Connection of Anaerobic Digestion Generators to Distribution Networks in Great Britain

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1. What this leaflet is about

One of the key components of your Anaerobic Digestion (AD) project is an economic connection to the electricity distribution and supply network (the Grid) to enable your generator to export electricity. Most embedded generation, also known as distributed generation i.e. that which is connected to the distribution network (up to 132kV in England and Wales but excluding 132kv in Scotland) which is capable of supplying customer load directly, at some point will produce more electricity than is consumed on the premises and will therefore have to export. For example a domestic solar panel will produce its peak output in the middle of the day when consumption by the residents could be negligible, if they are all out of the house, say at work. This relatively small amount of electricity still requires a connection that allows export. This is usually a simpler task than a connection with adequate capacity for the electricity produced by your AD project. The fundamental objective of your project is undoubtedly the profitable generation and export of electricity upon which the connection can have a major influence.

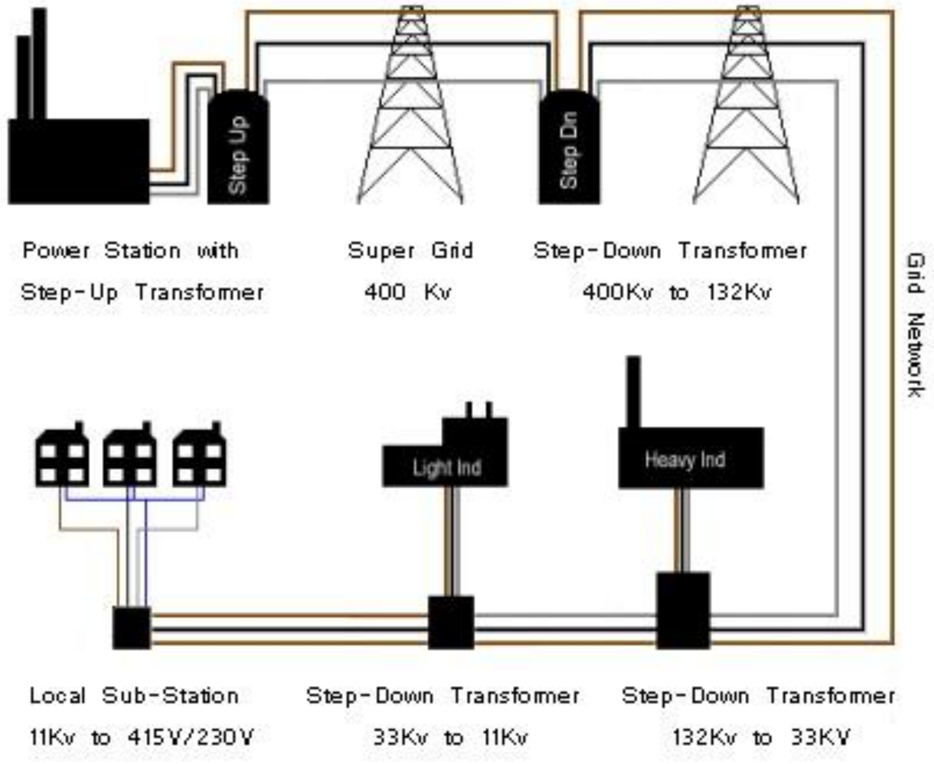
This leaflet is an introduction to some of the issues associated with the connection of an electricity generator fuelled by an AD plant to the Distribution Network in Great Britain. Its aim is help you get the most sensible connection at the least cost and is designed to give sufficient understanding to enable you to plan, negotiate, and monitor the connection process or at the very least hold informed conversations with professional advisors and technology suppliers. It is therefore divided into sections to provide a step by step understanding of how generators of between 25 kilowatts (kW) and 1 megawatt (MW), connecting in rural or semi-rural locations influence the electricity infrastructure and in turn what requirements may be imposed upon your project.

This leaflet does not cover “island” operation, where the system is not connected to the grid.

2. Structure of the electricity industry in Great Britain

National Grid Company
400kV and 275kV power lines
and some 132kV lines

The diagram shows which bodies own which physical assets but not the commercial arrangements i.e. who sells electricity to whom. That is described in section 3.1.



District Network Operators
132kV lines (except Scotland) and all 33kV, 11kV and,
415V / 230V

Electricity generation – Anyone from the large utilities such as EDF down to the householder with a solar panel on the roof can become a generator making electricity open to competition.

Electricity transmission - The National Grid Company (NGC) owns the high voltage transmission network in England and Wales whereas in Scotland it is owned by transmission subsidiaries of Scottish Power and Scottish and Southern Energy.

Electricity distribution - The District Network Operators (DNO), each with one or more of 14 geographic areas, undertake distribution of electricity and are regulated monopolies.

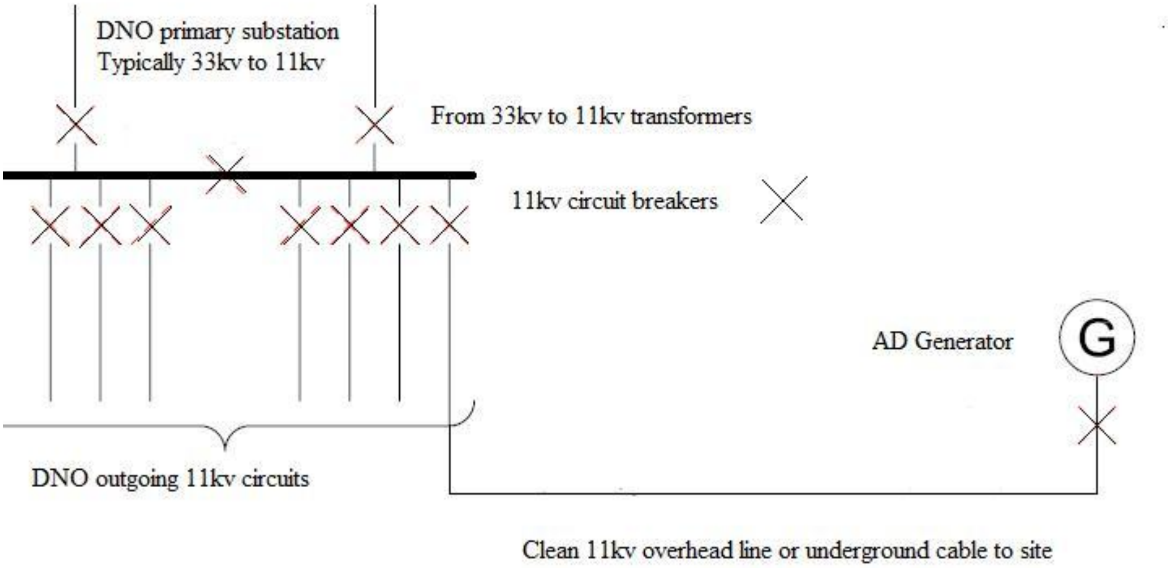
NGC also has a number of functions that apply to all of Great Britain. It directs the operation of the total system and acts as the interface between those parties directly connected to any transmission network and all transmission owners.

Application	Voltage
Local distribution	33 000 V
Railways	25 000 V
Heavy industry	11 000 V
Light Industry	415 V
Homes	230 V

2.1. Incorporating Embedded Generation

As well as generation connected to the transmission network it can also be connected to a distribution system or even into the wires owned by an end customer. Whether it is appropriate to connect at transmission or distribution voltages will be determined primarily by the size of the generation.

All AD plant will be connected to a distribution system, either directly or via your own farm wiring. The diagram below shows a generator connected to a clean 11kv feeder which corresponds to the connection method described in section 5.1.



3. Selling your electricity

3.1. The Electricity Market

The supply chain in electricity comprises producers (generators) who sell to entities known as suppliers who sell to end customers. Suppliers are so called because they supply final customers. Many but not all suppliers used to be part of groups that also performed distribution functions. Irrespective of the common ownership that still exists in a few cases, the distribution function of a company and the supply function are kept quite separate with strict provisions on confidentiality and Chinese walls between them. The Distribution companies (DNOs) operate the wires and are the party you will deal with regarding your physical connection. They do not either buy or sell electricity. It is the supply companies (suppliers) from whom you currently buy electricity and to whom you will sell your generation.

Electricity, like cereals has a futures and spot market. Energy suppliers, like grain traders, attempt to gain the best price possible from a package of generation contracted to them in order to supply their customers. Suppliers are also responsible for paying ongoing charges for using the transmission and distribution wires.

You may choose to contract your production to one of these companies and will then be quoted a bundled price for your generated electricity which would include all the components. You should check however whether the price is all inclusive or whether it will vary if for example some of the ongoing charges for using the distribution or transmission networks change.

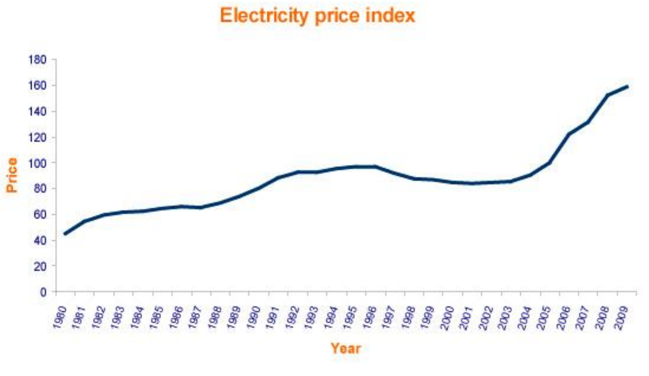
Electricity supply is a competitive market; therefore you can select whom you deal with. In practice you will already have a contract to purchase your electricity from a supplier. You may want to sell your generation to the same supplier or chose a different supplier. It is in fact possible to sell your electricity to one supplier and buy it from a different one.

3.2. The Price of your Electricity

For the sake of simplicity, this leaflet assumes you will be selling your electricity under the Feed in Tariff Scheme

The price you will receive for your generated electricity is made up from a number of components.

For every unit of electricity you generate a DNO will pay you a fixed tariff for a period of 20 years known as the Generation Tariff, and is payable upon all electricity you generate, regardless of where it is used, as part of the Feed in Tariff, the tariff being dependent upon your generating capacity. (See 10, Feed in Tariffs).



In addition, for every unit exported to the grid, you may choose either, to receive an extra 3p/kWh, the Export Tariff, or negotiate a higher price directly with a supplier.

The difference between electricity generated and exported would be your own use either in the process of generation (the parasitic load) or used in your other business and household. You will need appropriate electricity meters to determine the electricity generated and electricity exported and imported. Generators that export over 30kw require half hourly metering of the export. Meters may be arranged through your supplier but you could contract with a meter operator of your choice.

4. Connection to the Electricity Distribution Network

Essentially, you will need to connect your plant to a three phase supply, and make sure that the power factor is within a range specified by the DNO.

Your local DNO is obliged to offer you this connection and you will need a connection contract with that DNO where a significant number of issues can arise. This is irrespective of your agreement to supply electricity.

You will in fact already have a connection contract with the DNO associated with your consumption of electricity. It may be therefore that rather than enter into a new contract you agree to modify the existing one to allow for the generation. The issues involved in either case are the same. Note that the requirement for a new or modified connection contract applies whether the generator is to connect directly to the distribution network or to your farm network with no modification of the physical connection to the distribution network required.

The DNO may have concerns with your connection to their network which may lead to problems. (See section 6, Where connection problems lie) Some or all of these issues may be raised during the discussions on your connection.

If the size and output of your plant output closely matches the local demand these problems are least likely to arise (with the possible exception of islanding see section 6). You will never be prevented from connecting eventually, but if significant issues arise, connection could cost more and / or take longer than you would like.

If you can be flexible, over size, or limit a project's output at certain periods it could substantially reduce the cost. Sometimes having a restriction on output for a relatively short period of the year will reduce the cost of the connection considerably. For example if the limiting factor is voltage rise during low demand periods or when part of the distribution network is out of service for maintenance, then an arrangement for reducing power output at these times could cut the connection cost. It might be automatic or manual adjustment. Traditionally DNOs have been reluctant to accept such "active" management of their system, but this is changing.

All options should be explored with the DNO at the initial stages of discussing the connection options. It is important that you understand what factors are limiting the use of cheaper connection schemes and whether it would be possible and economic to accept some restriction in output in order to save money on the connection.

However, given that one of the key factors in profitability of your generator is run time and the health of your digester process is better maintained through constancy then these options to reduce connection costs should be rigorously assessed.

To understand the difference between single and three-phase supply; power factor, active power and reactive power; synchronous and non-synchronous generators, see section 9, Electricity generation and distribution fundamentals

4.1. Agreements to be Made

There will be at least two important agreements with the DNO, which will result in money changing hands. You may not be a direct party to one of them, although you will see its financial impact. In addition there will be other agreements if you are having part of the connection built by an Independent Connection Provider (ICP).

Whatever supplier you enter agreement with for the sale of your output they will then enter into contracts with the DNO and National Grid, who hold a monopoly in their respective areas (regulated by Ofgem), for using the distribution and transmission systems It is worth checking that under the agreement with your supplier the Use of System charges are within its rates, or if they are a separate pass-through item. (See Distribution Use of System below).

4.1.1. Connection Contract

This will be a contract directly between you and the DNO and will set out the obligations on you and the DNO and the charges to be paid for any DNO network alterations required.

4.1.2. Distribution Use of System Contract (DUoS)

This is a contract that entitles you to use the distribution network for the import and export of electricity. It is most likely that it will be between your supplier and the DNO, rather than you directly. The main feature of it is the obligation to pay use of system charges to the DNO. Currently charges associated with exports onto the low voltage or high voltage (generally less than 22kv) distribution networks are negative i.e. the DNO pays the supplier / generator for exports. It is possible that this position will change in the future. It is important that your contract with your supplier makes it clear whether its charges are “all inclusive” i.e. the supplier takes the risk of the DUoS charges changing or whether they are “passed through” and you get the benefit or pain of any changes.

4.1.3. Adoption Agreement

If you are getting part of the connection works done by an Independent Connections Provider (ICP) (see section 4.3.2) rather than the DNO, then you will have a direct agreement with the ICP for this work. When it is completed, however, it will form part of the Distribution System and as such will have to be “adopted” by the DNO. Standard forms of adoption agreements are available on DNO web sites.

4.2. Charges for Connection

Connections vary, depending on the existing network (both yours and the DNO's) and the size of your generator. A completely new connection may be required, or an existing connection might be modified. This may or may not involve reinforcing the distribution network (and possibly your own system) to accommodate the generator output. Any modifications to your own system will be at your own cost, but you are free to choose who will carry out this work. For the avoidance of doubt if you are connecting a generator of the size and type being considered in this pamphlet you will still have to apply to the DNO for a modified connection agreement, even if the generator is being connected to your farm network.

You will be charged for any extension of the network in order reach your generator, plus a proportion of any costs needed to reinforce the existing network. All DNOs publish Statements of Connection Charges which set out the methodology for calculating these charges together with examples of charges for particular connections. In addition to the charges for physical equipment there are charges for various services; for example providing specific information, design, testing, witnessing commissioning etc. and these are also laid out in these statements.

To help you understand what may need to be done (and hence what the charges may be) a brief description of some possible connection schemes is appended. (See section 5, Some Connection methods). It should be noted that which type of connection you have can only be determined following a design exercise and study work specific to your project and the DNO network conditions in the area.

Examples of charges for some elements of a connection

DNO connection charging statements typically give some examples of connections and their charges. Some typical cost components are given below. Underground cabling costs vary widely depending upon whether the land the cable is to be buried in is soft (easy excavation and reinstatement) or hard such as a road or pavement. Often costs given for cabling do not include the cost of providing a trench. Other extra costs can include buildings to house equipment or the cost to obtain easements or wayleaves (the amounts payable to landowners under/over whose land the assets pass). Remember, you can always get quotes from ICPs for work that does not involve altering the existing network.

Very ball park costs are:

- Low voltage overhead line - £23 per metre
- Low voltage underground cable - £70 per metre
- High voltage overhead line - £25 per metre
- High voltage underground cable - £100 per metre
- New hv / lv transformer - £3,000 to £25,000 depending on size and whether ground or pole mounted
- 11kv circuit breaker - £10,000 each

Note that much more detailed cost data is provided in each companies' Connection Charging Statement. The ball park costs above for cables and overhead lines assume relatively long routes (the cost per meter is more for shorter routes). Underground cable costs assume excavation in soft ground.

4.3. Process for connection

No two projects are exactly the same and the generic process below is a general guide. In practice some of the steps may be omitted, particularly for smaller schemes, and some repeated as the project concept is refined.

4.3.1. Information gathering / planning

Knowing the size of the AD project and possible locations you may wish to get a feel by yourself, with the help of a consultant or by discussion with the DNO, on what the connection possibilities may be. Each DNO produces a Long Term Development Statement (normally found on its web site). The summary is free, but some DNOs charge for the full document, or parts of it. It will detail the location of primary ehv / hv substations, which may be useful. Unfortunately no detailed information is provided on the low voltage networks or the high voltage networks emanating from the primary substations as part of the standard statement.

You can get the latter information directly from the DNO, usually in return for payment. Having narrowed down the optimum size and location, it is definitely worth meeting with the DNO and this is unlikely to cost anything. Giving the DNO as much information as possible before the meeting will make it more productive.

You can of course do this without any preliminary investigation of your own. At this stage the DNO may give a view as to what the best connection options are or say that further analysis is required (for example to determine if there is a voltage rise problem). You can ask the DNO to perform this analysis in a feasibility study or ask a consultant to perform it for you. You should be able to obtain any required network data from the DNO to do this. A feasibility study should give you some indicative (but not binding) costs for the connection.

The result of this process (which may be iterative) should be that you are relatively certain what type of scheme (if any) is optimum for you, taking into account connection costs and timescales as well as all the other factors. You should consider whether a slightly smaller electrical scheme might be optimum, perhaps finding a use for some of the energy produced by the process in the form of heat rather than electricity, and in particular whether you can make worthwhile savings on the cost of connection by accepting some restrictions on output for short periods each year.

All the above is voluntary, but you would be foolish not to have had some discussion with the DNO before going on to the next stage.

4.3.2. The formal connection application

The next stage is to make a formal connection application to the DNO, for a new connection or modification of your existing connection. The DNO will require some technical information on your generator (guidance can be found in the Distribution Code). The DNO will inform you if there is any more information it requires from you, after it receives your application.

If you let the DNO know you are considering having the contestable part of the connection work undertaken by an ICP, it will quote the cost of the non-contestable work (and may also quote for the contestable works separately). The DNO will also tell you in detail in the offer which of the activities are contestable and which are non-contestable. Having received the necessary data the DNO must make you an offer within three months. Once you get it you will probably want to discuss it, which may result in the DNO offering to amend some aspects of it. Finally you will reach the stage where either you are happy to accept the offer, and enter into an appropriate connection contract incorporating it, or you decide not to proceed with your project, in which case the offer will lapse.

If you are unable to agree some aspects of the offer and you feel the DNO is acting unreasonably, or more specifically not in accordance with the conditions in its Distribution License, you can refer the offer to Ofgem (the Regulator). Ofgem will determine what it considers appropriate terms for the offer (which may or may not be as originally offered) and the DNO is obliged to enter into a contract on those terms, providing you wish to go ahead.

4.3.3. The Construction phase

The next stage is to enter into a contract for the work. If you are having some of the work carried out by an ICP, you need to contract with it too. Any necessary consents / wayleaves etc. must obtained (by either the DNO or ICP).

As with any construction work, regular liaison is important between all parties to coordinate activity and resolve any possible conflicts in a timely fashion. It is obviously most important that safety issues on the site are properly coordinated between all parties involved.

4.3.4. Testing, commissioning and operation

Near to completion various tests will be carried out. Those which involve the generating plant (and any parts of the connection being built by an ICP) will also have to be witnessed by the DNO. The DNO will need 15 days (typically) notice of your readiness to perform certain tests / commission the plant and connection. A commissioning programme should be agreed between all involved parties.

It is also important that the appropriate commercial arrangements are in place before commissioning, especially for metering import and export, and a supplier has been appointed to trade the energy. In addition there may be requirements during the commissioning period to confirm or amend some of the data provided to the DNO at the application stage about the technical parameters of the plant. These should of course only be fine tuning of data that was known with less accuracy at the planning stage, rather than completely different data that may invalidate the connection scheme.

Operation of the plant is beyond the scope of this leaflet but generic requirements will be laid down in the distribution code and more specific stipulations will be in the various agreements between the DNO and you or your supplier.

4.3.5. Statutory timeframe for parts of the process

Since the beginning of October 2010 there are statutory regulations on the time that DNOs are allowed to complete certain activities associated with quoting for and delivering a connection, with compensation should these timescales not be met.

5. Some connection methods

5.1. New clean connection to a primary substation

The most expensive connection schemes will involve a new high voltage circuit (typically 11kv but sometimes 6.6kv or 20kv) all the way back to the nearest DNO primary substation i.e. high voltage (hv) to extra high voltage (ehv) transforming point. This will entail the line itself (either overhead or underground cable) a metering circuit breaker at the generator end and a new high voltage circuit breaker at the DNO primary substation. This type of connection will be needed if there is no high voltage connection point available or if there is a problem connecting to it.

For generators of up to 1MW thermal overloading is unlikely. Any problem is likely to be due to high voltages during periods of low demand and maximum generation, and this is more likely the further the connection is from the ehv / hv substation.

There are other ways in which it may be possible to avoid high volts and the need for a new circuit and they should always be investigated. For a new generator of around 1MW near to a DNO primary substation, a new clean circuit to that substation may be the most sensible option.

5.2. New connection to the existing high voltage (hv) network

This will be the most common connection method for larger schemes (typically over 100kw). This will require some switchgear in the existing high voltage network and a high voltage spur to the new connection point with a metering circuit breaker there. Alternatively, rather than a spur connection the existing hv network could be diverted so that it passes by the new connection point (where new switchgear would be installed to accommodate the generator).

5.3. Connection at low voltage (lv)

This may work where the generator size is under about 100kw, although larger generators may sometimes be connected at lv. It will require a connection to either the most suitable DNO hv to lv transformer or to the existing lv network, which may be yours or belong to the DNO. In some cases, it may be necessary to change the hv / lv transformer for one of a higher rating.

5.4. Need to increase existing DNO equipment fault level capability

For any of these methods it is possible particularly for the larger ones that DNO equipment (in particular switchgear) fault level ratings need to be increased although this highly unlikely for generators of 1MW or less, particularly in rural locations. If it is necessary the cost will be shared (“apportioned”) between you (as part of your connection cost) and the general DNO Use of System tariff (spread over all users of the system), according to rules laid down in the Statement of Connection Charges.

6. Where connection problems lie

6.1. Voltage rise

Power (and particularly reactive power) flowing along a circuit causes the voltage to decline. The more power that flows the greater the decline. There are statutory limits within which DNOs are obliged to maintain the voltage at the interface with their customers and to do this they have automatic voltage control schemes on their transformers at their primary substations (typically transformer the voltage from 33kv or higher down to 11kv or 6.6kv or occasionally 20kv). These schemes vary the turns ratio of the transformers by automatically selecting different winding tapings. The schemes are set up either to maintain a constant voltage at their lower voltage terminals or sometimes to increase this voltage the higher the demand on the substation. The latter “line drop compensation” scheme compensates to some degree for the additional voltage drop down the outgoing feeders as the demand and hence the flow down these feeders increases.

Some large customers take supply from these (most commonly) 11kv feeders. The majority of customers take a low voltage supply fed from hv/400volt (230 volt single phase) transformers and these transformers do not have tap changers that can be operated whilst carrying load. The primary substations are therefore generally the nearest place to end customers at which DNOs can take action to control the voltage on a minute by minute basis. They will set up the system so that at maximum demand conditions all customers and in particular those furthest away from the primary substation have voltages above the statutory minimum. Equally at minimum demand conditions the voltages must not exceed the statutory maximum levels.

If a generator is connected, particularly relatively far away from the primary substation, the system must still be set up so that all customers receive at least the statutory minimum voltage at maximum demand, assuming that your generator is not running (for you cannot provide a guarantee that it will be running at the time of peak demand). However they also assume that your generator will be running during low demand periods which will reduce the flow on the feeder from the primary substation and may even reverse it. This will cause the voltage to rise above the level it would be without your generation, hence the issue being described as voltage rise. If the voltage rises to a level above the statutory maximum then there is an issue which must be addressed. Effectively the addition of your generator increases the variation in demand on the feeder from “maximum demand less minimum demand” to “maximum demand less (minimum demand less generator output)”. If all points along the feeder can be kept within the statutory voltage range for the latter variation then there is no problem, if not another solution must be found.

6.2. Islanding

Faults on the distribution network may cause parts of it to become disconnected from the rest of the system and without any generation in the isolated (islanded) part of the system it will suffer a power cut until it can be reconnected. However if it has a generator within it and the generator output is around the same level as the demand in the island, a supply may be maintained. However there are a number of problems with the maintenance of an island which means that except in very special circumstances, the policy is to disconnect the generator to make the islanded system dead and then restore supplies from the main system. There are a number of different protection systems used to detect that islanding has occurred. These will generally operate most effectively the greater the difference between the demand of the islanded group and the output of the generator. If there is a risk that the generator output will be similar to the islanded demand then the generator control systems (power and voltage control) can be set up so that they do not maintain a stable voltage or frequency as the islanded demand changes and this should allow islanding to be detected and the generator to be tripped.

6.3. Fault level issues

Synchronous generators will provide an infeed during faults and will therefore raise the fault level on the distribution network. If it is raised above the level that the equipment is rated for the equipment will have to be replaced. It is expected that for the size of generators being considered and particularly for sites some distance from the supplying ehv / hv substations provided there is not a cluster of similar generators, instances of their connection causing fault level issues will be rare.

6.4. Thermal overloads

If more current flows through an overhead line, underground cable, switch or transformer than it is rated for it will overheat with resulting damage. It is unlikely that there will be any thermal overload issues on the high voltage system for the types of power levels considered but it is possible that if the generator is desired to be connected to an existing low voltage system and the generator capacity is significantly higher than the maximum demand currently fed from this system then there could be thermal overloading issues on the low voltage system or the high voltage / low voltage transformer. These will therefore either need reinforcement / renewal or it may be more economic to connect to the high voltage system.

6.5. Reverse Power flows

Some transformers have tap changers (that alter the voltage ratio between the windings to control the voltage) that are not able to deal with power flows from the low voltage to the high voltage windings. It is expected that this is only likely to be an issue when generators towards the upper power range considered are connected to a network with a very low minimum demand and a relevant ehv / hv transformer tap changer cannot cope with power flows from the lower voltage to the higher voltage windings.

7. Regulations, Codes and Standards

This leaflet does not cover other planning, building and health and safety regulations, nor the IEE Wiring Regulations. Because your AD plant is smaller than 50MW you do not need a generation license.

You must comply with the Electricity Safety, Quality and Continuity Regulations 2002 (as amended in 2006) which cover general safety and security related matters that are relevant to the generation, transmission and distribution of electricity.

You must also comply with the Distribution Code (which applies GB-wide). In practice this boils down to complying with a standard known as G59/2, available from the Energy Networks Association for £185

If you are appointing an Independent Connections Provider to construct part of the connection (described in the section on process for getting a connection) they will have to build the connection in accordance with certain technical standards laid down by the DNO.

The Electricity Safety, Quality and Continuity Regulations 2002 are available at http://www.opsi.gov.uk/si/si2002/20022665.htm

The IEE Wiring Regulations may be purchased at http://www.theiet.org/publishing/books/wir-reg/17th-edition.cfm

8. Where to get more help

There is a lot of useful further information available, much of it on the internet. In addition trade associations (for example the Renewable Energy Association) are able to provide some advice to members. Ofgem can be consulted particularly in cases where you feel that the DNO is being unreasonable. The DNOs themselves are usually willing to give advice.

Of course you may wish to appoint a consultant to help you and there are a number of companies and individuals that specialise in helping to get generation projects connected.

All DNOs belong to the Energy Networks Association (ENA) http://2010.energynetworks.org/ and a GB map and links to each DNO can be found on http://2010.energynetworks.org/electricity-distribution-map/

On the Engineering Documents page of this http://2010.energynetworks.org/link-to-engineering-documents/ there is a link to download a form to apply to connect a generator. You can also get access to a number of other Engineering Documents via this page. G59/2 (that covers the requirements to connect generators in the size range of interest) is probably the most important of these and unfortunately a charge is made for this.

The Distribution Code itself (which covers all generic technical interface issues related to Distribution Networks) may be downloaded free from http://www.energynetworks.info/the-distribution-code/

There is a special section on the ENA web site for generators connected to distribution networks http://2010.energynetworks.org/distributed-generation/ you can get a lot of useful material through here but the crown jewel is the “Guide for connecting Generation that falls under G59/2 to the Distribution System”.

From this page you can also get some links to all the DNO’s own web sites at http://www.energynetworks.org/ena_DG/DistributorNetworkOperatorContactDetails_071114.pdf. Each web site is laid out slightly differently but the main of interest at each are the “Long Term Development Statement” the “Statement of Connection Charges” and the “Statement of Use of System Charges”. Sometimes the connection charging statement is downloadable from the web pages headed “Use of System Charges”. There will also be a connections section which will give contact details of who to discuss connections involving generators. If you do not know which distribution network you are connected to a map is available at http://energynetworks.squarespace.com/electricity-distribution-map/

Ofgem (www.ofgem.gov.uk)The majority of Ofgem’s documents relate to ideas and proposals to change some aspect of the industry arrangements.

Distribution Company Licenses can be found on http://epr.ofgem.gov.uk/index.php?pk=folder100985
Generally it will be the “standard license conditions” that will give information about obligations in terms of timescales for doing things etc. Directions that lay down maximum timescales for performing various activities are also on the Ofgem web site.

The Balancing and Settlement Code, which covers the arrangements for wholesale trading of electricity is available at http://www.elexon.co.uk/bscrelateddocs/bsc/
One of the benefits of trading via a supplier rather than in the wholesale market directly is avoiding the need to become familiar with and a party to agreements of this complexity!

The generic arrangements for connection to and use of the distribution system are in the DCUSA available at http://www.dcusa.co.uk/Public/Default.aspx again your supplier will be a party to this (although you could become a party to it yourself).

Metering Codes of Practice are available at http://www.elexon.co.uk/bscrelateddocs/CodesOfPractice/default.aspx

9. Electricity generation and distribution fundamentals

9.1. Synchronous Generation

Electricity is generated in a synchronous generator by rotating a cylindrical magnetic field source (the rotor) within a stationary annular arrangement of electrical coils (the stator). In smaller machines the rotor magnetic field may be provided by a permanent magnet but for the size range under consideration the rotor magnetic field will normally be produced via an electromagnet i.e. passing direct current through a winding in the rotor. By varying this current the strength of the magnetic field may be varied, the effect of which will be described later.

All synchronous machines connected to the mains in Great Britain rotate at exactly the same speed which relates to the frequency of the alternating current mains, the voltage in which goes from positive to negative to positive again 50 times a second. For a rotor with two poles (one “north” and one “south” pole produced by the electromagnet) and electrical frequency of 50 cycles a minute (Hertz abbreviated to Hz) will mean that the rotor goes around at 3000 RPM. An arrangement of the electromagnet on rotor that has four poles (two “north” and two “south”) would have a rotational speed of 1500 RPM.

The frequency may vary slightly from its nominal value of 50 Hz (generally within the band 49.8Hz to 50.2Hz but occasionally over a wider range) but all synchronous generators will at any one instant always be operating at exactly the same relative speed (so a four pole machine will be operating at half the speed of a two pole machine). This is in contrast to induction generators, commonly used for example for wind power generation where their speed will not be synchronised with each other’s and the frequency of the mains.

9.2. Single and 3 Phase

The arrangements of the electrical windings in the stator produce three separate voltage outputs, with the instantaneous voltage in each winding separated from those in the others by one third of an electrical cycle i.e. the point in the positive - negative - positive sequence where they are at any instant. This produces what is known as a three phase supply with most domestic premises connected to only one of the phases but larger premises connected to all three. Whilst around a typical farm most power outlets will be of the standard domestic single phase type, larger motors require a three phase supply. You will have noticed that most overhead electrical lines have three conductors, one for each phase. Larger lines with six main conductors will be carrying two circuits, which can be routed separately and switched on and off independently.

9.3. Power Factor

The current (flow of electricity) in an alternating system is not always exactly in phase with the voltage in the system. In other words whilst the frequency of the current and the voltage will be identical the current may get to its positive peak a bit before or a bit after the voltage gets to its peak (and the same for its negative peak). The extent to which the current and the voltage are out of phase is described by the term power factor, a power factor of one meaning that the voltage is exactly in phase with the current (always at exactly the same point in the positive - negative - positive cycle) whilst a power factor of less than one indicates that the current is either leading the voltage by a time in its positive – negative – positive cycles or lagging it. Although the current might be leading or lagging the voltage, their frequency will be identical. If the current and voltage are not in phase then the power consumed or generated is said to be split into real power (related to the component of the current that is in phase with the voltage and performs useful work) and reactive power (related to the component of the current that is one quarter of a cycle out of phase with the voltage and performs no useful work).

There are two parameters that can be controlled in a synchronous generator operating in parallel with the mains. The first is the real power output which is controlled by varying the fuel input to and hence the power output of the prime mover (in this case the AD gas engine). The second is the reactive power output which is controlled by varying the strength of the magnetic field on the rotor. If the generator were disconnected from the mains altering the rotor field magnetic strength would alter the voltage being generated rather than the reactive power output, hence the term automatic voltage control system or AVC used to describe the control system that adjusts the strength of the rotor magnetic field. The AVC can be set up in a number of different modes.

9.4. Power Transmission

Electrical power transmission is more efficient at higher voltages which require less current to transmit the same power. The longer the distance and the higher the power level to be transported the higher the voltage that becomes economic. Hence transmission networks that transport large amounts of power over long distances operate at the highest voltages and distribution networks operate at between transmission voltages and the low voltage system. Transformers are connected between voltage levels to allow power to flow between them. Power engineers tend to refer to systems by the voltage difference between any two of their phases rather than between a single phase and earth. Thus the common voltages of 11kv and 33kv for example are references to the voltages between any two phases of that system rather than the voltage between a single phase and earth. The low voltage system, although 230volts between any single phase and earth, is 400 volts phase to phase.

The lines, transformers, generators and customer installations are all divided into circuits which either have protection operated circuit breakers at their connection to other components or for the lower voltages sometimes fuses. Apart from enabling individual components to be taken out of service for maintenance these are set up so that if a particular plant item is faulty the circuit containing that plant item is automatically disconnected from the rest of the system, limiting the damage to the faulty item and allowing the remainder of the system to continue to operate normally. Such “faults” may be the results of breakdown in equipment or the equipment being impacted by an external event such as a lightning strike on an overhead line, a short circuit to nearby vegetation in high winds or an underground cable being struck during an excavation. Whatever the cause, often very high currents flow during the fault and the fault level of a system is a very important parameter as all system components have to be rated to withstand the maximum possible fault current without damage and circuit breakers in particular have to be capable of breaking the maximum fault current that they might be called upon to break. Extra sources of synchronous generation will increase the fault level on the system – if this results in the fault level rating of any system component being exceeded then either the system will have to be reconfigured or the inadequately rated component will have to be replaced.

10. Feed In Tariffs

Technology	Scale	(p/kWh) [NB tariffs will be inflated annually]			Tariff lifetime (years)
		Year 1: 1.04.10-31.03.11	Year 2: 1.04.11-31.02.12	Year 3: 1.04.12-31.03.12	
Anaerobic digestion	≤500kW	11.5	11.5	11.5	20
Anaerobic digestion	>500kW	9	9	9	20
Hydro	≤15 kW	19.9	19.9	19.9	20
Hydro	>15 - 100kW	17.8	17.8	17.8	20
Hydro	>100kW - 2MW	11.0	11.0	11.0	20
Hydro	>2MW - 5MW	4.5	4.5	4.5	20
MicroCHP pilot*	≤2 kW*	10*	10*	10*	10*
PV	≤4 kW (new build)	36.1	36.1	33.0	25
PV	≤4 kW (retrofit)	41.3	41.3	37.8	25
PV	>4-10kW	36.1	36.1	33.0	25
PV	>10 - 100kW	31.4	31.4	28.7	25
PV	>100kW - 5MW	29.3	29.3	26.8	25
PV	Standalone system	29.3	29.3	26.8	25
Wind	≤1.5kW	34.5	34.5	32.6	20
Wind	>1.5 - 15kW	26.7	26.7	25.5	20
Wind	>15 - 100kW	24.1	24.1	23.0	20
Wind	>100 - 500kW	18.8	18.8	18.8	20
Wind	>500kW - 1.5MW	9.4	9.4	9.4	20
Wind	>1.5MW - 5MW	4.5	4.5	4.5	20
Existing microgenerators transferred from the RO		9.0	9.0	9.0	to 2027

Source, Department of Energy and Climate Change