



DTI New and Renewable  
Energy Programme

## **MICRO-GENERATION NETWORK CONNECTION (RENEWABLES)**

**Report Number: K/EL/00281/00/00**  
**URN 03/1019**

**Contractor**  
Halcrow Group Ltd  
(Subcontractors EMS Consulting Limited and TXU-UK)

**Prepared by**  
J Thornycroft  
T Russell  
J Curran

The work described in this report was carried out under contract as part of the DTI New and Renewable Energy Programme, which is managed by Future Energy Solutions. The views and judgements expressed in this report are those of the contractor and do not necessarily reflect those of the DTI or Future Energy Solutions.

First Published 2003  
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**dti**

Department of Trade and Industry

## **Preface**

The project was managed by Halcrow Group Ltd with subcontractors EMS Consulting Limited and TXU-UK. The work for the report was carried out between February 2002 and April 2003.

## **Acknowledgements**

Input is acknowledged from Mike Lees and Jeremy Harrison of EA Technology, Tony Lakin of I-Power Ltd, John Sinclair of Electricity Association, Pete Thomas of SP Power Systems, Arne Povlsen for input on Denmark and Hermann Laukamp and Lutz Fischer for input on Germany.

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# **INTRODUCTION**

## **Background**

It is now accepted that one of the results of the desire to reduce CO<sub>2</sub> emissions will be a very significant increase in the number of small renewable generation units seeking a connection to the distribution network. This change will have a profound effect on the way the distribution network is designed, operated, managed and developed, and will require a radical change to enable the Government targets to be met for this type of plant.

Small self generation will impact on all aspects of the electricity industry. As well as simplified connection it is expected that the distribution network will need to be actively managed, and there will be less demand for supply from the grid. Metering will need to become more sophisticated and an agreement reached on how costs should be allocated when customer imported demand is reduced and surplus electricity is exported onto the system.

Because of their small size it would be beneficial to provide simplified arrangements for these small participants, rather than treat them the same as larger sizes of generator.

This report focuses on the issues most relevant to renewable generators, although some of the themes will be common to whichever generation technology is used.

## **Aims & Objectives**

The overall aims and objectives of the project are to examine connection issues related to micro-generation from renewables, and its large scale integration into the UK electricity distribution network.

This is in part to help answer the recommendation of the OFGEM Embedded Generation Working Group whose report identified the need to analyse technical connection and charging & tariff issues related to micro-generation, with a view to achieving this by January 2003.

This study specifically examines the connection issues that relate to micro-generation from renewables, scoping the subject and providing possible solutions to how the network can accept large amounts of micro-generation and how this is costed and charged for.

Key activities to achieve this are:

Review of existing standards and those in the process of being drafted that are relevant for the connection of small renewable generation. These will include G77/1, G83/1, and G59/1 in the UK, and foreign standards.

- Evaluate the impact of mass connected micro-generation on the supply and distribution industries.
- Appraise how the network might accommodate mass connection of micro generation and what technical and commercial actions may need to be taken to make this possible.

- Outline new standards that may be necessary as part of a new approach to network connection and management of a network with mass micro-generation capacity, where possible including standards for connection, micro-generators and for the network.
- Produce a framework for governance for any new standards and procedures.
- Test proposals with relevant industry experts.
- Provide outline costs for potential connection for micro-generator connectees and the network operators.
- Investigate overseas networks with significant micro-generation penetration, drawing from lessons learnt on connection, management and technical issues.

## **Content**

The report is structured as follows:

### **PART 1**

*Chapter 1* is a description of the existing framework within which micro-generation must be connected to and allowed to operate on the network in Great Britain. *Chapter 2* looks more specifically at three standards relating to the connection of small generation to the network, two of them existing and one in the course of preparation. *Chapter 3* looks at how some other countries have approached the subject of dense connections, and *Chapter 4* examines the technical impact of large amounts of small renewable generation on distribution networks. Part 1 ends with *Chapter 5* that looks at the financial impact and significance of various aspects of the issues covered earlier.

### **PART 2**

Part 2 starts with *Chapter 6* which looks at the possible options both technical, financial and governance which could move the existing situation forward. *Chapter 7* then takes a broader view and looks at the theoretical and practical basis for the requirements without being constrained by the existing documents. *Chapter 8* reviews the financial requirements in a similar way to Chapter 7. *Chapter 9* lists preferred options, with these being brought together and summarised as Conclusions and Recommendations in *Chapter 10*.

## **PART 1**

### **1 EXISTING FRAMEWORK**

#### **1.1 Technical Connection Documents**

The technical connection documents relating to interfacing distributed generation with the distribution network are Engineering Recommendations published by the Electricity Association on behalf of the Electricity Industry. They obtain their mandatory status through being referred to, as a standard that should be complied with, in the Distribution Code.

The long standing document, Engineering Recommendation G59/1 covers all types of embedded generator up to 5MW, and is backed up by some explanatory notes in ERT 113. Although G59/1 has recently been amended, it does not closely address the needs of micro-generators and especially ‘micro-renewables’ because of its size ceiling of 5MW and because the notes were written before there was much renewable generation to include in the guidance.

This has been recognised to some extent by the development and publishing in 2000 of an Engineering Recommendation specific to Photovoltaics (PV). This was released as ER G77 and has now been revised to include some two years of operating experience as ER G77/1 released in October 2002. Open technical discussions were held during its development both within the Electricity Industry, and including representatives from the PV industry as well. Because of the relatively slow introduction of PV this has proved a useful testing ground for the concepts which are now being picked up by a follow-on working group to address all small generation (see G83 below). The size limit in G77/1 was set at 5kWp partly to reflect the total area of PV that could be installed on a likely (domestic) building, and partly to be in line with other countries guidance that were also under development.

ER G83 extends the work of G77 to include other micro-renewables, and in fact non-renewables such as domestic CHP. These are both inverter connected (as in G77/1) and more conventional ‘rotating machine’ generators. The format of the document will comprise a ‘generic’ section similar to G77/1, and then sections specific to each technology. The power limit chosen is 16A per phase to be in line with the generic standards for ‘white goods’ such as domestic appliances, and corresponds to 3.68kW for single phase rising to 11kW three phase. A first release of the generic section and annex for Domestic CHP was published in October 2002 as ‘G83’. A version including additional annexes for micro-wind, micro-hydro, micro-pv and micro-fuel cells is expected to be published as G83/1 in the summer of 2003.

Greater detail and discussion of the issues involved in the above are in *Chapter 2*.

#### **1.2 Parallel Connection Agreements**

Parallel Connection Agreements, i.e. connection agreements that give details of and conditions associated with the generator connected in parallel with the system, are currently required for any generator connected in parallel with the Distribution Network. This applies whether or not the plant is designed to be, or is capable of, exporting electricity to the grid. The conditions are to help ensure the safety and reliability of the system as a whole by

specifying the protection system requirements in the event of out of limits operation, and also the quality of the power that results on the network. Liabilities for failure to ensure this, are contained in the Agreement which is executed between the 'Owner' of the system, and the Distribution Network Operator (DNO).

Currently, each DNO produces their own agreements to reflect their own commercial terms, which are geared towards relatively large commercial conventional generators, and can be daunting documents to understand for a domestic houseowner, with no easy access to legal advice.

This has been recognised for the PV community, where an example shortened connection contract has been developed for use with small scale PV customer-generators, under the 'Scolar' project for schools. However the experience so far under the 3 year PV Major Demonstration Programme grant scheme started in mid 2002, is that this has not yet been adopted by all DNOs.

### **1.3 Tariff Agreements**

Typically a small generator will "trade" all of its output via a supplier i.e. the contract between the customer/generator and Electricity Supplier will cover both electricity imported from the network and that exported to it. This supplier may or may not be in the same ownership as the DNO to whose system the customer is connected, but in any event it will be separately licensed and the DNO will have to act in a completely non-discriminatory manner towards all suppliers.

For Domestic Tariffs the ratio between the price for power imported and that paid by its supplier for electricity exported can be 3:1 (6p 'avoided cost' on import, but only 2p on export minus the cost of metering). For this reason many domestic size systems do not go to the trouble of arranging to be paid for exported electricity and thus 'spill' excess electricity back into mains with no charge to electricity companies. There is however a saving to be made at full price from generation displacing electricity that would otherwise have been imported.

As in practice, micro-generators can only sensibly sell their output via a supplier, the existence of competition in the domestic supply market is important as in some cases these suppliers also compete by offering more competitive credits for electricity exported.

An added benefit of being a 'renewable' generator is the potential to earn Renewable Obligation Certificates 'ROCs'. This currently requires sale through a Licensed Supplier and appropriate metering. At present this is potentially worth more than the sale of exported electricity itself, but as it needs to be 'aggregated' via a licensed supplier it is not directly available to the private generator. The DTI Distributed Generation Working Group DGWG has a workstream WG4/P04 which is researching how this limitation might be overcome.

### **1.4 Metering Standards**

There are currently no profiles (algorithms that create a deemed half hourly demand pattern from a quarterly meter advance and temperature/daylight data) available that allow for micro-generation within a premises and in particular no profile that allows for the possibility of power being exported. Net metering i.e. ordinary accumulating meters that are able to run

backwards when the customer/generator is exporting are not allowed in Great Britain so the only options for a micro-generator are therefore limited either to "giving away" any units exported or having a separate export meter which, because of the lack of any profiling for generation, would currently have to register half hourly figures.

This is unlikely to be economic for a small generator, which only occasionally exports. Whilst services are now being developed for reading half hourly meters remotely via telecommunication interfaces and posting the values securely on the internet, these still currently have running costs of the order of £100 per year. In addition there are currently considerable settlement charges associated with half hourly metering. For micro-generation that absorbs most of its output on site and may perhaps export under £100 worth of electricity per year it can be seen that such systems are totally uneconomic.

However, a proposal to alter the Balancing and Settlement Code P81 'Removal of the Requirement for Half Hourly Metering on Third Party Generators at Domestic Premises' has now been accepted, with the target to produce calculated profiles to correct simple import and export meter readings, by Autumn 2003.

Other work is also being undertaken under the auspices of the Distributed Generation Co-ordination Group to recommend the optimum longer term solution to metering the output of micro generation. One of the issues being considered is how best to allow appropriately authorised installers of such plant to change the meters if necessary whilst they are on site to install the generation, thus saving the cost of a visit by a separate authorised meter operator.

### **1.5 Use of System charges**

Currently distributed generators pay no distribution use of system charges, DUOS being levied solely on demand. For domestic scale demand this is on the basis of units supplied so units not imported due to generation avoid payment of DUOS. Clearly though if a large volume of micro-generation were to reduce the DNO DUOS income without there being a corresponding reduction in distribution costs, the financial position of DNOs would be unsustainable. It is therefore quite possible that the basis of DUOS charging may change from April 2005. For example in its October 2002 update document on the Structure of Distribution Charges Ofgem asks for views on "The advantages and disadvantages of, over time, moving to capacity charging for all customers, either by a proxy or by installing meters that can record maximum demand." The same document considers in some detail the merits of charging DUOS charges for generators.

### **1.6 Connection Costs**

Currently DNOs charge "deep" reinforcement costs to generators that connect to the system i.e. all costs that they incur as a result of the connection. This is in contrast to shallow connection costs paid by transmission connected generation (which does however pay Transmission Use of System charges). There has been much discussion since 1990 as to whether distribution connected generation ought to pay deep reinforcement charges and this has been the subject of a number of recent Ofgem consultations, work in the DTI/Ofgem Working Group on embedded generation and network management issues of 2000/2001 as well as the current Distributed Generation Co-ordinating group and indeed other DTI projects. Whilst the issue is unlikely to be resolved before the next DNO price control review to be

active from 2005, there appears to be a general move towards shallower charging combined with distributed generators paying a form of DUOS charge.

Having said that, it is generally true that if the connection of a micro-generator were to attract costs of any reinforcement to the distribution system over and above that of linking up to it at the nearest point, the scheme would be unviable. Indeed many micro-generators connect to an existing customer installation and it is how that is allowed to be done and the resultant costs that are often a critical factor for the scheme's viability.

## **2 G77/1, G83/1, & G59/1**

G77/1 and G59/1 are the current connection standards relevant to micro-generation. G83 has been issued for Domestic CHP and is planned to be reissued as G83/1 to include micro-renewables in 2003 and is thus destined to become the master connection standard for generation up to 16 amps per phase.

### **2.1 G77/1**

Engineering Recommendation ER G77 was published in 2000 by the Electricity Association to facilitate the connection of photovoltaic (PV) generators to public distribution networks. It was developed by the 'ER G77 Working Group' that was set up under a previous ETSU contract.

It is specifically restricted to photovoltaic (PV) generators of up to 5kW connected via inverters. Considerable international effort has gone into the connection of PV under the International Energy Agency IEA Task V. This standard drew on some of this experience, as systems are currently much more widespread overseas. It is based on the concept of 'Type Tested' equipment as it was realised that for both cost and practicality reasons, witnessing of every system on commissioning would not be possible. Also, a variation from G59/1 is that the protection system resets automatically after a delay after sensing the network has reverted to normal. This does not require the intervention of trained DNO personnel. In addition, the inclusion of the automatic protection system, removes the need for a manually lockable isolation device to be provided external to the building.

Much of the interest from the Electricity Companies was not just in the applications to PV which were seen to have a relatively slow introduction, but also the implications for other emerging 'micro-generator' technologies such as micro-turbines which can be inverter connected. These have now being developed under a separate Engineering Recommendation 'G83' which is strongly based on the work carried out for ER G77.

The decision to publish G77 in mid-2000 was made in the knowledge that because there were relatively few installations and thus limited experience in the UK at the time, it was best to publish the recommendation to make it available to all. It would then provide increased help to connection managers in interpreting G59/1, which was the existing recommendation for all generation below 5MW, and would also provide feedback on its effectiveness and practicality. It has now been reissued as ER G77/1 in October 2002 to include this feedback.

A major item of discussion during its development was what standards the protection system should be designed to, and whether semiconductor devices could be relied upon. It was concluded that semiconductor switching could be allowed subject to:

- self-certification by the manufacturer that the inverter, including the control circuits, meets specific levels for IEC60255 as listed (these were required in the absence of a product specification, which would otherwise have allowed this aspect to be covered by the normal CE mark).
- the unit having a self-monitoring function that ensured that no unsafe output was produced in the event of a fault within the unit.

- provision of an additional switch-disconnector to be mounted locally to the inverter in the event that this is remote from the lockable device placed adjacent to the Consumer Unit.

Other editorial changes made during the ‘bedding in’ period were to:

- clarify that three phase systems could be included with a single phase inverter on each phase, provided that the total power does not exceed 5kW and that the phases are balanced as far as practicable
- include a statement that the DNO should assess the likelihood of interaction of the automatic protection based on a statement from the supplier on which active anti-islanding method is used. Also include that the Type Tests are already designed to test against this effect as far as possible
- add the Type Test Certificate as an Appendix, and extend its scope to incorporate other ER G77 requirements such as the CE Mark and whether the settings are adjustable etc, in a format familiar to connection engineers
- add an Application Form and Commissioning form as Appendices
- introduce a flowchart to the application and commissioning process as an Appendix
- replace the ‘typical’ diagram of figure 1 with a block schematic, to avoid misinterpretation of the information

The activities of the G77/1 Working Group are now complete with the document live and in use, and the focus has moved onto development of a ‘wider’ standard to cover all micro-generation technologies. This is described below.

## **2.2 G83 & G83/1**

This standard has been issued for micro generation and the technology specific annexes for other types of generation are currently under development. What follows is a brief summary of some of the more controversial points that were being discussed between the various groups and interested parties in the debate about connection standards for very small generators, defined as up to 3.68 kW per phase.

Work was started on ‘G83’, following on from recognition of the need from within the Electricity Industry, reinforced by the recommendations of the DTI Ofgem Working Group. It now consists of a generic section designed to be common to all ‘prime mover’ technologies, and connection interfaces (i.e. inverter connected or rotating machine). This will then be complemented by technical annexes that will bring out all additional information relevant to the sub-categories of generators.

At present, only the Annex for Domestic CHP has been issued, so clearly there is a very important activity pending for Renewables, and representative experts are drafting the annexes for these for release in mid 2003. Current categories include, micro-hydro, micro-wind, and fuel cells, as well as photovoltaics. For photovoltaics, the current version of G77/1 will stand until superseded by G83/1, but there is not expected to be any major change as most of G83 is based on the structure established for G77/1.

The main changes introduced in G83 include, 1) Voltage limits, and 2) The fit and inform principle:

### **1) Voltage limits**

It became apparent that using the voltage limits originally proposed at 207 and 253V would in practice lead to a very/unacceptably high number of micro-generator trips, particularly for high voltage conditions. This was modified to voltage limits of between 207 and 264 volts outside which limits the generator should trip with a 1.5 second delay and a minimum of 3 minutes stable operation within the above voltage limits before reconnection. This has now been accepted.

### **2) Fit and inform**

Possibly the most controversial issue within the new standard was to endorse the principle of "fit and inform" rather than having to obtain the agreement of a DNO prior to connecting a generator designed to run in parallel with the network. This has now been accepted for single generators within a single Customer's installation. Planned installation of multiple generators in the same geographic area still requires prior approval from the DNO. This would be required for example for multiple systems installed as part of a new housing development, or under a refurbishment programme within the same road or street.

It is planned to reference G83 from the Distribution Code, but at present this is still being discussed.

## **2.3 G59/1**

This covers all Embedded Generation plant of any technology, of up to 5MW and connected at voltages of up to 20kV. It is thus currently the standard for all generation below these limits including micro-generation with the exception of small photovoltaic systems that are covered by G77/1 and micro CHP covered by G83.

The main points in G59/1 relevant to renewable micro-generators are:

- Powers much higher – up to 5MW
- Rotating as well as inverter equipment
- 'G59' protection relay normally sold as a separate unit, cost £500 to £1,000
- Witnessing of tests often required to be paid for by the Generator
- List of equipment is maintained by the Electricity Industry
- Manual reset required for G59 relay – manual intervention
- Some problems with ROCOF protection settings giving nuisance tripping on wind farms

The main issue for micro-generators is one of cost, both in the purchase of the 'G59 Relay' and provision of the externally lockable external switch, and in the possible witnessing of the tests. The length of time and resources required from both parties for this process is not seen as appropriate for the long term development of these very small scale generators. To start to address this issue the 'G83' working group described above has been set up for micro-generators up to 3.68kW per phase.

In Part 2 of this report the place for possible additional standards is also reviewed.

## **3 OTHER COUNTRIES' EXPERIENCES**

### **3.1 Experiences in Germany**

Connection of micro-generators to the grid in Germany is now fairly mature, especially for PV where over 10,000 systems have been connected using the 'ENS' system. The procedure for PV is now very simple, with many utilities leaving it completely to the PV system installer to take care of the technical and administrative issues.

The process developed for PV has now been streamlined and includes the concepts of 'post notification' and 'type testing' as below. The procedures are specifically for PV systems up to 5kW but are also used for larger PV systems. It is also expected to apply to non PV micro-generators using ENS, at least as an interim:

- Once a customer has decided to contract an installer to build and connect a PV system, he is no longer required in the process. The administrative and technical procedures are carried out entirely by the installation company:
- The installer then obtains the additional energy meter to record units exported to the network from the respective utility, and installs both the PV system and energy meter
- Shortly before or shortly after completion of the system, he fills in a standardized form which is used to record new connections to the low voltage grid, as well as to report the completion of the installation
- Along with this form, technical documentation has to be provided including the single phase circuit diagram, and a list of all relevant safety equipment such as over current, over voltage and frequency deviation protection equipment including specifications and set thresholds. In most cases that is all. In some cases a formal approval from the utility is received
- Sometime after this procedure has been completed, the utility sends a person to seal the energy meter to prevent electricity power theft
- Some utilities request a formal announcement about three months before the installation. They then issue an approval to the announcement
- For larger systems sometimes a test is required and conducted by the respective utility, to check that the grid capacity is high enough to accept the additional power from the PV system. The test costs between 1,000 and 1,500 Euros and this has to be paid by the customer. In inner-city locations this test is not necessary, because the line impedance is typically low.

It should be noted that in Germany, electrical installations in buildings including a PV system, may be carried out by any skilled electrician without further qualification (equivalent of NICEIC in the UK).

#### **Utilities**

In Germany, the local utilities have quite a lot of freedom as far as the technical and administrative procedures for grid connection of PV systems are concerned. Small utilities with little experience with PV installations tend to be more conservative and more formal, larger regional utilities with a lot of experience rely very much on the installer of the system and do without any acceptance tests by themselves.

General rules for grid connections of any customer systems are the TAB Technical Connection Rules and the Guideline for Operation of Private Power Supplies in Parallel to the Public Grid. Both are issued by the Association of German Electric Power Companies VDEW.

The practices for proper installation vary among the utilities despite the general guideline by VDEW. For example of the three utilities local to Freiburg none require the announcement 3 months ahead. Only one requires a report on completion, and two out of the three allow the meter to be installed by the installer, with only one requiring that they do this themselves.

It is expected that all utilities will follow the trend to simplified guidance, since this practice also reduces the costs to their company. This is in parallel with the practical implications of processing and connecting the large number of new installations in the wake of the New German law for Renewable Energies which calls for the procedure to be as simple as possible.

### **Protection Systems**

For small systems (<5kW) the standardized ENS safety device between the PV system and the grid has now been widely accepted and proven its feasibility in more than 1,000 systems. Its use is strongly supported by the mandatory employers insurance company in Germany. Therefore, safety concerns for utility workers doing maintenance work on the grid have been taken care of and present no obstacle to distribution of PV any more.

The ENS device requires two independently operated switching devices connected in series to provide redundancy, one of which must be a 'relay' device providing mechanical opening of contacts. It is proved by a 'type test' and has been adopted also in neighbouring countries. However, its adoption as an international standard is unlikely because of its effect on the distribution network, and a 'functional testing' non technology specific approach being favoured internationally.

Large utilities do not conduct acceptance tests for residential PV systems. They rely on the ENS device to provide a safe interface to the grid, and this has generally been accepted by VDEW. Also the older method of a three phase undervoltage detection which is applied to larger systems, is still accepted for small systems.

Until five years ago some utilities installed at their own expense an external lockable disconnection switch. This practice has now completely been abandoned for cost reasons. It is held that the ENS operating at single phase assures the same level of safety for maintenance workers.

Between 5kW and 30kW, if no external disconnect switch is fitted then a three phase AIF (Automatic Isolating Facility) similar to the ENS is required. Over 30kW the freely accessible disconnection box is still mandatory.

The ENS device has been found to work well in the urban situation with a low grid impedance. It sometimes created problems on rural grids with higher line impedances. In the main it has not been adopted internationally because it injects disturbance onto the grid in the form of current pulses and has been found to interfere with other ENS systems if in an area of 'dense' installation.

The 'ENS' is not specific to PV or indeed to inverter fed systems in Germany, and will be expected to cover other forms of micro-generation as they become more widespread.

### **Network Issues**

The allocation of reinforcement costs in Germany is such that the generator is required to pay for any additional installation or reinforcement costs directly related to their connection. However, the cost of administration to the electricity companies is initially paid for by the electricity company, but is then recovered by adding it to the operating costs of the grid, and averaged so that every user has to pay a little.

Two laws regulate the payment of enhanced rates for export to a generator. The first is the 'EEG' for Renewable Generators where for instance PV is entitled to an enhanced payback rate of 48.3 eurocents/kWh, and secondly the 'KWKG' for CHP devices, where CHP systems less than 50kWe receive 5.11 cents/kWh on top of the 'market price'.

No control is possible from the utility over the generator's output, except in the case of a protection issue where the automatic ENS operates.

Connection to a final (mixed) circuit is allowed if a study is carried out to demonstrate that the cable has sufficient capacity, but connection in this manner is unusual because of the enhanced rates that are available if connected back to the export meter on a separate circuit.

### **Problems Experienced in Germany**

In Germany because of the metering arrangements, problems have sometimes occurred where the utility itself installs the energy meter. These result from the relative inexperience of conventional electricians with private power generating systems. Compared to conventional meter installation the meter has to be connected backwards because the power flow also is backwards. If the utilities installer is unaware of this situation the meter is wrongly connected and runs backwards.

Connection to the public grid either needs a special license or a 'concession' from the local utility. Most PV installers do have a concession by their local utility.

Some utilities require the installation of new meter sites where the meter can be plugged in later on. This way the installation can all be done by the PV installer and the meter is added by the utility. Thus the likelihood of a wrong meter connection is reduced. However, in some cases a very attentive utility installer noticed the 'wrong' connection of the meter and repaired it. This caused the meter to run backwards!

It has been noted that in common with other countries, keeping a good relation with the local utility helps avoid such errors, and achieve a good overall quality of installations.

## **4 TECHNICAL IMPACT**

### **4.1 Technical Issues**

The effects of connecting a significant amount of micro-generation to a distribution network fall into groupings that are the same as for the connection of all generation. Briefly these include:

#### **Thermal, including phase unbalance**

Thermal overloading occurs when the current in a conductor reaches a level where an unacceptable temperature is reached. It is thought unlikely that domestic scale micro-generation (1kW or 2 kW per installation) will result in any thermal overloads but it is clearly possible that a cluster of larger micro-generators (say 10kW to 20kW each) that are connected to the low voltage network could, particularly if they were not associated with any demand e.g. very small wind farms. In these cases it may be necessary to reinforce the system, either by using larger conductors or by connecting at 11kv, both a considerable cost. In many cases however even generators of this size will reduce flows on most sections of an lv main.

There may be a specific issue with phase unbalance causing problems particularly if individual dwelling micro sized generators are installed in nearby houses in a manner that does not distribute the generation evenly between phases. Swapping services between phases to spread evenly those with generation would generally seem the appropriate course of action if there were a problem.

#### **Voltage**

This is expected to be one of the most difficult issues associated with the connection of large amounts of micro-generation. High voltage to 400volt transformers do not have on-load tap changers so there may be expected to be a problem with high voltages if there is significant generation when the demand is low, as may be anticipated for example with solar power in a domestic housing area. Because the hv/lv tap positions are set to ensure that voltage is maintained at the far end of the feeder at maximum demand conditions with no generation, generation at low demand times can result in an unacceptable voltage rise. This issue is discussed further in the studies that are described later in this section.

#### **Fault levels**

Inverter connected generation makes no significant contribution to fault levels but synchronous and induction generator connected plant do (as do synchronous and induction motors) and clearly network fault levels must be kept within allowable limits. It should be noted that generation connected at low voltage will increase the fault level at all higher voltages as well as at lv.

#### **Protection Complications**

The protection arrangements for micro-generators need to be co-ordinated with those for the rest of the network, particularly automatic re-switching and re-closing features. It is important that if the network is lost and the micro-generation trips it does not try to re-close until the network conditions have been stabilised.

### **Flicker and harmonics**

Harmonics may be an issue with inverter connected generation but this should be dealt with by means of approved standards for the inverters. Flicker could be an issue for generators, the output of which can vary significantly and which are large relative to their nearby demand. One can envisage this being an issue with wind generators in particular.

### **Safety issues**

This is the most important area to consider as the connection of generation gives an additional source of infeed to both the distribution system and indeed that of the generator host, which in many cases will be a domestic dwelling. Both parties working on distribution systems and parties working on their own systems, including homeowners working on their own house wiring need to be aware of this and adequately protected from the risk of shock.

### **The importance of diversity of micro-generation types**

It is worth commenting that a generic difference between micro-generation and larger generators is that it is expected that there will be a large number of microgenerators and these will be of a number of different types. From the point of view of the effect on distribution networks an important split is between those types that will generally be operating when the demand is high and those types that are just as likely or even more likely to be operating when the demand is low e.g. PV systems.

A lot of work looking at network issues previously has looked at problems with for example voltage rise assuming that the micro-generation may coincide with minimum demand and without considering that there may be a similar amount of micro-generation at times of maximum demand. This is significant.

micro-generation at times of maximum demand is generally helpful as far as voltage control (and current limits) are concerned. At times of minimum demand it can give rise to voltage rise problems. A simple method of overcoming this such as either lowering the set voltage point at the main substation or “permanently” changing the tap position of the 11kv to lv transformers is often discounted because it would lead to unacceptably low voltages at times of high demand. However if an amount of micro-generation equivalent at least to that running at times of low demand, is running at times of high demand, (it may be either the same generation or different generation), then the maximum net demand will be reduced and a lower set voltage will not give rise to low voltage conditions at high gross demand periods.

In summary providing there is as much micro-generation at times of high demand as low, voltage problems may be overcome relatively straightforwardly by lowering the voltage set point at the primary substation or “permanently” altering the tap positions of the 11kv/lv transformers.

There is an equivalent argument that can be made for increases in fault level. Providing there is enough diversity in the types of micro-generation to produce a similar value of additional fault infeed at times of high and low demands, an increase in impedance provided either by series reactors or higher standard transformer impedances should keep fault levels down to rated levels without leading to voltage control problems.

The above should be borne in mind in the next section which summarises the key findings from two other investigations of the subject, both dealing with PV, one in Denmark and one in the UK. As these deal purely with PV they are in some respects a worst case scenario i.e. a

source of generation that is at its maximum when demands are low and considered in isolation from diverse sources of micro-generation that will be at their maximum output at other times i.e. when the system demand is likely to be high.

We now summarise the key findings from two other investigations of the subject, both dealing with PV, one in Denmark and one in the UK.

#### **4.2 Task V report from Elsam, Denmark**

In Denmark the experiences are as follows. They are for PV but will be broadly applicable for other renewable technologies as well, with the proviso that many other technologies are less likely to be at maximum output at times of low demand than PV so some of the limits are less likely to be active in practice:

##### **Introduction**

The amount of installed power generating capacity from PV systems is steadily increasing. The PV systems are typically installed in residential areas and connected to the existing low voltage (LV) networks.

The instantaneous power production from PV often exceeds the instantaneous power consumption in residential areas with a high concentration of PV systems. In many cases, the imbalance in power creates a net power flow backwards through the MV/LV transformers, i.e. the power flows from the LV network to the medium voltage (MV) network.

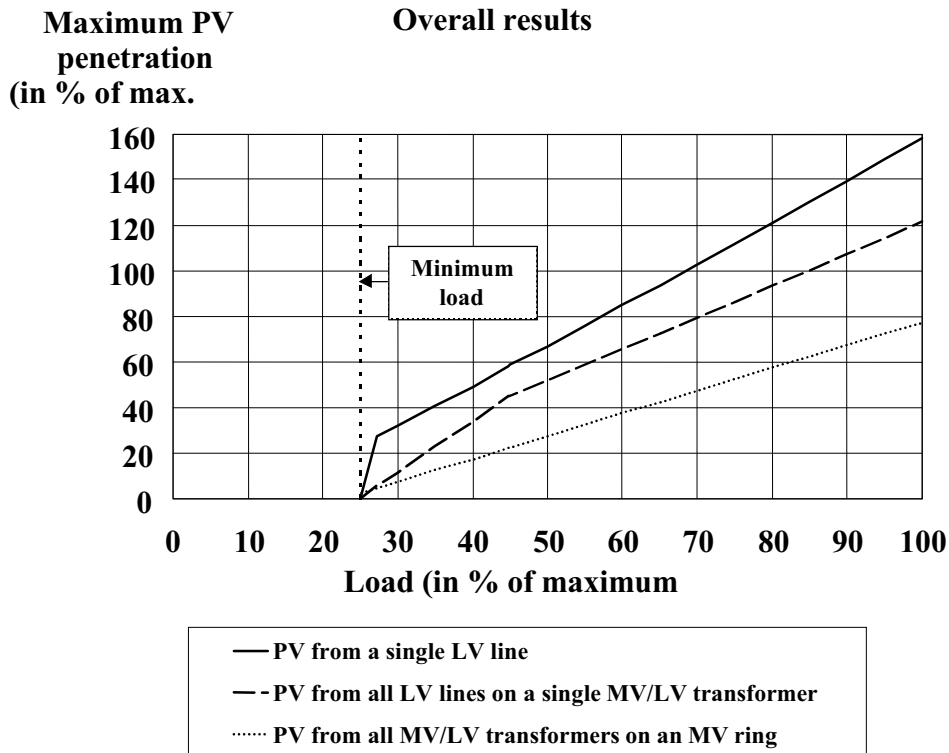
What are the upper limits to the amount of PV that can be fed into a power system without causing problems to the power systems? And what sets the limits? What are possibilities of stretching the limits? And finally, what are the financial aspects of high concentrations of PV in a power system?

##### **Results**

In principle, no PV penetration is allowed for at minimum load. However, the excess voltages are rather limited for PV penetrations up to the minimum load.

In addition, only a small increase in the load from the minimum load opens up for a considerable amount of PV, especially if PV power only penetrates from a single LV line.

Of course, the restrictions at minimum load are only a problem if the power generation from the PV systems coincides with minimum load situations. The figure below shows the overall limits of PV penetration as analysed in the report:



**Figure of Overall limits of PV penetration into existing power systems**

### **Measures to stretch the limits of PV penetration**

Measures to increase the amount of PV penetration are only necessary if large power production from PV coincides with minimum load situations. This is the case during the summer holidays in many countries, especially if the use of air-conditioning is limited.

#### Separate PV reception networks

An ultra cautious way to avoid over-voltages from PV penetration would be to build separate reception networks for PV systems (i.e. PV networks separated from the consumer networks). By separating the PV reception network in this way the injection of power does not affect the voltage on the network to which customers are connected. Such measures are often seen in the open country with high concentrations of wind power.

- The power networks are, however, not very often well established to begin with in the open country.
- On the contrary, one of the big advantages of PV is in fact to connect to the existing power networks as well as to use the existing buildings for mounting.
- The costs of PV would increase to unacceptable levels if separate power networks were required, especially if the problems only occurred a few times per year.

#### Controllable PV systems

Another way to avoid over-voltages could be to let PV systems reduce their power generation in case of over-voltage.

- Such a measure would add unacceptable costs to PV systems, especially if the measure is not needed in the majority of cases.
- In addition, over-voltage monitoring systems would make PV more sensitive to short-term disturbances in the network.

#### Adjusting the transformer tap changer position

A more feasible solution to allow for more PV penetration at minimum load during summer days is to change the MV/LV transformer tap changer positions in the summer period when maximum load situations are not expected.

- Such a measure would require an interruption of the electricity supply twice a year for adjustment of the offload tap changers.
- The costs of this measure are likely to be rather limited.

#### Customer initiatives

One of the most efficient measures to allow for more PV is perhaps the customers' own changes of behaviour.

- Experience with PV systems in Denmark shows that the customers change their consumption behaviour when at the same time they become power producers.
- Many customers who have PV installed endeavour to move their consumption to moments with high power production from PV. This tendency is especially noticeable if the customers experience different buying and selling prices of electricity.

#### **Conclusions**

The following are the conclusions from the study which are broadly transferable to the UK situation along with the UK report in *section 4.3*:

- The limits to the amount of PV power that can be fed into a power system are least critical if the PV power penetrates from only a single LV line.
- The limits are more severe if PV power penetrates from multiple LV lines connected to the same MV/LV transformer or even multiple MV/LV transformers.
- The most severe limits occur in minimum load situations, especially if the power system beforehand is operated to its design limits.
- However, an amount of PV penetration equal to the minimum load only causes slight excess voltages in the power network.
- Only a small increase in the load from the minimum load opens up to a considerably larger amount of PV, especially if the PV power only penetrates from a single LV line.
- The most feasible solution to stretch the limits to PV penetration is to review the procedures for adjusting the MV/LV transformer tap changer positions. The costs of such a solution are likely to be rather limited.
- In the longer term, it is expected that more flexible and accommodated consumption will remove the barriers of limits to PV penetration.
- Concerning the financial aspects of PV penetration, PV is likely to offer benefits to the network that far exceed the limited costs of PV penetration.

#### General comments on above conclusions

Two of the above conclusions from the Danish study deserve a comment. The first and most important one is that the most severe limits occur at minimum demand if the power system beforehand is operated to its design limits. This is taken to mean that at minimum load without PV generation voltages at some points are at their maximum allowable levels. This would correspond to maximum utilisation for the network without generation.

If however one allows for there to be some generation that is not present at low demands to be present at higher demand levels (perhaps wind or micro CHP or even slightly larger CHP that

operates during working days only) then the maximum net demand would also be lower so it would be possible to adjust tap changers so that voltages could be maintained within allowable limits for some generation at minimum demand. It is effectively the difference between the net minimum and net maximum demands on a network that determine whether it can stay within voltage limits throughout the load cycle. A small change in the values of the net maximum and net minimum demands whilst keeping the difference between them the same can generally be accommodated by altering transformer tap positions.

The second Danish conclusion worthy of comment that is related to the first (although the Danish study does not discuss the issue of generation type diversity) is that adjusting MV/LV tap positions is likely to be a way of stretching the limits of PV penetration. Off load tap changing twice a year with a consequent interruption of supply would certainly not be acceptable in the UK (and as it is understood that the tap changers on the equivalent transformers in Denmark are also off load only it would be surprising if it were acceptable there either). However providing the “excess” generation at minimum demand is balanced by additional generation also at high load periods then a one off adjustment of the taps (or perhaps one every few years as generation penetration increased) may be an acceptable way of keeping the voltages within limits throughout the year.

There may also be scope for alternatively/ additionally lowering the voltage set point at the primary substation. Alternative voltage control strategies at primary substations involving new methods of compounding i.e. changing the target voltage with net demand, may also have a role to play to allow a greater variation between net maximum and minimum demands to be catered for.

### **4.3 UK report on PV from EATL & UMIST**

#### **Network Constraints**

The impact of high penetration levels of photovoltaic systems on electrical distribution networks was investigated under ETSU project S/P2/00310 which published its report in late 2002. This work was carried out in conjunction with International Energy Agency IEA Task 5 on distributed PV generation, and specifically focused on what levels of PV generation could be expected before changes to the existing network and network design standards would be required. It is also applicable to other forms of distributed generation as a general case, although some details of the generators will differ.

Factors influencing the ability of the network to accept distributed generation capacity were:

- Voltage control
- Current-handling capacity (cables, transformers)
- Fault level situation
- Stability of generators
- Active management of network power flows

For inverter connected generators such as PV, the fault level contributions are small, so the main constraints were found to be voltage related followed by power flow management once the density of systems is such that generation exceeds the local load, and net exports occur.

#### **Voltage Levels**

For voltage control, three main cases were considered:

- Commercial buildings

- Domestic retrofit
- Domestic new build

In the first case for commercial buildings, no significant impact on network voltages was found, mainly because the levels of PV generation were not significant relative to the existing load, and also the match between generation and demand with respect to the time of day was good.

For domestic retrofit, at the worst case of systems being fitted to every house, 640Wp could be fitted per house. However, a more realistic situation was thought to be 4 houses in 10 fitted with PV (40%), where the permitted average size of systems would rise to 1.6kWp. Above this level reverse power flow at the transformers was noted, with excursions outside the statutory voltage limits possible at system sizes above 2.3kWp.

For new build domestic houses, two changes to the above are noted. The first is that the buildings themselves are likely to be designed to be more energy efficient, which would tend to make the situation worse, and the second is that the design standards for the LV network have also been updated to incorporate higher rated cables which would improve the situation. The net result is that for the worst case situation of all houses in an area being fitted with PV, the size of systems that are possible without changing the network rises to 1kWp per building.

It is worth commenting on the suggested effect of increased energy efficiency. It may be argued that although efficiency is increasing more electrical appliances are being used so the effect of increased energy efficiency on demand levels needs to be tempered by this. Although fridges and freezers are becoming more energy efficient (and these devices may be significant components of the minimum demand) it is likely that the largest effect of increased energy efficiency will occur at times of high demand associated with more efficient lighting and possibly heating, to the extent that electricity is used for this. Additional electronic devices will be used relatively uniformly between summer and winter, with a possible skew towards winter. Thus overall it is felt that any reduction in minimum demand due to increased energy efficiency is likely to be less than the reduction in maximum demand and overall the variation in demand attributable to increased energy efficiency will decrease. There is therefore an argument that this will make micro-generation at times of low demand easier to accommodate by allowing changed transformer tap settings as discussed earlier.

Above this level, reverse power flow at the transformer again becomes a problem, and tap changing of the transformer to reduce the ratio of voltage across it becomes necessary. For example, to accommodate 100% penetration of 3kWp systems, on an estate with energy efficient houses using only 2,000kWh/yr energy load, the secondary transformer voltage would need to be reduced by 4% i.e. 10 volts. This however, has the undesirable effect of meaning that feeder lengths would need to be shorter, and implies the use of more distribution transformers but at a lower power rating.

### **Future LV design**

The study concluded that in order to accommodate significant levels of micro-generation the following changes need to be made:

- Changes in voltage control policy (e.g. lower the nominal secondary voltage set point for new LV networks).

- Changes in LV network design policy (e.g. use of non-tapered feeder designs, reduced lengths of LV network feeders)
- Changes in generator connection policy
- Incentivise the network operator to recover his costs as distributed generators become connected.
- Incentivise customers to install 'appropriately sized' systems

It concluded that 'appropriately-sized' PV for a domestic situation was likely to be in the range 500W-2kWp of PV generation per house.

It also noted that this share of generation capacity would also need to be shared with other forms of micro-generation and so the level available to PV would be less than this in that situation. However, the overall ceiling for micro-generation would likely be larger than the PV only limit due to the diversity in the output from the different types of micro generators. A comprehensive study of this is still to be performed.

## **5 FINANCIAL IMPACT & SIGNIFICANCE**

A number of factors that are critical to the viability of micro-generation are discussed in this section, followed by the conclusions of the Danish study on the financial impact of PV penetration. The financial impact of micro-generation on DNOs must be taken into account in any arrangements particularly ensuring that their revenue and costs continue to be balanced at increased levels of penetration. This is addressed first.

### **5.1 Incentives on DNOs**

It has been acknowledged by all parties that DNOs are currently at best held neutral to the connection of distributed generation. To the extent that the generation operates they may actually be worse off if their units distributed, which is one of their overall revenue drivers, falls. Changing this situation has been a key recommendation of many reports including the joint Ofgem/DTI Embedded Generation Working Group that undertook the bulk of its work during 2000.

It is clear that Ofgem has taken this firmly on board and in addition to consulting about a number of ways of ensuring that DNOs may be kept whole or better if they connect new distributed generation over the next two years, is making incentivising of DNOs to do this a fundamental part of its work for the review of DNO price controls to come into effect from April 2005. A major open letter to DNO Chief Executives in January 2003 consults in some detail on the type of incentive that may work best.

Options include a new MW of connected distributed generation revenue driver, a MWh generated or exported revenue driver, allowing capital investment made to accommodate distributed generators subject to a favourable allowed rate of return, allowing DNOs to benefit if they utilise distributed generation to avoid network reinforcement and utilising a strengthened incentive to reduce distribution losses. Whilst there are other possible incentives such, as allowing DNOs to benefit if they make less use of the transmission network, it is apparent that the issue is now being adequately addressed in the right place and one may anticipate incentives being put in place such that when a generator asks to be connected to a distribution network, the DNO and the generator have a common interest in accommodating this.

### **5.2 Type Testing**

It is clear that as the numbers of micro-generators increases it will become impractical to examine each application individually, both logistically and financially. It is expected that this will be addressed (as it has for PV in G77/1) by using type tested equipment which, whilst not guaranteed in all cases to be acceptable for connection, does at least guarantee factors such as the effectiveness of the protection system and, for inverters, the quality of the output. There is a huge saving in cost to both electricity companies and PV installer if commissioning tests do not have to be witnessed. Clearly however for this to become acceptable there needs to be a 'central' body to keep a register of equipment, and oversee the testing process. Costs for type testing are currently thought to be of the order of £2,000, as a one off payment, although as inverter manufacturers can carry out the tests themselves as a 'self certification' then these internal costs are likely to be lower. This compares to an inverter cost currently around £500 per kW.

### **5.3 Post Notification**

The use of type tested equipment and standard connection arrangements leads naturally to the abolition of the need for pre approval for the connection of certain types of micro-generation equipment, with savings in administrative costs. Clearly the types of equipment that are allowed to be connected without prior approval must be ones whose connection will not give rise to potentially dangerous conditions, either on the network or for the generator or other connectees. The question of whether a modified connection agreement is required remains an issue. There may be an argument that the standard lv connection agreement should be amended to allow certain classes of generation to be connected under specific conditions.

### **5.4 Connection to final Circuit**

A very small self-contained PV generator is now available for generation at the very low powers of around 100W. Obviously for this scale of generation (which could be thought of as ‘pico-generation’) the overall economics are even more sensitive to connection costs.

Connection from the inverter which would typically be on the roof of the house, to the Consumer unit on the ground floor could cost perhaps £150 to £200 if carried out by a qualified electrician. This compares with a product cost of say £500 for the generator. However if safe installation could be made to the standard ringmain, then the connection cost could be reduced to say £25, for connecting to a hardwired ‘spur box’ installed in place of a conventional 13A socket outlet, and wired via a lockable isolator located adjacent to it.

The main technical issue appears to be the fusing of the system, so that the thermal rating of the cable is not compromised. This could happen in theory, if no measures were put in place, by excess current being drawn from the generator, and then used at an adjacent load connected to a socket outlet, without increasing the level of current drawn through the main fuse for the circuit in the Consumer Unit. The risk of this is thought to be low in practice because of the low chance of the load being maintained so close to the fuse rating for any length of time. Possible regulations suggested to prevent this would be to limit the amount of generating capacity that is allowed to be connected, or perhaps to de-rate the main fuse by the amount of extra current that might be generated. The issue is one of interpreting the IEE wiring regulations, which do not seem specific on the subject at the moment.

In Holland the equivalent of 500-600W of this type of device can be connected to the final circuit (radial in the case of Holland) without overrating the cable. There is obviously scope for this to be extended to other technologies of generation, but only after a detailed examination of the issues. Being able to connect safely into existing house wiring is financially important probably for most domestic scale generation costing under say £2,000.

The technical issues surrounding this are discussed further in *Chapter 7*.

### **5.5 Renewables Subsidy**

It is recognised that for some Renewables technologies subsidies are required for market enablement. This could be ‘Grant’ based as a subsidy or advantageous loan against capital cost, ‘kWh’ based such as ‘net-metering’, or maybe tax based such as ‘Green Mortgages’. Examples for PV are the Major Demonstration Programme where a capital grant is made

against the capital cost of the system, and also the reduction of VAT to 5% for installations by professional installers. For connection issues it is thought important to keep these subsidies separate from any costs for connection, so that they do not affect the fair assessment and division of these costs.

## **5.6 Danish Study**

The Danish study concluded the following on the financial aspects of connecting low power PV generators in large quantities to the Danish network. It is endorsed by the IEA Task 5 who have included the results in one of their reports:

- In general, PV is unlikely to present conceptually novel issues requiring fundamental, additional investments in the power systems. PV is more or less just another element of distributed generation contributing to the general competition in generation, transmission and distribution.
- The marginal costs per kWh that PV imposes on the power system are likely to be substantially lower than for bulk power. PV penetration implies only minor costs of the measures of stretching the limits for penetration. If PV becomes a significant element in power generation, it must be integrated into the dispatch protocols of the independent system operators.
- On the contrary, PV offers benefits to the power systems like all other elements of DG (distributed generation). PV reduces the peak power demand from the network if high PV penetration coincides with peak demand situations.
- The benefits appear especially when PV is combined with flexible and accommodated consumption. The major benefits are the independent supply security and the reduction in network losses.

Commenting on these points in turn:

1. It is agreed that there is nothing novel about PV's incorporation into the power system but it may precipitate the need for some expenditure on networks that are operating at their maximum capability with respect to net demand range to avoid unacceptably high voltages. This is because in the UK (as in Denmark) its maximum output is likely to be at low demand periods, unless it is balanced by a source of distributed generation output at times of high demand (which it is anticipated it will be in general in the UK),
2. It is agreed that the cost that micro PV imposes on distribution networks in the UK is likely to be low. It is not clear that there is likely to be sufficient in the UK to make participation in the centralised despatch arrangements necessary but it is possible that some sort of "automatic despatch" to pull back at times of high voltages may be a means to accommodate more PV.
3. It is of course unlikely that PV will coincide with the peak demand in the UK.
4. Adjusting consumption to accommodate more PV is possible but it is thought unlikely to be a preferred route in the UK.

## **PART 2**

### **6 OPTIONS**

#### **6.1 Generation Connection Standards**

With G77/1 as a low-power connection standard for PV, and G83/1 for all micro-generation with currents up to 16 amps per phase (corresponding to power levels of up to 3.68kW single phase or 11kW three phase) several major barriers to domestic and small-scale grid connections have been removed. However for medium power systems and systems of several hundred kW and above, then a different approach needs to be considered.

This could take three forms, the first would be to consider a rewrite of G 59/1, the second to increase the upper limit of G83 and the third is to produce another new connection standard which covers these medium power levels - the problem with the latter approaches is setting the new power thresholds.

#### **G59/2**

This approach is to be preferred because it gives the opportunity to include many of the lessons learnt in producing G77/1 and G83/1. It would also give the opportunity to include many of the better aspects of other relevant international standards such as the American Underwriters Laboratory inverter specification UL1741. This could then very well allow those sectors of British industry involved in distributed generation to produce competitive equipment compatible with not only the British market but with the wider international marketplace. Initial discussions with the main parties who would be involved have been very positive. It is suggested that a project be considered under DGCG to look at the feasibility of this and how best it might be achieved.

The technical Arguments for updating G59/1 include:

- It was written some time ago mainly for rotating generators
- Inverters are not covered well (only thyristor based equipment)
- It is out of line with developments in related International Standards from the International Electrotechnical Commission (IECs)
- It has no statement on Direct Current injection levels
- No functional tests for islanding are included
- UL1741 is becoming adopted as a de-facto general guide for all inverters
- It does not reference current IECs
- It could add 'tiered' disconnect voltage settings (e.g. a longer disconnection time for a small out of tolerance voltage to allow ride through of short-term disturbances and avoid 'blackout')
- It will help to open markets to UK manufacturers

#### **G83/1 Size Increase**

A second proposal might be to increase the limit on G83/1 to 32A to align with the largest household load such as an electric shower, or cooker circuit. Alternatively it could be investigated if the 11kW (16A three phase) equivalent of 48A single Phase should be allowed, if the effect on the network is similar apart from the balancing between phases.

### **New Intermediate document**

A third alternative would be to introduce an intermediate document with an upper limit either based on the effect on the network, or on the relative price of the connection versus the system cost.

## **6.2 Network Design Standards**

### **General**

Clearly in addition to possible changes in standards for the connection of micro generators to the network there is a need to consider what changes may need to be made to the standards to which the network is planned and designed.

There are a number of general effects that the mass connection of micro-generation may have on networks which may be summarised as

- An increase in fault levels
- A change in the pattern of net demand on the distribution network

### **Increase in fault levels**

The former is associated largely with non inverter-connected generation and is likely to be more of a problem for the connection of larger generators than those of up to 30kW. Many smaller non inverter-connected renewable micro generators e.g. small wind turbine and micro hydro are likely to be connected in lower network density areas where high fault levels are unlikely to be an issue (the situation may be different for micro CHP units but this is not the subject of this report.)

If there is a fault level issue with mass connected micro generation, apart from the obvious remedy of uprating equipment (which is unlikely to be practical for LV mains and connections to it, including of course in principle customers' installations) and splitting networks (which is unlikely to be generally applicable at LV) then the use of non fail safe fault level limiting devices e.g. explosive fuses should be reconsidered.

These have not been accepted, primarily because they are not fail safe. There is a case that if used in large numbers and situations where, in order to control the fault level adequately, it is only necessary for a given percentage to operate correctly, the statistical probability of failure of more than the critical number of these devices, could result in a lower probability of the fault level being exceeded than the probability of a fully rated device to fail catastrophically (which is non zero). Thus they provide a network that is just as safe as one that does not rely on (a proportion of) non fail safe devices working.

It is therefore recommended that, should there be situations where the fitting of these devices to a large number of locations, only a percentage of which would have to operate correctly to ensure safety, a risk analysis is carried out with the aim of establishing whether the Health and Safety Executive would accept this practice.

### **Change in pattern of net demand**

Clearly the mass introduction of micro generation will lead to a changed pattern of net demand on the distribution network. This will affect network flows and hence could lead to both thermal and voltage control issues. In general micro-generation, which is limited to the order of magnitude of the demand taken from the same point, ought to reduce the power flows on the distribution network. However there is a difference between those technologies that

generally generate at times of higher or even peak demands (e.g. wind and micro CHP) and those that may be at their maximum at times of very low demand and contributing very little at times when demand is at its highest (e.g. solar).

The former will tend to reduce the after diversity maximum demand per customer and thus will reduce reinforcement that would otherwise be needed particularly at 11kv and above where the benefit of diversity may be enjoyed. They may not lead to much benefit at low voltage and particularly service cable level if the maximum demand without generation for individual customers has to be catered for but higher up the network the effect of diversity in reducing the overall demand may be allowed for.

### **Importance of variation in conditions**

Generally it is an increase in the variation of conditions on the network that will create a problem rather than a change in the conditions themselves. Thus for example a reduction in the net demand without any increase in the variation between peak and minimum net demand can be catered for with respect to voltage control by an adjustment of AVC settings at the primary substation. If however the range of net demand increases because of a greater amount of generation at times of low demand than at times of higher demand then more expensive methods of maintaining satisfactory voltage control will have to be employed.

In the case of micro-generation it is not clear that there will be extensive areas of the network with more operating at low demand times than at high demand times. In these circumstances the general affect on the network will be a lower maximum and minimum demand but the difference between them should not increase. This may be accommodated relatively easily by changing voltage set points at main substations and catering for lower peak demands at points far enough upstream in the network for diversity to be allowed for.

### **Conclusion**

Unlike larger distributed generators diversity between the types of microgenerator in most parts of the network should lead to no increase in the difference between minimum and maximum demands and thus should not present major problems with respect to voltage control. Generally this will lead to a lower after diversity maximum demand per customer which should allow for savings in the cost of distribution in the long run. At this stage we do not therefore think that it is necessary to alter standards to which distribution networks are designed in order to accommodate micro-generation. The situation needs to be kept under review particularly if it emerges that there are significant areas of the network that have more generation running at times of low load than at times of high load.

## **6.3 Governance**

Two aspects of this are considered: type testing and the governance of the electrical standards themselves.

### **Type Testing**

For Type Testing, it would make sense to have an independent third party body administer and adjudicate on the type testing register. This would be because the tests would largely be by self-certification by the manufacturer or a test house chosen by them. At present registers are kept for PV on the DTI Grant Programme website, but this is only an interim solution.

## **Governance of Electrical Standards**

Following a consultation in the summer of 2002 Ofgem published its final proposals on the Governance of Electrical Standards in October 2002. They propose bringing applicable Electricity Association Engineering Recommendations under the umbrella of the Distribution Code and Grid Code Review Panels. A working group of these panels is currently discussing the implementation of this governance.

The key framework recommended by Ofgem in October 2002 is given below:

### **KEY FRAMEWORK:**

1. The remit of the code review panels shall cover any technical specifications, engineering recommendations and any other technical documents that directly affect network users.
2. The code review panels shall be empowered to discuss commercial considerations insofar as they interact with technical standards.
3. The code review panels shall be the only vehicles for initiating work to introduce new standards or to amend existing standards that directly affect network users.
4. The code review panels shall adopt and publicise formal document publishing and revision procedures.
5. The code review panels shall adopt and publicise formal consultation procedures setting out as a minimum, criteria for deciding who to consult and time-scales for completion of work.
6. The code review panels shall provide a high degree of visibility and transparency of the consultation process by use of internet and e-mail during consultation. Publication of final standards on an open-access internet site should be considered.
7. Governance arrangements and membership of the panels shall be reviewed periodically.
8. Consumer representatives and representatives of other users shall be invited to sit on the panels.
9. The relationship with service providers that perform drafting, publishing or other services shall be formalised by means of service provider agreements.
10. The panels shall publish an annual report of their activities including work plans for the next period.

The key recommendation is number 3 which ensures that all changes to standards that affect network users come under the auspice of the appropriate code review panel, which for micro generators will be the Distribution Code Review Panel. The formal key to having adequate small generator influence on the development of standards is therefore to have adequate small generator influence on the Distribution Code Review Panel.

The Great Britain Distribution Code Review Panel, set up in 2002 combining the England and Wales and Scotland Panels, has two members representing generators that are not subject to the Balancing and Settlement Code i.e. smaller generators. Clearly however this encompasses generators of up to several tens of MW so it does not necessarily ensure that the specific interests of microgenerators are taken into account, although the panel members do have to represent the interest of all their constituents. The main difficulty in practice when new standards are to be discussed is foreseen as being finding suitable people to sit on the working groups that will be set up to develop new standards.

Ofgem has rejected funding for such representatives to be made available by DNOs and expects in the main for them to be nominated (and therefore presumably funded by)

appropriate trade associations. Providing the trade associations can provide sufficient representation to man working groups and respond in an informed and timely manner to consultations the above arrangements should work adequately.

Consideration should therefore be given to providing resources to ensure that this can be achieved.

#### 6.4 **Financial**

Costs for connection could be made more in line with the cost of micro generators if:

- they did not need the hardware cost to install the G59 relay
- no witnessing of the test was required which is normally charged to the generator
- Post Notification meant that there was a savings in the overall process as it would be quicker

A summary table of estimated costs is included for comparison below. Although there may be considerable variation in the range of charges/costs, the comparison is intended as a typical like for like generator being connected under different procedures.

	<b>G59/1 - Pre Notification</b>	<b>Type Tested - Pre Notification</b>	<b>Type Tested - Post Notification</b>
<b>Costs to Generators</b>			
Relay	£1,000	Nominal	Nominal
Type Testing	(Low thousands one off, included in cost of relay/ inverter/generator)		
Witnessing	£350	-	-
Pre-notification	£500	£250	-
Post-notification	-	-	£30
	<b>£1,850</b>	<b>£250</b>	<b>£30</b>
<b>Costs to DNOs</b>			
Witnessing	£350	-	-
Pre-notification, network check	£500	£250	-
Post-notification	-	-	£250
	<b>£850</b>	<b>£250</b>	<b>£250</b>

In addition G59/1 relays generally have to be reset manually. Whether it is necessary for the DNO to attend to do this (for example because it is on the DNO circuit breaker) or the generator can do it himself although often with a delay, this will result in a lost generation opportunity cost, compared with a protection system that resets automatically.

To put these costs in perspective, a 1kWp PV System might cost say £7,000, a 5kW system £30k, and a 10kW PV system say £50k, so it could be argued that even at this level, the cost is a significant overhead. Of course, the safety requirements are still paramount, but it would indicate that it was worth putting effort in to see if refinements can be made. This argument is stronger for cheaper technologies.

#### **Allocation of Connection/Network Costs**

Micro generators will generally be connected to a customer's network. As discussed in section 6.1 in general micro generation should not cause any additional expenditure for a

DNO, unless a particular area of network has significantly greater micro-generation that generates at times of low demand than at times of high demand. It is not anticipated that such situations will be common. There should thus be no reinforcement costs for the DNO in general. Indeed the general reduction of the diversified demands of customers with generation that operates at times of high demand should in the long term reduce network costs.

Recognition of this is currently given as import distribution use of system charges are unit related so a displacement of imported electricity avoids these charges on the import displaced. Whether this is completely appropriate is open to question and is being addressed as part of the review of the structure of distribution charges leading up to the new DNO price control period from 2005. The possibility of use of system charges for export is also being considered.

Whereas there is merit in a component of network charges being related to the maximum required import or export of a customer/generator it is important to recognise the effect that parties have when taken as a whole on networks further upstream. For microgenerators that operate at times of high demand this will be to reduce the cost of the network and the saving they generate should continue to be rewarded.

## 7 TECHNICAL CHANGES

There are two areas that are considered worthy of fundamental consideration in routes for the further development of micro-generation connection requirements. These are:

- 7.1 What is the protection for, in particular is it necessary to prevent islanding?
- 7.2 How should micro-generation be connected into domestic wiring i.e. can in be connected to a normal domestic ring or must it have a separate circuit?

### 7.1 Interface With Network

#### **What is the protection trying to achieve?**

Clearly there are a number of objectives of protection fitted to micro-generation. These are to:

- Protect the network (people & physical assets)
- Protect other customers connected to the network (people and physical assets)
- Protect the property where the micro-generation is connected (people & equipment)/  
Protect the Generator itself.

#### **Protect Network**

##### *People*

The primary safety consideration with respect to the network is to avoid the possibility of people working on the network, believing it to be dead when in fact it is energised via one or more micro generators still connected. This is part of the justification for anti-islanding protection. It is understood however that it is now universal practice to treat the lv mains as live unless proven dead e.g. by spiking a cable or applying an earth to an exposed conductor. As a matter of choice DNOs tend to work on lv systems when live if safe to do so to avoid interrupting consumer demand. Providing networks are treated as live until proven dead there should be no risk to people working on them from back energisation from generation. Clearly there is the issue of how to make part of a network dead, if dead working is essential, and the network is being fed by generation connected to it. In this case either anti-islanding protection or a form of isolation of the generation that can be activated by the DNO would be necessary.

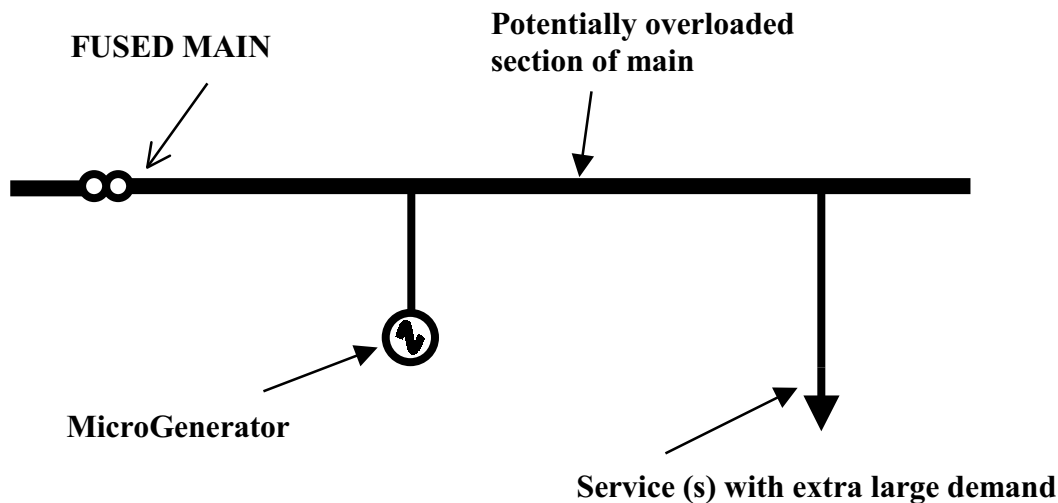
In summary it is not considered necessary for the protection of personnel working on the network to avoid back energisation of that network from generation providing the network is assumed to be live until proven dead. However so that it can be made dead if necessary either some form of automatic anti-islanding trip or alternatively a means of disconnection from the network that can be activated by the DNO would appear to be necessary.

Where an anti islanding trip is not fitted (perhaps because it is a part of the network where operation in island mode is allowed) and it is uneconomic to fit a conventional means of disconnection that can be activated by the DNO, earthing the circuit should ensure the safety of personnel and trip any generation still feeding the network. This would be very much the last choice method of ensuring safety.

### ***Physical Assets***

As regards protecting the physical assets of the network these will always be of higher current carrying capacity than the generator and so for a single micro generator whatever form of overcurrent device is used to protect the generator should also protect the network. In the case of a network fed by multiple micro generators the same should apply on the assumption that the amount of generation connected at each point is lower than the demand normally supplied at the same point. This is because the network is designed so that at any point it is not overloaded by the connected demand in the absence of any micro-generation, so, although the direction of power flow may reverse, multiple microgenerators of size no greater than the maximum connected demands at each point should not cause an overload. Thus whatever overcurrent device is necessary for the micro generator itself should protect the network from overcurrent under fault conditions.

This does not deal with either changes to normal load flow patterns as a result of micro generation or increased fault level issues. It is assumed that these will be dealt with at the system design stage (notwithstanding any “fit and inform” philosophy) although there may be instances in which some form of short circuit limiting devices are a mandatory requirement if “fit and inform” is desired. It would theoretically be possible for part of a main to be overloaded in much the same way as is discussed for a domestic ring circuit. The former is shown below.



Clearly if the downstream service(s) was/were taking an exceptionally large demand the presence of the generator could result in the section of main indicated not being protected from overload by the fuse at the source of the main. It is thought that this ought not to present a problem in practice as the main will have been designed for normal service demands and any combination of downstream demands that would overload the section of main considered would also have overloaded it if the microgenerator were not present. It is not usually the fuse that is the main means of preventing overload, more the estimate of the after diversity maximum demand of the downstream supplies compared to the cable rating.

### **Total network / other customers**

As regards protecting the network in the sense of the total power system (whether islanding has occurred or not) it is clearly not good practice to trip generation if the frequency is low, until it gets down to 47.5 or 47Hz. It is demand that should be tripped in these circumstances and it is a potential source of greatly increased system reserve costs if a large amount of generation were to trip at frequencies above 47 Hz. Some types of micro-generation may of course not be able to operate at such low frequencies and this is a potential source of increase in the amount of frequency response required.

Considering voltage issues, tripping generation generally decreases network voltages so has merit when the voltage is too high but no merit when too low, unless the network is isolated and tripping all generation sources connected to it makes it dead which is preferable to staying alive at below statutory voltage levels.

There is of course a philosophical issue regarding voltage and frequency (to which there is no right or wrong answer in any absolute sense) as to whether micro generators should be regarded as negative customer demand and it is up to the DNO (or total system operator in the case of frequency) to regulate the voltage and frequency, given whatever demand and micro-generation devices are connected to the system. It could be argued that requiring micro generators to trip where this aids the system frequency or voltage is no more justified than requiring consuming equipment to do the same. Demand of course is interrupted if extreme voltage or frequency conditions are encountered to prevent the situation deteriorating further but it could be argued that there is just as much justification for requiring consuming devices to trip at 49.5Hz, the lower statutory limit, as requiring generators to trip at 50.5Hz, the upper statutory limit, which is what is in the latest draft of G83.

To put this another way it is true that in general, whether islanded or not, tripping microgenerators for high frequencies and voltages will help keep the voltage and frequency within allowable limits but is there any more justification for doing this than there would be for tripping demand for low frequencies and voltages? Tripping generators for low frequencies and voltages is in general a bad idea and is only likely to exacerbate the situation. It may be justified for extreme conditions with the objective (for an island) of letting the network become dead rather than keeping it alive at unacceptable voltage and frequency that may damage other customers' equipment.

The issue of whether if there is islanding it should be allowed to continue (reclosure out of phase is addressed in the next section) is associated with responsibility for the maintenance of acceptable voltage and frequency in the islanded network. In general it should not be assumed that what is acceptable coincides with the "normal" ranges given in the regulations. It can be argued that islanding constitutes "exceptional circumstances" and thus there is no statutory reason why an island could not remain running outside the "normal" ranges.

Having said that variation in voltage above or below the normal limits could cause damage to equipment and so should be avoided. It may however be preferable to continue maintaining an island within a frequency range of say 48 Hz to 52 Hz than to have no supply. It is clearly a major issue as to who would be responsible for maintaining a reasonable frequency and voltage but this is not discussed further here as it is understood to be addressed in another report.

### **Protection of House/Generator itself**

Protection of the house wiring is discussed in the section on how to connect the generator into the wiring. As regards the protection of the generator itself clearly this is primarily of concern to the generator manufacturers. Some types of synchronous generators may not operate well at frequencies away from 50Hz but as discussed above the system needs are best served by not tripping them for low frequencies for as long as possible, at least for frequencies above 47Hz.

Synchronous generators are at risk if there has been islanding followed by a reclosure out of phase. An islanding followed by a reclosure is unlikely to be in phase unless synchronising is carried out as part of the reclosure process. There is therefore a case for tripping generation that would be damaged by reclosure out of phase (induction generators would not) where this is likely to take place. This requires some form of anti-islanding protection.

Induction generators and inverters can not generally support an island on their own as they require a source of reactive power. This could theoretically sometimes come from the capacitance of the island network but more probably occasionally from synchronous machines connected to the same island. Thus whilst one could assume that an induction or inverter connected generator would shut down of its own accord if it were the only type of generator connected to the island, this can not be relied on. The question of whether it is necessary to protect against islanding to protect the generator from out of phase reclosure thus is determined by whether the generator would be damaged by such a reclosure.

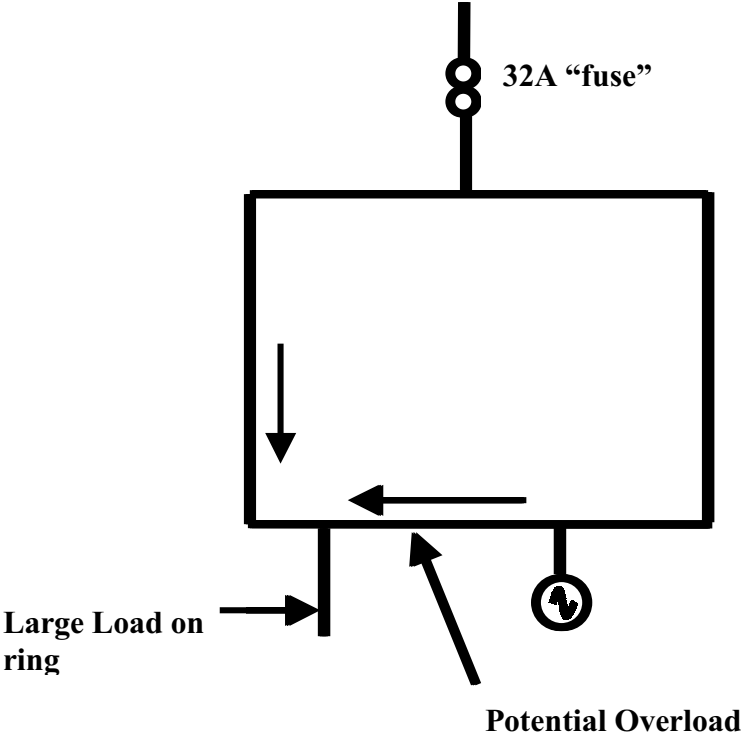
### **In summary**

1. It is necessary to mandate automatic anti-islanding protection only when:
  - There would be no means of the DNO isolating the generator manually in order to make the network dead or provide another means such as earthing the network in order to ensure safety when live working is not possible or
  - It is necessary to protect the generator from out of phase reclosure or
  - There are no satisfactory arrangements for maintaining a reasonable frequency or voltage of the island.
2. It is never sensible (other than as part of anti-islanding protection if required or to protect the generator itself) to trip generation when the frequency or voltage is low, other than in order to make the network dead when the voltage or frequency has got to extremely low values.
3. Although it may make sense to trip generation when the voltage or frequency are high it is not clear that for domestic micro-generation there is any more justification for doing this than there would be for tripping demand when the frequency is low. The latter is clearly only undertaken to prevent prolonged excursions outside the statutory limits.

## **7.2 Connection to Domestic Wiring**

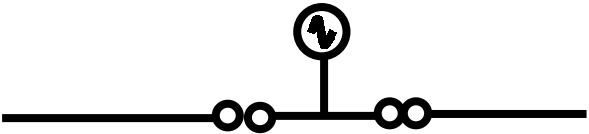
The issue here is whether generators may be connected directly into a ring main or a special circuit back to the main consumer unit is required. Leaving aside for the moment issues to do with interpretation of the IEE wiring regulations (BS7671) and the mechanics of revising these or otherwise allowing connection to a ring main the main technical issue appears to be that the connection of a generator to a ring main would allow a section of the ring to be

overloaded and not protected by a fuse or circuit breaker from this overload. This is illustrated below.



It can be seen that the section between the generator and the large load could be loaded to above the value that the main fuse or circuit breaker (normally 32A) is designed to protect against. There are two possible ways to maintain the normal protection against overloads whilst avoiding a dedicated circuit for the generator.

1. Replace the main fuse/circuit breaker by one of lower rating. In principle it should be the nominal rating without the generator minus the maximum output of the generator.
2. When connecting the generator break into the ring and insert fuses either side of the generator as shown below



This would provide overload protection for the ring itself. It would not though protect a spur off the ring that had enough 13A sockets connected to it to draw over 32A (leaving aside the allowability of such a spur) as the spur could be fed by both the connection round one side of the ring from the mains and the generator. The obvious solution to this is only to allow such

spurs if they themselves are fused where connected to the ring. It is thought unlikely for this to be a common situation.

Thus there are at least two methods to protect a ring from sections becoming overloaded with a generator connected to them.

There is also the question of protection from shock for parties working on the ring wiring. Clearly the ring must be disconnected from both the main incoming supply and the generator. Placing a clear notice to this effect at the main distribution board is one level of protection. Another is that apart from synchronous generators the generator is unlikely to be able to operate without the connection to the mains anyway. It may be desirable to provide another level of protection by mandatory use of a residual current device at the generator connection.

## **8 FINANCIAL CHANGES**

### **8.1 P81 Metering**

The P81 Balancing and Settlement Code modification will allow credit to be given to suppliers for exports to the network without a half hourly meter (and half hourly settlement) being employed for the export. The profiling of import and export (as opposed to generation and demand) is however somewhat problematic and it is accepted that the errors between profiled import/export and actual import/export on a half hourly basis resulting from such profiling will be higher than the ordinary demand profiling errors.

There is a project within the auspices of the Distributed Generation Coordination Group looking at options for more satisfactory solutions. What is clear is that micro-generation itself covers a large cost range of investments e.g. from £20,000+ for a photovoltaic scheme down to a few hundred pounds for the incremental cost of micro CHP. What is reasonable in terms of metering costs for one project may kill the economics of another.

Whereas the cost of many types of meter that may be considered suitable for measuring either generation or export are relatively cheap, of the order of several tens of pounds, a special site visit by a party purely to change the metering system adds significantly to the cost. The work being done to develop the facility for generator installers to fit a new metering system whilst installing the generation should lead to an economic solution that does not compromise the integrity of metering or the settlement process.

### **8.2 ROCs**

Whilst the value of a Renewable Obligation Certificate (ROC), for 1MWh generated by a renewable generator might theoretically be worth more than the electricity produced, there is at present no simple mechanism by which this can be credited to the generator.

Currently the Buy-out price for a ROC which allows an electricity supplier to make up any shortfall between the amount of their obligation and the number of ROCs presented, is set at £30.51 which has increased from £30 for last year. However, the 'market value' of ROCs is presently above this with them trading at around £54 or 5.4p/KWh.

However, a small PV system of say 1.5kW might generate only one ROC each year (1MWh), and at present a level of six ROCs per year (worth about £180 buy-out or £320 market value) is seen by OFGEM as a sensible level at which to administer the scheme. Clearly in terms of benefit to the environment there is no difference between a 10MW wind farm and 10,000 1kW windmills. It is therefore illogical to place barriers to microgenerators being able to obtain the same per KWh benefit as their larger versions.

### **8.3 Renewables Subsidies**

The present UK Government grant schemes for Renewables are for a subsidy to the initial capital cost of buying and installing the equipment. This obviously helps the uptake for the duration of the scheme (typically 3 years), but relies on lowering of prices and an increase in awareness of environmental benefits, to add to this 'kick start' and make a sustainable industry. It also does not link to the actual energy production of the systems other than by checking for good design at the design stage. A second method, but more costly to

administer, is to reward generators on units generated. This has been adopted in other countries, but has some of the cost of administration problems associated with ROCs. However, the supply industry is keen to keep 'subsidy' separate from payments that are linked to DNO costs so that these can be kept as 'real' costs for all types of generator.

## **9 PREFERRED OPTIONS**

**9.1** Clearly there has been a lot of progress in facilitating the connection of micro renewable generators over the past two years and more progress is anticipated to be achieved from the work undertaken by the Distributed Generation Coordination Group and the increased focus of Ofgem on the subject. This report has outlined a number of options for further development in a number of areas and a number of key ones with a preference are discussed below. It is accepted that the arguments used are not exhaustive but never the less the views expressed should be useful to provoke further debate.

**9.2** The key areas relating to connection requirements upon which preferences will be given are:

- a) Size range of standards
- b) Generic anti islanding protection
- c) Connection of generation to domestic wiring

**9.3** As regards the size range of standards there is much merit in not introducing a new standard for a very limited gain. G83 should become the framework standard for generators connected at lv of up to 16A per phase (with one exception discussed below). 16A is becoming established via the Electricity Safety, Quality & Continuity Regulations and appears to be a sensible limit for the lowest level standard.

**9.4** G77/1 should be absorbed into the G83 framework as intended. The one issue arising is that it is nominally for installations of up to 5kW whereas G83 is restricted to 3.68kW single phase. It is felt that the scope of G83 could be changed to cover inverter connected systems of up to 5kW as well as non inverter connected ones of up to 3.68kW single phase. Technically (although this should be subject to further assessment) G83 requirements should be sufficient for 5kW inverter connected systems. The area that may need further consideration due to the Electricity Safety, Quality & Continuity Regulations is the fit and inform philosophy. If necessary a special section could be added to G83 giving an additional requirement for inverter connected systems in the range 3.68kw to 5kw single phase to inform the Distribution Network Operator before connecting. Given that such systems are unlikely to be impulse buys and take a considerable time to install it is not felt that this would be unduly onerous or discourage such schemes. This is in contrast to for example boiler replacement by micro CHP for which the fit and inform philosophy is essential. These installations would not however be unduly limited by keeping within the 16 amp/phase limit for which a fit and inform philosophy would be retained.

**9.5** It is recommended that G59/1 be revised to update certain areas as discussed in *Section 6.1*. In addition to a general update consideration should be given to reformatting it in a modular fashion. This would not necessarily be on a prime mover technology specific basis but might be for example with separate sections for hv connection, lv 3 phase connections and lv single phase connection. Inverter connected systems might be felt to be best dealt with in a separate section. The process of discussing suitable divisions would bring out whether for example a generic level of say 100 or 32 amp lv would merit its own section. Certainly a discussion of whether these devices require full current G59/1 protection should be initiated.

**9.6** On Generic anti islanding protection there should be a review of the fitting of devices that trip generators for low frequency, downward rate of change of frequency and low voltage

conditions. They should only be fitted if there is no other alternative to prevent islanding and it is clear that such islanding would be undesirable. As regards the tripping of generation for high frequency, high voltage or upward rate of change of frequency this should, unless it is essential for anti islanding protection and such islanding would be undesirable, be regarded as an ancillary service and remunerated accordingly. For tripping at frequencies above 51Hz say there should not be any remuneration in the same way that demand is shed with no payment for equivalent extreme low frequencies.

**9.7** As regards the connection of micro-generation into domestic wiring ring mains the options considered in *Section 7.2* should be considered. In addition work should be initiated to work out the probability of overloads if connection of devices of up to say 5 amp single phase were connected onto a 32 amp ring main to establish whether it might be acceptable to do this (or acceptable up to a different limit) without the additional precautions discussed in *Section 7.2*.

## **10 CONCLUSION**

### **10.1 Conclusions**

The improvements made to the technical connection requirements in G77/1 for PV and in the pending G83/1 for other renewables have shown an acceptance of the need for such simplified guidance, and also some ground breaking moves in how this can be achieved. Notable changes are:

- Type testing (no requirement for ‘one-off’ studies or witness tests)
- Post notification (no delay and related costs in waiting for approval)
- Integration of protection into generator itself (economies in manufacture)

To build on this work, further refinements have been discussed in *Chapters 6 & 7* to look at how this can be extended without compromising safety, and examining whether the cost savings offered are justified against the capital cost of the schemes. Specific recommendations are made below.

It is not envisaged at this stage to be necessary to change any of the standards used for network design, beyond what is being considered already to modify P2/5 to better take account of modern types of distributed generation. A watch should be kept on the changes in both net maximum and net minimum demands to determine the extent to which after diversity maximum demands allowed for per customer can be reduced and whether an increasing difference between the two that would require significant modification to voltage control strategy is emerging. It is emphasised that the foregoing deals purely with what is deemed to be necessary for increasing amounts of micro-generation. Larger distributed generation penetration may well precipitate the need for more radical network design reassessment.

Progress on the other issues highlighted are mainly being addressed under the DTI DGWG Distributed Generation Working Group. Specific recommendations are considered below.

### **10.2 Recommendations**

#### **Technical**

- Update G59/1 to G59/2 to include latest generator types including micro/mini-generation of above 16 amps per phase ac connected or above 5kw single phase inverter connected
- Make G59/2 modular to allow for simplified connection arrangements for certain groups within its scope (e.g.LV Connected)
- Extend coverage of G83 to inverter connected systems of up to 5kw
- Initiate work to investigate the acceptability of ensuring safety by using non fail-safe devices to limit short circuit current in circumstances when safety would be ensured providing a given proportion of them operated correctly
- Consider how UK guidance will align with emerging International IEC guidance
- Investigate connection to ‘final circuits’ as in Chapter 7 for very small equipment, possibly for generators under a certain size with no need for any modifications to house wiring protection
- Review need for anti islanding protection

- Ban disconnection of generators for low frequency/voltage unless absolutely essential to disconnect
- Consider making disconnection of generators for high frequency and voltage a remunerated service

### **Financial**

- Progress P81 metering proposals to adjust simple import and export meter readings to allow for fair recompense for Renewable Generators
- Support work in Distributed Generation Coordination Group aimed at developing satisfactory long term metering and settlement arrangements for micro-generation
- Pursue simple mechanism to reward small generators with credit for ROCs
- Consider best financial mechanism to sustain growth stimulated by present Government grant schemes

### **Governance**

- Appoint independent 3<sup>rd</sup> party to set-up, administer and adjudicate on central register for Type Tested equipment.
- Progress governance of electrical standards in line with Ofgem recommendations. Ensure that resources are made available to ensure that micro-generation representatives are made available for working groups as necessary and the micro-generation community can respond to consultations on the development of standards.

## **FURTHER READING/ REFERENCES**

- 1) **Engineering Recommendation G.59/1**  
Recommendations for the Connection of Embedded Generating Plant up to 5MW for Operation in Parallel with Public Electricity Supplier's distribution systems.
- 2) **Engineering Recommendation G83**  
Recommendations for the Connection of Small-Scale Embedded Generators (up to 16A per Phase) in Parallel with Public Low-voltage Distribution Networks
- 3) **Balancing and Settlement Code Proposal P81**  
Removal of the Requirement for Half Hourly Metering on Third Party Generators at Domestic Premises
- 4) **Electricity Safety, Quality and Continuity Regulations 2002**
- 5) **BS7671 Requirements for Electrical Installations**  
IEE Wiring Regulations Sixteenth Edition
- 6) **Elsam Report, IEA-PVPS T5-10:2002**  
Impacts of Power Penetration from Photovoltaic Power Systems in Distribution Networks, Arne Povlsen, Eslam, Denmark
- 7) **UK EATL/UMIST Report, ETSU S/P2/00310/00/00REP**  
The Impact of High Penetration Levels on Electrical Distribution Networks