scheme should be considered as part of the normal planning activities within System Planning.

A5.3.1 Single Constraint

Where there are multiple Power Generating Facilities affected by a single constraint on the Northern Powergrid system, single Power Generating Facility Event initiated solutions may be extensible to include two or more Power Generating Facilities. In this case binary signals would be sent to more than one Generator to initiate a reduction in export to the agreed level. Such applications should be discussed with the System Planning Manager as implementing an area wide ANM scheme may be a more appropriate enduring solution.

A5.3.2 Multiple Constraints – Active Network Management

Flexible connection solutions affecting multiple Power Generating Facilities are considered to be part of an ANM scheme. An ANM scheme can be offered where:

- the part of the Northern Powergrid network to which the Generator requires a connection has been authorised for Active Network Management (ANM) enablement;
- a new unconstrained connection would require significant reinforcement expenditure;
- the network constraint relates to a thermal, voltage or tapchanger limitation on any part of the Northern Powergrid system or any reasonably manageable combination of these limitations;
- the Generator wishes to proceed with an ANM connection offer;
- The total registered capacity of any generation plant proposed at a single connection is not less than 190kW (200kVA at 0.95pf), and
- The proposed connection voltage is at high voltage or above.

ANM schemes should be designed to meet the requirements set out in IMP/001/016, Code of Practice for the Application of Active Network Management.

An ANM scheme can be used to manage multiple constraints associated with multiple Power Generating Facilities that relate to any combination of the following constraints under system intact and/or first circuit outage conditions:

- Thermal capability;
- Voltage; or
- Tapchanger capability.

ANM enabled connections shall not be offered, at present, where the constraint relates to fault-level or harmonic issues.

ANM schemes are generally a cheaper alternative to system reinforcement and the constraints that a Generator would need to comply with are typically considered to be acceptable by the Generator.

ANM schemes monitor power flows or voltages at key points on the Northern Powergrid distribution system and use this information to issue target export set-points to ANM controlled generation plant to ensure that system limitations are managed.

A5.3.3 Connection Agreement

In addition to the requirements that should be included in the Connection Agreement set out in A5.2.4, the following should be included for ANM connections:

- Within the operational timeframe of the ANM system:
  - Northern Powergrid's entitlement to instruct the curtailment of flow of electricity through the Point of Supply and specify the maximum level of import / export of electricity;
  - Northern Powergrid's obligation to cease / lessen curtailment as soon as is reasonably practicable within the operational timeframe after the circumstances leading to the curtailment have ceased to exist;
  - A requirement for the Generator to act upon an instruction from Northern Powergrid to ensure that the electricity flow through their connection point does not exceed the maximum level being permitted at that time;
  - A requirement for the Generator to instigate the curtailment necessary to comply with Northern Powergrid's curtailment instruction within two seconds of receipt; and
  - Northern Powergrid's entitlement to de-energise the Generator's installation on failure of the customer to comply with either the level of curtailment required or the time in which it is required to effect such curtailment.
- An estimate of the energy likely to be constrained over a year and based on a past year including a description of the assumptions that have been made and the uncertainties inherent in producing the estimate;
- An explanation of the use of LIFO in that Generator's connection and what that means, their position number in that LIFO queue and order of curtailment and a statement strictly limited to the number of connections, generation or demand type (grouped) and installed ANM capacity above that Generator in the LIFO queue;
- A statement restricting the divulgence of any part of the ANM connection agreement to any third party without the prior written consent Northern Powergrid;
- An indication of the likely outages that may lead to a significant increase in curtailment;
- Northern Powergrid's right to reserve a proportion of the Generator's capacity for network optimisation purposes; and
- Northern Powergrid's right to request a specific ramp rate within the capabilities of the Generator's plant and the Generator's obligation to act upon such a request.

Appendix 6 - Data to be provided by the Generator

This Appendix indicates the minimum information that should obtained from the Generator prior to the connection being energised. In practice, for connection requests >50kW, this data would normally be provided by the Generators submitting data as part of the ENA generation connection Standard Application Form, which forms the basis of the Information Document for Type A Power Generating Modules and the PGMD for Types B, C and D Power Generating Modules.

The Standard Application Form is based on the Standard Planning Data (SPD) and Detailed Planning Data (DPD) requirements of Distribution Data Registration Code 6 (DDRC6) contained within the Distribution Code. To ensure full compliance with the Distribution Code, the Generator should provide all the Standard Planning Data at the time of application, however it is recognised that such detailed information may not be available at that time and that, as permitted in the Distribution Code, Northern Powergrid may need to make estimates of any unavailable data when designing a connection (see Section 3.4.4 of the Code of Practice). It is, however important that the Standard Planning Data and Detailed Planning Data is provide by the Generator in sufficient time prior to the energisation of a connection to allow any assumptions made during the connection design to be verified and any remedial works implemented.

The data schedules contained in this Appendix identifies those SPD and DPD items which ideally would be provided by the Generator prior to energisation, and also indicates data items where these requirements can be relaxed when data is not readily available or where the current modelling tools used by the company may not be able to use the data. It is anticipated that, over time, there will be a reducing number of occasions when it is appropriate to apply such relaxations.

To avoid confusion with the data schedules in DDRC6, the schedules in this Appendix retain the same references as those in the Distribution Code. Those terms highlighted in bold have specific definitions that are cited in the Distribution Code. The table below indicates the data schedules for the different types of Power Generating Modules that can be connected to the Northern Powergrid system. Generally a Generator will need to present a submission including the information set out in Schedules 5a, 5b and 5c.

Schedule Number:-	Title	Applicable to:-
Schedule 5a	**Power Station Data**	All **Power Stations**
Schedule 5b	**Generation Set Data**	All embedded **Generation Sets**
Schedule 5c	**Generation Set Data**	For specified types of **Generation Sets** and ancillary **Plant and Apparatus** (i) Synchronous **Generation Sets** (ii) Fixed speed induction **Generation Sets** (iii) Doubly fed induction **Generation Sets** (iv) Series Converter Connected **Generation Sets** (v) Transformers

Where the generation is being connected in single premises or multiple premises under the Engineering Recommendation G98 connection procedure, the information to be provided by the Generator is specified in Appendix 3 of Engineering Recommendation G98.

Schedule 5a

DATA REGISTRATION CODE

POWER GENERATING FACILITY DATA FOR ALL EMBEDDED POWER STATIONS EXCLUDING THE OTSO

DATA DESCRIPTION 5a Power Station Data	UNITS	DATA CATEGORY	COMMENTS
APPLICANT'S DETAILS			
Customer's Details			
Company name	Text	SPD	
Company registered number	Text	SPD	
Postal address	Text	SPD	
Contact name	Text	SPD	
Email address	Text	SPD	
Telephone number	Text	SPD	
Facsimile number	Text	SPD	
Consultant's Details (if applicable)			
Consultant's name	Text	SPD	
Postal address	Text	SPD	
Contact name	Text	SPD	
Email address	Text	SPD	
Telephone number	Text	SPD	
Facsimile number	Text	**SPD**	
POWER GENERATING FACILITY LOCATION AND OPERATION			
Power Station name	Text	SPD	
Details of any existing Connection Agreements for this Power Station	Text	SPD	
Target date for provision of the connection / commissioning of the Power Station	Text	SPD	
Postal address or site boundary plan (1/500)	Text / Plan	SPD	Plan should indicate the preferred connection point.
Connection Point (OS grid reference or description)	Text	SPD	For Generators with existing electrical connections, the name of the connection point (defined as the Connection point is defined as the entry/exit point) is required. The geographic name of the location of the connection point should also be provided.

DATA DESCRIPTION 5a Power Station Data	UNITS	DATA CATEGORY	COMMENTS
Connection Point voltage	V	SPD	Preferred voltage should be stated (if any) for new connection requests.
Single line diagram of any on-site existing or proposed electrical plant or, where available, Operation Diagrams	Diagram	SPD	The diagram should show the connections between the Generation Sets and the Connection Point.
What security is required for the connection?	Text	**SPD**	The DNO will assume a single circuit connection to the Power Station is required unless stated otherwise. Options include: (a) Single circuit connection, (b) Manually switched alternative connection, (c) Automatic switched alternative connection, and (d) Firm connection (secure for first circuit outage).
Number of **Power Generating Modules** in **Power Station**	Number	**SPD**	Number of generators forming the installation.
Are all **Power Generating Modules** of the same design/rating? (If not complete the relevant Schedules 5b and 5c for each type)	Y/N	**SPD**	
Will the **Power Station** operate in islanded mode?	Y/N	**SPD**	Any requirement for the customer's site to operate in island mode should be stated.
Will **Power Generating Module** supply electricity to on-site premises?	Y/N	**SPD**	Any requirement for the customer's site to supplied by the **Power Station** should be stated.
POWER GENERATING FACILITY STANDBY IMPORT REQUIREMENTS			
Maximum **Active Power** import	MW	**SPD**	This relates to operating conditions when the **Power Station** is importing **Active Power**, typically when it is not generating. The maximum **Active Power** import required and the associated maximum **Reactive Power** import and/or export required from a Northern Powergrid network under this operating scenario should be stated. Where detailed information on the maximum power import is provided, details of Standby Supplies need not be presented here.
Maximum **Reactive Power** import (lagging)	MVAr	**SPD**	
Maximum **Reactive Power** export (leading)	MVAr	**SPD**	
POWER GENERATING FACILITY TOP-UP IMPORT REQUIREMENTS			
Maximum **Active Power** import	MW	**SPD**	This relates to operating conditions when the Power Station is importing Active Power, typically when it is generating but is not generating sufficient power to cater for all the on-site demand. The maximum Active Power import required and the associated maximum Reactive Power import and/or export required from a Northern Powergrid network under this operating scenario should be stated. Where detailed information on the maximum power import is provided, details of Standby Supplies need not be presented here.
Maximum **Reactive Power** import (lagging)	MVAr	**SPD**	
Maximum **Reactive Power** export (leading)	MVAr	**SPD**	

DATA DESCRIPTION 5a Power Station Data	UNITS	DATA CATEGORY	COMMENTS
POWER GENERATING FACILITY EXPORT REQUIREMENTS			
Total **Power Station** output at **Registered Capacity** (net of auxiliary loads)			
Registered Capacity (maximum **Active Power** export)	MW	**SPD**	This relates to operating conditions when the **Power Station** is exporting **Active Power.** The **Active Power** export and associated maximum **Reactive Power** range (export and/or import) should be stated for operation at **Registered Capacity**.
Maximum **Reactive Power** export (lagging)	MVAr	**SPD**	
Maximum **Reactive Power** import (leading)	MVAr	**SPD**	
Total **Power Station** output at **Minimum Generation** (net of auxiliary loads)			
Minimum Generation (minimum **Active Power** export)	MW	**DPD**	This relates to operating conditions when the **Power Station** is exporting **Active Power**. The **Active Power** export and associated maximum **Reactive Power** range (export and/or import) should be stated for operation at **Minimum Generation**.
Maximum **Reactive Power** export (lagging)	MVAr	**DPD**	
Maximum **Reactive Power** import (leading)	MVAr	**DPD**	
Power Station performance chart (net, at **Connection Point**, as per DPC7 Figure1)	Figure	**DPD**	
POWER GENERATING FACILITY MAXIMUM FAULT CURRENT CONTRIBUTION			
Peak asymmetrical short circuit current at 10ms (i_p) for a 3Φ short circuit fault at the **Connection Point**	kA	**SPD**	Fault current data as per Engineering Recommendation G74, ETR 120 and IEC 60909 should be provided. Additionally, fault current contribution data may be provided in the form of detailed graphs, waveforms and/or tables. Where detailed fault level contribution / impedance data is provided for each **Power Generating Module** in Schedule 5b or 5c, the fault level at the connection point need not be provided.
RMS value of the initial symmetrical short circuit current (I_k”) for a 3Φ short circuit current fault at the **Connection Point**	kA	**SPD**	
RMS value of the symmetrical short circuit current at 100ms ($I_{k(100)}$) for a 3Φ short circuit fault at the **Connection Point**	kA	**SPD**	
Short circuit time constant T”, corresponding to the change from I_k” to $I_{k(100)}$	s	**DPD**	
Positive sequence X/R ratio at the instant of fault	-	**DPD**	

DATA DESCRIPTION 5a Power Station Data	UNITS	DATA CATEGORY	COMMENTS
POWER GENERATING FACILITY INTERFACE ARRANGEMENTS			
Means of connection, disconnection and synchronising between **DNO** and **User**	Method Statement	**SPD**	The interface arrangements need to be agreed and implemented between the **User** and the **DNO** before energisation and consideration should be given to addressing the Distribution Code requirements including DGC5, DGC8, DPC6.7, DPC7.2.6, DOC5, DOC7.4, DOC8.6.3, DOC8.6.4, DOC9 and DOC10. For example DOC7 requires that up to date contact details are provided and procedures are agreed to establish an effective means of communication between the **Generator** and **DNO**. Where details are provided on the interface arrangements for individual **Power Generating Module**, it is not necessary to present information here.
Site protection / co-ordination arrangements with **DNO**	Report	**DPD**	
Precautions should neutral become disconnected from earth (LV only see Engineering Recommendation G59/3-4)	Report	**DPD**	
Site communications, control and monitoring (HV / LV)	Report	**DPD**	
POWER GENERATING FACILITY G59 or G99 protection			
U/V Stage 1	V and s	**SPD**	Required for compliance with G59 or G99
U/V Stage 2(if fitted)	V and s	**SPD**	Required for compliance with G59
O/V Stage 1	V and s	**SPD**	Required for compliance with G59 or G99
O/V Stage 2	V and s	**SPD**	Required for compliance with G59 or G99
U/F Stage 1	Hz and s	**SPD**	Required for compliance with G59 or G99
U/F Stage 2	Hz and s	**SPD**	Required for compliance with G59 or G99
O/F Stage 1	Hz and s	**SPD**	Required for compliance with G59 or G99
O/F Stage 2 (if fitted)	Hz and s	**SPD**	Required for compliance with G59
LoM RoCoF	Hzs^{-1} and s	**SPD**	Required for compliance with G59 or G99
LoM Vector Shift	degrees	**SPD**	Required for compliance with G59
LoM Other		**SPD**	Required for compliance with G59 or G99

Schedule 5b

DATA REGISTRATION CODE

POWER GENERATING MODULE DATA FOR ALL EMBEDDED GENERATION SETS

DATA DESCRIPTION 5b Power Generating Modules Data	UNITS	Data Category for Generators connected at LV	Data Category for Generators connected at HV	COMMENTS
GENERATION SET GENERAL DATA				
Number of **Power Generating Modules** to which this data applies	Value	**SPD**	**SPD**	
Type of **Power Generating Modules**: Synchronous Generator, Fixed Speed Induction Generator, Double Fed Induction Generator, Series Converter Connected Generator, Other (provide details)	Text	**SPD**	**SPD**	Type of **Power Generating Module** should be stated.
Technology / Production Type	Text	**SPD**	**SPD**	Compliance with Grid Code PCA3.1.4.
Operating regime – intermittent or non-intermittent	Text	**SPD**	**SPD**	As per Engineering Recommendation P2 definition Intermittent Generation: Generation plant where the energy source for the prime mover cannot be made available on demand Non-intermittent Generation: Generation plant where the energy source for the prime mover can be made available on demand.
POWER GENERATING MODULE OUTPUT DATA				
Rated terminal voltage (generator)	V	**SPD**	**SPD**	
Rated terminal current (generator)	A	**SPD**	**SPD**	
Power Generating Modules Registered Capacity	MW	**SPD**	**SPD**	
Power Generating Modules apparent power rating (to be used as base for generator parameters)	MVA	**SPD**	**SPD**	
Power Generating Modules rated **Active Power**	MW	**SPD**	**SPD**	
Maximum measured **Active Power** P_{60}	MW	**DPD**	**DPD**	Only required for wind turbines – IEC 61400-21.
Maximum measured **Active Power** $P_{0.2}$	MW	**DPD**	**DPD**	Only required for wind turbines – IEC 61400-21.
Minimum Generation (set connected; net of auxiliary loads)	MW	**DPD**	**DPD**	

DATA DESCRIPTION 5b Power Generating Modules Data	UNITS	Data Category for Generators connected at LV	Data Category for Generators connected at HV	COMMENTS
Power Generating Modules Reactive Power capability at rated **Active Power** (gross, at generator terminals)				
Maximum **Reactive Power** export (lagging)	MVAr	**DPD**	**SPD**	
Maximum **Reactive Power** import (leading)	MVAr	**DPD**	**SPD**	
Power Generating Modules performance chart (gross, at **Power Generating Modules** terminals, as per DPC7 Figure 1)	Figure	**DPD**	**DPD**	
POWER GENERATING MODULE MAXIMUM FAULT CURRENT CONTRIBUTION				
Peak asymmetrical short circuit current at 10ms (i_p) for a 3Φ short circuit fault at the **Power Generating Modules** terminals	kA	**None**	**SPD**	Fault current data as per Engineering Recommendation G74, ETR 120 and IEC 60909 should be provided. Additionally, fault current contribution data may be provided in the form of detailed graphs, waveforms and/or tables. Where detailed fault level contribution / impedance data is provided for the site in Schedule 5a or for each **Power Generating Module** in Schedule 5c, the fault level here need not be provided.
RMS value of the initial symmetrical short circuit current (I_k") for a 3Φ short circuit fault at the **Power Generating Modules** terminals	kA	**None**	**SPD**	
RMS value of the symmetrical short circuit current at 100ms ($I_{k(100)}$) for a 3Φ short circuit fault at the **Power Generating Modules** terminals	kA	**SPD**	**SPD**	
Short circuit time constant T", corresponding to the change from I_k" to $I_{k(100)}$	s	**None**	**DPD**	
Positive sequence X/R ratio at the instant of fault	-	**None**	**DPD**	
POWER GENERSATING MODULE VOLTAGE CONTROL				
If operating in Power Factor control mode, allowable Power Factor Range		**SPD**	**SPD**	
If operating in Power Factor control mode, allowable Power Target Power Factor		**SPD**	**SPD**	
If operating in voltage control mode, voltage set point	V	**SPD**	**SPD**	
If operating in reactive power control mode, reactive power set point	VA	**SPD**	**SPD**	

DATA DESCRIPTION 5b Power Generating Modules Data	UNITS	Data Category for Generators connected at LV	Data Category for Generators connected at HV	COMMENTS
If operating in any other control mode, description of parameters and set point	Text	**SPD**	**SPD**	
Frequency Response Settings				
Frequency response droop setting in LFSM	Per cent	**DPD**	**DPD**	
Frequency response droop setting in FSM (if applicable)	Per cent	**DPD**	**DPD**	
POWER GENERATING MODULE INTERFACE PROTECTION				
U/V Stage 1	V and s	**SPD**	**SPD**	Required for compliance with G59 or G99
U/V Stage 2(if fitted)	V and s	**SPD**	**SPD**	Required for compliance with G59
O/V Stage 1	V and s	**SPD**	**SPD**	Required for compliance with G59 or G99
O/V Stage 2	V and s	**SPD**	**SPD**	Required for compliance with G59 or G99
U/F Stage 1	Hz and s	**SPD**	**SPD**	Required for compliance with G59 or G99
U/F Stage 2	Hz and s	**SPD**	**SPD**	Required for compliance with G59 or G99
O/F Stage 1	Hz and s	**SPD**	**SPD**	Required for compliance with G59 or G99
O/F Stage 2 (if fitted)	Hz and s	**SPD**	**SPD**	Required for compliance with G59
LoM RoCoF	Hzs^{-1} and s	**SPD**	**SPD**	Required for compliance with G59 or G99
LoM Vector Shift	degrees	**SPD**	**SPD**	Required for compliance with G59
LoM Other	V and s	**SPD**	**SPD**	Required for compliance with G59 or G99

Schedule 5c (i)

DATA REGISTRATION CODE

POWER GENERATING MODULE DATA FOR EMBEDDED GENERATION SETS

DATA DESCRIPTION 5c (i) Synchronous Power Generating Module (or Equivalent Synchronous Power Generating Module)	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
POWER GENERATING MODULE MODEL DATA				
Power Generating Module identifier	**Text**	**SPD**	**SPD**	
Type of Power Generating Module (round rotor, salient pole or asynchronous equivalent)	**Text**	**SPD**	**SPD**	Asynchronous generators may be represented by an equivalent synchronous generator data set. Not required for normal network analysis.
Positive sequence (armature) resistance	**per unit**	**DPD**	**SPD**	Not required for normal network analysis.
Short circuit ratio	Number	**DPD**	**DPD**	The short circuit ratio (SCR) of **Power Generating Module** is one measure of the performance of a machine under short circuit conditions and is important in determining the unit's stability performance. The reciprocal of the per unit on rating saturated synchronous reactance, X_d (sat), is equal to the SCR. Not required for normal network analysis.
Inertia constant (**Power Generating Module** and Prime Mover)	MWsec / MVA	**DPD**	**SPD**	Required to perform stability studies.
Direct axis reactances: Sub-transient (X''_d) – unsaturated / saturated Transient (X'_d) – unsaturated / saturated Synchronous (X_d) – unsaturated / saturated	 per unit per unit per unit	 **SPD / SPD** **DPD / DPD** **DPD / DPD**	 **SPD / SPD** **SPD / SPD** **SPD / SPD**	 Required to perform stability studies. Required to perform stability studies. Required to perform stability studies.
Quadrature axis reactances: Sub-transient (X''_q) – unsaturated / saturated Transient (X'_q) – unsaturated / saturated Synchronous (X_q) – unsaturated / saturated	 per unit per unit per unit	 **None** **None** **None**	 **DPD / DPD** **DPD / DPD** **DPD / DPD**	 Required to perform stability studies. Required to perform stability studies. Required to perform stability studies.

DATA DESCRIPTION 5c (i) Synchronous Power Generating Module (or Equivalent Synchronous Power Generating Module)	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
Time constants: State whether time constants are open or short circuit D-axis sub-transient – unsaturated / saturated D-axis transient – unsaturated / saturated Q-axis sub-transient – unsaturated / saturated Q-axis transient – unsaturated / saturated	 Text s s s s	 **DPD** **DPD / DPD** **DPD / DPD** **None** **None**	 **SPD** **SPD / SPD** **SPD /SPD** **DPD / DPD** **DPD / DPD**	 Required to perform stability studies. Required to perform stability studies. Required to perform stability studies. Required to perform stability studies. Required to perform stability studies.
Stator leakage reactance (unsaturated)	per unit	**None**	**DPD**	Required to perform stability studies.
Zero sequence resistance (earthed star only, including any neutral earthing resistance)	per unit	**DPD**	**DPD**	Not required for normal network analysis.
Zero sequence reactance (earthed star only, including any neutral earthing reactance)	per unit	**DPD**	**DPD**	Not required for normal network analysis.
Negative sequence resistance	per unit	**DPD**	**DPD**	Not required for normal network analysis.
Negative sequence reactance	per unit	**DPD**	**DPD**	Not required for normal network analysis.
Rated field current	A	**DPD**	**DPD**	Not required for normal network analysis.
Field current open circuit saturation curve (from 50% to 120% of rated terminal voltage)	Graph	**DPD**	**DPD**	Not required for normal network analysis.
Potier reactance (if saturation factor available)	per unit	**DPD**	**DPD**	Only required if the saturation factor is available. The saturation factor is defined as the pu value of field current required to generate 1.2pu stator terminal voltage on open circuit.
Saturation factor (pu field current to produce 1.2pu terminal voltage on open circuit	per unit	**DPD**	**DPD**	Not required for normal network analysis.
Frequency response droop setting	Per cent	**DPD**	**DPD**	
Frequency response mode LFSM-O or FSM				
POWER GENERATING MODULE MODELS				
Governor and prime mover model	Model	**DPD**	**DPD**	**SPD** will normally be sufficient, except where the **DNO** considers

DATA DESCRIPTION 5c (i) Synchronous Power Generating Module (or Equivalent Synchronous Power Generating Module)	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
AVR / excitation model	Model	**DPD**	**DPD**	that the stability and security of the network is at risk. Sufficient **DPD** should then be provided in order to build up a suitable **Power Generating Module** dynamic model for analysis. Alternatively a 'Black Box' dynamic model of the **Generation Set** may be provided. All models should be suitable for the software analysis package used by the **DNO**.

Schedule 5c (ii)

DATA REGISTRATION CODE

POWER GENERATING MODULE DATA FOR EMBEDDED GENERATION SETS

DATA DESCRIPTION 5c (ii) Fixed Speed Induction Power Generating Module	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
POWER GENERATING MODULE MODEL DATA (see note)				
Magnetising reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Stator resistance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Stator reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Inner cage or running rotor resistance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Inner cage or running rotor reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Outer cage or standstill rotor resistance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided. Often referred to locked rotor resistance.
Outer cage or standstill rotor reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided Often referred to locked rotor reactance.
State whether data is inner-outer cage or running-standstill	Text	**DPD**	**SPD**	
Number of pole pairs	number	**DPD**	**DPD**	
Gearbox ratio	number	**DPD**	**DPD**	
Slip at rated output	%	**DPD**	**SPD**	
Total effective inertia constant (generator and prime mover)	MWsec/ MVA	**DPD**	**SPD**	
Inertia constant of the generator rotor	MWsec/ MVA	**DPD**	**DPD**	
Inertia constant of the prime mover rotor	MWsec/ MVA	**DPD**	**DPD**	
Equivalent shaft stiffness between the two masses	Nm/ Electrical radian	**DPD**	**DPD**	

DATA DESCRIPTION 5c (ii) Fixed Speed Induction Power Generating Module	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
Describe method of adding star capacitance over operating range	Text	**DPD**	**DPD**	LV connected generators may just have a simple fixed capacitor bank. If electronic power factor control (e.g. SVC) is installed, details of the operating range and characteristics e.g. pf or MVAr range - operating regime: constant or voltage set-point / slope and response times must be provided.
Shunt capacitance connected in parallel at % of rated output Starting 20% 40% 60% 80% 100%	kVAr or Graph	**SPD**	**SPD**	kVAr value rather than the actual value of the capacitors is required.
Active Power and **Reactive Power** import during start-up **Active Power** and **Reactive Power** import during switching operations e.g. '6to 4 pole' change-over	MW-MVAr / Time Graphs	**SPD** **DPD**	**SPD** **SPD**	
Under voltage protection setting & time delay	puV, s	**SPD**	**SPD**	
Governor and prime mover model	Model	**DPD**	**DPD**	**SPD** will normally be sufficient, except where the **DNO** considers that the stability and security of the network is at risk. Sufficient **DPD** should then be provided in order to build up a suitable **Power Generating Module** dynamic model for analysis. Alternatively a 'Black Box' dynamic model of the **Power Generating Module** may be provided. All models should be suitable for the software analysis package used by the **DNO**.

Note: An Asynchronous Power Generating Module may be represented by an equivalent synchronous data set. The **User** will need to provide the above data for each asynchronous Power Generating Module based on the number of pole sets (i.e. two data sets for dual speed 4/6 pole machine).

Schedule 5c (iii)

DATA REGISTRATION CODE

POWER GENERATING MODULE DATA FOR EMBEDDED GENERATION SETS

DATA DESCRIPTION 5c (iii) Doubly Fed Induction Power Generating Module	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
Power Generating Module maximum fault current contribution data	Schedule	**SPD**	**SPD**	Fault current contribution data should be provided under schedule 5b.
GENERATION SET MODEL DATA (see note)				
Magnetising reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Stator resistance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Stator reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Running rotor resistance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Running rotor reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Standstill rotor resistance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Standstill rotor reactance	per unit	**DPD**	**SPD**	Alternatively, equivalent circuit diagram can be provided.
Rotor current limit	A	**DPD**	**DPD**	
Number of pole pairs	number	**DPD**	**DPD**	
Gearbox ratio	number	**DPD**	**DPD**	
Generator rotor speed range (minimum to rated speed)	rpm	**DPD**	**SPD**	
Electrical power output versus generator rotor speed	Graph / Table	**DPD**	**DPD**	
Total effective inertia constant (generator and prime mover) at rated speed	MWsec/MVA	**DPD**	**SPD**	
Inertia constant of the generator rotor at rated speed	MWsec/ MVA	**DPD**	**DPD**	
Inertia constant of the prime mover rotor at rated speed	MWsec/ MVA	**DPD**	**DPD**	
Equivalent shaft stiffness between the two masses	Nm/ Electrical radian	**DPD**	**DPD**	
DFIG unit models including excitation and prime mover control systems (see note)	Models	**DPD**	**DPD**	

Note: **SPD** will normally be sufficient, except where the **DNO** considers that the stability and security of the network is at risk. Sufficient **DPD** should then be provided in order to build up a suitable **Power Generating Module** dynamic model for analysis. Alternatively a 'Black Box' dynamic model of the **Power Generating Module** may be provided. All models should be suitable for the software analysis package used by the **DNO.**

Schedule 5c (iv)

DATA REGISTRATION CODE

POWER GENERATING MODULE DATA FOR EMBEDDED GENERATION SETS

DATA DESCRIPTION 5c (iv) Series Converter Connected Power Generating Module	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
Power Generating Module maximum fault current contribution data	Schedule	**SPD**	**SPD**	Fault current contribution data should be provided under schedule 5b.
POWER GENERATING MODULE MODEL DATA (see note)				
Gearbox ratio	number	**DPD**	**DPD**	
Generator rotor speed range (minimum to rated speed)	rpm	**DPD**	**SPD**	
Electrical power output versus generator rotor speed	Graph / Table	**DPD**	**DPD**	
Total effective inertia constant (generator and prime mover)	MWsec/MVA	**DPD**	**SPD**	
Inertia constant of the generator rotor at rated speed	MWsec/ MVA	**DPD**	**DPD**	
Inertia constant of the prime mover rotor at rated speed	MWsec/ MVA	**DPD**	**DPD**	
Equivalent shaft stiffness between the two masses	Nm/ Electrical radian	**DPD**	**DPD**	
Series Converter **Power Generating Module** models including excitation, voltage/**Reactive Power** and prime mover control systems (see note)	Models	**DPD**	**DPD**	
Number of operations of fast fault current injection that can be sequentially accomplished and any limitations in time, thermal limitations, protection etc.	Text	**DPD**	**SPD**	

Note: **SPD** will normally be sufficient, except where the **DNO** considers that the stability and security of the network is at risk. Sufficient **DPD** should then be provided in order to build up a suitable **Power Generating Module** dynamic model for analysis. Alternatively a 'Black Box' dynamic model of the **Power Generating Module** may be provided. All models should be suitable for the software analysis package used by the **DNO**. Where required by the **DNO,** generator electrical parameters should be provided based on Schedule 5c (i) or 5c (ii), according to the type of machine used.

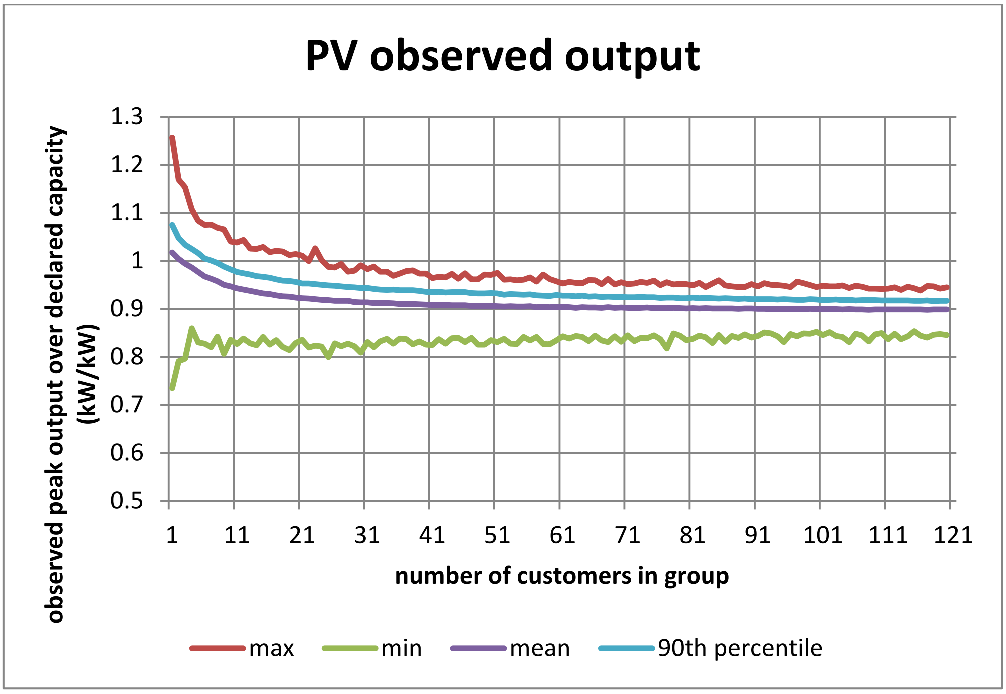
Schedule 5c (v)

DATA REGISTRATION CODE

POWER GENERATING MODEL DATA FOR EMBEDDED GENERATION SETS

DATA DESCRIPTION 5c (v) Transformers	UNITS	Data Category for Generators Connected at LV	Data Category for Generators Connected at HV	COMMENTS
Transformer identifier	Text	**SPD**	**SPD**	
Transformer type (Unit/Station/Auxiliary)	Text	**SPD**	**SPD**	
Number of identical units	Number	**SPD**	**SPD**	
Type of cooling	Text	**SPD**	**SPD**	
Rated (apparent) power	MVA	**SPD**	**SPD**	
Rated voltage ratio (on principal tap)	kV/kV	**SPD**	**SPD**	
Positive sequence resistance at principal tap	per unit	**DPD**	**SPD**	
Positive sequence reactance at principal tap	per unit	**SPD**	**SPD**	
Positive sequence reactance at minimum tap	per unit	**None**	**DPD**	
Positive sequence reactance at maximum tap	per unit	**None**	**DPD**	
Zero sequence resistance	per unit	**DPD**	**DPD**	
Zero sequence reactance	per unit	**DPD**	**DPD**	
Winding configuration (e.g. Dyn11)	Text	**DPD**	**SPD**	
Type of tapchanger (on load / off circuit)	Text	**SPD**	**SPD**	
Tap step size	%	**SPD**	**SPD**	
Maximum ratio tap	%	**SPD**	**SPD**	
Minimum ratio tap	%	**SPD**	**SPD**	
Tap position in service (for off load tapchangers only)	%	**DPD**	**DPD**	
Method of voltage control	Text	**DPD**	**SPD**	
Method of earthing of high-voltage winding	Text	**SPD**	**SPD**	

Appendix 7 - PV Installations on Domestic Premises



The graph above is derived from data in the CLNR L095 project. It shows how the average per unit observed output from a PV installation in a group varies depending on the number of customers (with a PV installation) in that group. This concept of the graph is comparable with the idea of ADMD of load customers: the ADMD reduces as the number of customers in the group.

This graph has been used to establish the guidance given in section 3.5.12. The mean PV observer output value has been used where there orientation of the PV arrays is random; the 90th percentile PV observer output value has been used where there orientation of the PV arrays is aligned.