WORKING GROUP REPORT

Small embedded generation

Working Group

Prepared by the E3C Small Embedded Generation Working Group for submission to the Grid Code and Distribution Code Review Panels

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b Distribution

Name	Organisation

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1.0 SUMMARY AND RECOMMENDATIONS

1.1.1 Following a low frequency incident on the GB system in May 2008 the Government's Energy Emergency Executive Committee (E3C) placed actions on the Grid Code and Distribution Code Review Panels to implement measures to improve the resilience of Embedded generating plant in the Small Power Station category.

1.1.2 The Small Embedded Generation Working Group, comprising members from across the industry, was established by the panels to make proposals to meet the actions.

1.1.3 This report to the GCRP and DCRP describes the work and recommendations of the group.

1.1.4 The group has identified two separate measures to address the issue:

- Modifications to the requirements of the Distribution Code are proposed in this report. The proposal introduces a performance requirement for existing Embedded generation of 5 MW and above, and for all new Embedded generation, relating to operation at abnormal system frequencies. The requirement is considered to be a pragmatic approach to increasing system resilience whilst recognising the concerns of Generators and the requirements of DNOs.
- DNOs have written to their generation customers with a registered capacity of 5 MW and above, requesting they modify the settings of frequency based trip relays to more resilient values where these are not currently used.

1.1.5 The Small Embedded Generation Working Group recommends that the proposed Distribution Code modifications are incorporated with those already developed by the DCRP G59/G75 Review Working Group (on a wider review basis) and consulted on in the same process within the industry.

1.1.6 In advance of consultation on the proposals, a number of DNOs have adopted these proposed frequency relay settings for application to new generation currently under development.

2.0 BACKGROUND

2.1.1 On May 27th 2008 there was an incident on the GB transmission system that resulted in the electricity supplies to 550,000 customers across GB being disconnected for approximately 30 minutes, although some customers were affected for longer than this. The incident occurred as a result of the loss of large generators connected to the system which led to the automatic shedding of demand as system frequency fell. Details of the incident and the findings of an investigation by NGET into its causes are included in a report submitted to E3C by NGET. This report is available at: http://www.nationalgrid.com/NR/rdonlyres/E19B4740-C056-4795-A567-91725ECF799B/32165/PublicFrequencyDeviationReport.pdf

2.1.2 Following this incident the Government's Energy Emergency Executive Committee (E3C) placed a number of actions on the Grid Code Review Panel (GCRP) and Distribution Code Review Panel (DCRP) to further investigate the causes of the incident, including the performance of small generators connected to distribution systems, and to make any reasonably practicable recommendations that would reduce the risk of a similar incident occurring in the future.

2.1.3 As a result of these actions the GCRP and DCRP established a joint working group comprising representatives of Generators, Distribution Network Operators (DNOs), NGET, and OFGEM, with the specific actions, as recommended by the E3C, to:

1. Modify, where reasonably practicable, the frequency range settings on small embedded generation plant to improve their resilience to frequency excursions.

2. Address the lack of an explicit frequency range requirement on small embedded generation plant in the Distribution Code. Review and align the Grid and Distribution Codes as far as reasonably practicable.

2.1.4 Whilst the recommendations arising from the E3C investigation were focussed on the performance of generating plant at low frequencies, the GCRP and DCRP both agreed that the working group should consider the performance of generating plant under low and high frequency conditions. This change was as a result of work reported to the panels highlighting that a significant number of Small Power Stations, with a total installed capacity of over 6000MW, may trip if the system frequency increases to 50.5 Hz. This generation is not expected to all be connected at any time and some of it will have high frequency trip settings above 50.5Hz. Consequently this amount of generation will not be lost in an incident. However, the loss of half of this capacity could be sufficient for the system frequency to drop rapidly, leading to unnecessary widespread electricity supply loss to customers. A rise of system frequency to 50.5 Hz is permitted within National Grid's licence standards and must be considered to be within the potential range of operation.

3.0 PURPOSE AND SCOPE OF THE WORKING GROUP

3.1.1 The Working Group was established and tasked with discussing and reviewing the technical issues associated with the resilience of small embedded generation to frequency excursions, with specific actions to make recommendations to increase their resilience.

3.1.2 The Terms of Reference were formally agreed at the first working group meeting and approved at the November 2008 GCRP meeting. They were later modified and agreed at the May 2009 GCRP meeting. The DCRP agreed the initial terms of reference in February 2009, and subsequently agreed that the group should consider high frequency resilience. The final terms are included in appendix 1.

4.0 WORKING GROUP DISCUSSIONS

Existing obligations

4.1.1 Through the statutory National Electricity Transmission System Security Standards, NGET is required to maintain the GB transmission system frequency so that:

- following a loss up to 1000 MW the maximum frequency excursion is not greater than 0.5 Hz, with restoration to 49.5 Hz within one minute
- following a loss above 1000MW and up to 1320 MW the maximum frequency excursion is not greater than 0.8 Hz, with restoration to 49.5 Hz within one minute

4.1.2 In operating the system NGET aims to maintain the system frequency within an operational limit of 50 +/- 0.2 Hz, with a standard deviation of 0.07 Hz.

4.1.3 The frequency of the DNO's Distribution System shall be nominally 50.0 Hz and shall normally be controlled within the limits of 49.5 to 50.5 Hz in accordance with the principles outlined in the ESQCR. The frequency of DNO networks will be that of the transmission system.

4.1.4 Initial discussions within the group indicated that there are a number of documents that include requirements and recommendations that affect the resilience of generating plant to frequency excursions. The group has written a paper describing the documentation and the practice of the DNOs in applying recommendations, particularly to Small Power Stations. This paper is included in appendix 3 and is summarised as follows.

4.1.5 The requirements of the Grid Code do not apply to Embedded Small Power Stations. As one of the E3C actions is to align the Distribution and Grid Code requirements as far as practicable, the Grid Code requirements (specified in CC.6.1.3) are relevant to the group. For Medium and Large Power Stations they are:

Frequency range	Requirement
47.5 Hz – 52 Hz	Continuous operation is required
47 Hz – 47.5 Hz	Operation for a period of at least 20 seconds is required each time the frequency is below 47.5 Hz

4.1.6 The Grid Code additionally specifies minimum requirements for the maintenance of active power output with falling system frequency (clause CC.6.3.3).

4.1.7 The Distribution Code specifies (in DPC7.4.1) that

"A Generation Set or Power Station must be capable of supplying its Registered Capacity within the System Frequency range 49.5 to 50.5 Hz."

4.1.8 The Distribution Code refers to a number of Engineering Recommendations, which are included in Annex 1 of the code. In general these documents make recommendations on best practice for the connection and operation of generating units of all sizes connected to DNO networks (and in some cases the transmission system). Recommendations G75 and G59 contain clauses relevant to the discussions of the working group.

4.1.9 Engineering Recommendation G75/1 states that generating units should be encouraged to remain in parallel with the distribution system until the frequency falls to 47Hz.

4.1.10 Engineering Recommendation G59/1 requires protection to be provided for the purpose of protecting the Distribution Network. This is commonly referred to a 'G59 protection' and includes under-frequency and over-frequency protection.

4.1.11 In the case of LV connected generators, G59/1 recommends the following settings for this protection:

- The generator should trip if the frequency drops to 47 Hz for 0.5 seconds
- The generator should trip if the frequency rises to 50.5 Hz for 0.5 seconds

4.1.12 In the case of HV connected generators, the settings are required to be agreed with the DNO; in practice it is common to use the above settings.

4.1.13 Additional under-frequency and over-frequency relays may be provided by the DNO (as back-up protection), and/or by the Generator for the purpose of protecting the generating plant.

4.1.14 The Distribution Code requires that settings for interface protection that can open the interface or generator circuit breaker are co-ordinated and agreed with the relevant DNO. The interface protection includes frequency based protection.

4.1.15 Discussions highlighted the fundamentally different principles of the requirements of the Grid Code and Distribution Code, and the recommendations of G59/1.

4.1.16 The Grid Code requirements specify generation performance: the generator must remain connected and maintain its output to some extent within the specified range. Operation across a wider range is not prevented, and is considered beneficial. The basis of these requirements is security of supply.

4.1.17 The G59/1 recommendations are based on disconnecting generation from islanded parts of DNO networks. Consequently they recommend settings at which a generator should disconnect: operation across a wider range is not permitted. Tripping within the range is not prevented, but would need the agreement of the DNO, who agree the trip settings.

4.1.18 In general the frequency protection settings that DNOs agree with generators are consistent with those recommended in G59/1 as the inclusion of the document in the Distribution Code annex leads them to be considered mandatory, although more sensitive settings are sometimes used.

4.1.19 These differences of principle were discussed extensively in developing the group's proposals. The discussions are described further in paragraphs 4.1.39 to 4.1.66 of this report.

Review of G59/1 frequency related protection settings

4.1.20 A DCRP working group was established in 2006 to review and, if necessary, update the requirements of G59/1. This review included the settings of frequency based relays.

4.1.21 The group considered both the primary purpose of the G59 settings, to prevent generation within an islanded area of a DNO network, and the implications for total system security of tripping a large volume of embedded generation, particularly at high frequencies (ie 50.5 Hz). The group has proposed revisions to the recommended G59 protection in an updated document, G59/2. The group has also proposed inclusion of the protection details in the Distribution Code.

4.1.22 The proposal is for revised settings so as to reduce nuisance tripping and enable generators to support the system during abnormal events. It is considered that the revised protection, in conjunction with other G59 protection relays, will continue to provide adequate protection of the Distribution Network. The revised protection comprises two stage relays as shown below.

Protection	Trip Setting	Tripping Time
Under frequency (1st stage)	47.5Hz	20 s
Under frequency (2nd stage where available)	47Hz	0.5 s
Over frequency (1st stage)	51.5Hz	90 s
Over frequency (2nd stage where available)	52Hz	0.5 s

4.1.23 The G59 working group is intending to consult on its proposals in January 2010, with the expectation that, if approved, the revised Distribution Code and new ER G59/2 will be implemented in April 2010.

4.1.24 The Small Embedded Generation Working Group agreed that any proposals it makes in respect of the Distribution Code should be co-ordinated with the proposals of the G59 group, both because of the overlap of the issues addressed and because the groups have made recommendations at the same time.

System frequency performance

4.1.25 The policy of DNOs in generally using the recommended G59/1 settings was reflected in the May 2008 low frequency incident when 371 MW was reported to have been disconnected by DNOs, indicating a significant proportion of the embedded generation remained connected as the frequency fell to 48.8Hz.

4.1.26 The group agreed that the consistent application of high frequency trip settings of 50.5 Hz, in line with recommendations, was of greater concern for system security than the low frequency settings generally used. Previous work undertaken by the GCRP indicated that there is more than 6GW of small embedded plant that is likely to have a high frequency trip setting of 50.5 Hz. When the load factor of this generation is taken into account it is expected that the loss of embedded plant due to a 50.5 Hz high frequency incident could cause a rapid frequency fall leading to supply loss to customers. A rise in system frequency to 50.5 Hz could occur following an event considered credible within National Grid's statutory standards.

4.1.27 This view led to the clarification of the group's initial terms of reference by the GCRP and DCRP to explicitly include consideration of high frequency resilience.

4.1.28 The group considered the historic frequency performance of the system. National Grid presented data showing the number and duration of high and low frequency incidents since 1995. These showed

Date of incident	Generation loss (MW)	Minimum freq (Hz)	Time below 49.5 Hz (minutes)
27/05/08	1993	48.795	9
26/05/03	1260	49.416	<1
19/02/96	1000	49.038	3
13/12/95	1490	49.48	<1
17/11/95	1485	49.184	3
25/09/95	1400	49.4	<1

26/04/95	2000	49.457	<1

Based on these and other historic records, the total number of frequency incidents in the last 35 years are:

- 43 Low frequency incidents, with two below 49 Hz
- 1 high frequency incident since

which includes a system split in 1981 where

- Import group fell to 47.3 HZ and was sustained at 48.5 Hz for 20 minutes
- Export group rose to 50.7 Hz and was sustained above 50.5 Hz for 20 minutes

4.1.29 NGET stated its view that the future system performance cannot be derived from the historic performance. It is expected that there will be significant changes in generation and load performance in the future. The impact of intermittency of wind generation on system performance is a widely accepted concern. NGET's view is that these changes are likely to impact on the controllability of the system frequency and may affect the rate of occurrence and duration of frequency excursions. Some group members commented that it is unknown whether there will be an impact and, if there is, how significant it will be.

Meeting with manufacturers

4.1.30 With support from the Association of Electricity Producers, contacts with major small plant manufacturers were established. Representatives from a sample of these manufacturers and consultants were invited to a technical meeting with working group members. They were asked for their views on the ability of plant, both existing and future, to operate across the frequency range within the settings proposed by the G59 Review Working Group. Subsequent to the meeting they completed questionnaires to confirm their comments.

4.1.31 In general the responses were supportive of changes to improve system resilience. The manufacturers did not envisage major technical issues with revising frequency trip settings to those in the proposed G59/2.

4.1.32 The impact of operation at abnormal frequencies varied across plant types. In some cases, for example where plant has been designed for operation at either 50 or 60Hz, there are not likely to be issues. In general there are no issues with wind farms. The wind turbine units in small wind farms will usually be of the same design as those in large wind farms. Large wind farms, and hence their individual wind turbine generating units, are designed to meet the Grid Code requirement of continuous operation across the range from 47.5 Hz to 52 Hz. Units of a similar design, when placed in a small wind farm, should be able to meet the same requirement.

4.1.33 In a minority of cases, it is possible that extended operation at extreme frequencies would need to be assessed and could lead to increased maintenance requirements. The impact would depend on how often, and for how long, operation outside the designed range was required. It was agreed that a reduction of power output at abnormal frequencies would reduce plant stress. It was noted that operation at reduced output is beneficial for system security compared with the tripping of generation.

Modification of existing protection settings

4.1.34 The E3C made a specific recommendation to modify frequency range settings on existing plant as far as practicable, in order to increase their resilience.

4.1.35 Taking account of the work of the G59 group and the views of manufacturers, the group agreed that each DNO should write to its embedded generation customers to request that they modify all of their frequency based protection settings to those proposed by the G59 working group. It was agreed that the letters should be sent to owners of Small Power Stations with a Registered Capacity at or over 5MW as

- this would include the majority (approximately 70%) of the 6GW of embedded plant
- it would be a manageable number of customers for the DNOs to contact
- the group believed that the response from smaller generators would be low

4.1.36 Letters were sent in October and early November 2009, based on a generic version developed by the group. The generic letter is attached in appendix 4.

4.1.37 The letter requested confirmation, by the end of October / November 2009, that the settings have been modified, or that the generator would change the settings to a timescale agreed with the DNO (in some cases the DNO wished to be involved in commissioning the new settings). It was reported at the November 2009 GCRP that the response rate at that time was low. The GCRP agreed that the Chair would write to the generators, via the Association of Electricity Producers, reminding them of the urgency of the issue. The DNOs agreed to follow up all of the initial contacts where no response had been received. At the time of this report the response has been varied. In general less than 20% of generation has confirmed that it already has or will adopt the recommended settings. The majority of generation has either not yet responded or has indicated that it is in discussion with the manufacturer of the plant to determine whether it will be able to adopt the recommendations. A small percentage of generation has indicated that it cannot implement the recommendations.

4.1.38 The group agreed to recommend that the DCRP should formally monitor progress on this issue, and take a view on whether further action is required on the basis of the responses.

Alignment of the Distribution and Grid Code requirements

4.1.39 The working group debated at length the E3C action to align the requirements of the Distribution and Grid Codes as far as reasonably practicable. The issues considered and views of the group members are discussed below.

4.1.40 A paper was submitted to the group by a group member informing it of the current requirements of generators in the Grid Codes of Great Britain and across Europe, and of the standards to which generating units are designed. This paper is attached in Appendix 5.

4.1.41 The paper showed that there is considerable variation in the requirements of the different codes. The majority of codes require continuous operation within a defined central frequency range, with operation for specified minimum times required at frequencies outside the central range.

4.1.42 The design standards (eg BS EN 60034-1 and BS EN 60034-3) specify that generators shall be capable of continuously providing rated output over the range of 49 Hz to 51 Hz (providing the generator terminal voltage is within 3% of rated voltage). Plant could operate outside this range but may be unable to generate its continuous rated output level. In general the standards describe how operation outside of this range may impact on plant wear and maintenance requirements. They advise that to minimise the adverse effects on generator wear and lifetime, operation outside the continuous range should be limited in extent, duration and frequency of occurrence, and that output should be reduced or other corrective measures taken as soon as practicable. The standards do not specify limits, either in time or in number of occurrences, at which operation outside the continuous range will begin to impact on the plant.

4.1.43 The relative merits of specifying a performance requirement or specifying relay trip settings was debated. The group also debated the application of new requirements to new and existing generation.

New generation

4.1.44 The current Grid Code and Distribution Code provisions specify generating unit performance requirements, that is a frequency range over which a unit must be capable of operation, and a minimum level of active power that it should be capable of generating.

4.1.45 The proposals of the G59 group are to include protection relay settings in the Distribution Code and G59/2, and to provide text stating that plant is expected to remain connected across the operating range within the settings. The proposals do not include requirements related to active power output outside the range 49.5 to 50.5 Hz. The Distribution Code already includes a requirement that generators should be capable of supplying their Registered Capacity across the range 49.5 to 50.5 Hz.

4.1.46 The consensus within the Small Embedded Generation Working Group was that there should be a performance requirement in the Distribution Code specifying frequencies at which generation must remain connected. This approach will more clearly emphasise the importance of remaining connected. The importance would not be conveyed as clearly by a requirement based on protection settings.

4.1.47 Some group members believe that the requirement should be specified in terms of a normal frequency range of 49Hz to 51Hz, together with time periods for which generation is required to operate at abnormal frequencies (ie. outside 49Hz to 51Hz). They consider that such a specification is optimum because it is reasonably compatible with plant design standards and warranties, it follows the form used by a number of European Grid Codes, and it would ensure that Small Embedded generators have the capability to support the system during abnormal events.

4.1.48 NGET do not believe that this approach is appropriate, stating that the prediction of future events and future plant performance is not possible, although some members believe that it should be possible to do so. Similarly, it is not possible to identify operating times beyond which generating plant will be stressed. Although frequency incidents are rare (one high frequency incident and 43 low frequency incidents have been reported in the last 35 years) and to date have been short in duration, longer duration events could occur in the future. System security will benefit from maximising the amount of generation that remains connected during a prolonged incident. Simultaneous tripping of a large volume of small embedded plant (potentially several GW) at a specified time when the System is under stress could jeopardise the chance of system recovery, leading to staged automatic demand disconnection. Given the trend of continual growth of embedded generation (with some forecasts suggesting 20 GW), the simultaneous loss of even half of this capacity could drive the system to an unmanageable position, leading to a total system blackout. System restoration is an extremely complex process, as reported by the recent investigation conducted by the government. The best black start strategy is to avoid a total blackout.

4.1.49 NGET acknowledged that plant design standards and the views of manufacturers mean that operation of plant at abnormal frequencies will become stressful for plant if the operation is required for significant durations.

4.1.50 On this basis, NGET proposed that a performance requirement is introduced that requires generating plant to remain connected for as long as the plant is not being damaged. This qualification is not included in either the Grid Code or current Distribution Code requirements, and is intended to account for the concerns of generation owners whilst maximising system security.

4.1.51 The proposal does not include a requirement to maintain a level of active power. This is intended to allow generators flexibility in controlling their output to a level which could reduce the stress on the plant during a prolonged period of off nominal frequency operation. It was agreed that generators are unlikely to reduce active power output during an incident, even if there is no requirement to maintain output, if there is no plant protection issue.

4.1.52 This principle was agreed by the majority of working group members, on the basis that it represents the most pragmatic solution to the issue that could be reached in the group's timescales. Some group members remain of the view that time durations should be specified.

4.1.53 Appendix 2 contains the proposed Distribution Code text, developed in line with the principle agreed by the majority of the group.

Existing generation

4.1.54 Application of the requirements proposed for new generation to existing generation was debated.

4.1.55 It was agreed that implementation of the requirement would incur costs for the generators in changing protection settings on their plant. Where generators have changed settings in response to the DNO letter, further costs will not be incurred.

4.1.56 NGET stated their belief that these costs would be significantly less than the costs of holding response to cover for the potential loss of a significant amount of generation.

4.1.57 A member of the working group is of the opinion that the costs of holding response cannot be considered in determining the costs and benefits of applying the proposed requirement to existing plant as NGET is not currently contracting for response to cover the loss of this plant.

4.1.58 In its report to the E3C following the May 2008 incident (link included in section 2.1.1), NGET stated that it considered the cost of holding this reserve unjustifiable, and that it would not do so. The report recommended that the risk to system security should be minimised by promptly taking action to increase the resilience of small embedded generation. This view was endorsed by the E3C, which specified times for completion of the actions described in section 2: June 2009 for modifying the protection settings, and December 2009 for introducing a Distribution Code requirement.

4.1.59 As a consequence, NGET believes that the inclusion of response holding costs in the cost / benefit analysis is appropriate. This view is supported by the majority of the group. These costs are expected to be approximately £150 million per annum for procuring additional response. This level of response holding would cover the loss of a substantial volume of Embedded generation, but would not be sufficient to cover very high losses at times when a large proportion of the generation is connected.

4.1.60 If the response to a generation loss is insufficient to contain the frequency fall, demand shedding will be instigated through the low frequency demand disconnection (LFDD) scheme. With a cost of lost energy of £45k per MWhr, the loss of 2GW of demand for 1 hour would cost £90m. Operation of stage 1 of the LFDD scheme at an average system demand level would result in the loss of 2GW of demand.

4.1.61 Based on the costs submitted by the generator representatives, the cost of applying the Distribution Code proposals to existing plant would be up to £20000, as a one off, per site, assuming that no replanting is necessary. The proposals allow for Generators and DNOs to agree different protection settings where justifiable. It is intended that replanting will not be necessary. The requirement will apply to fewer than 300 sites. The cost of applying it at 300 sites will be up to £6m. Additional costs will be incurred by DNOs, should they wish to witness the application of new settings.

4.1.62 On this basis the majority of the group believe that application of the requirement to existing plant is appropriate.

4.1.63 The group considered whether a threshold should be used, specifying a minimum size of generating unit to which the requirement applies.

4.1.64 On the basis of the analysis work of the GCRP, which indicates that over 4 GW of the small embedded generation is in the category of 5 MW and above, the group believes that, considering the likely load factor of the generation, 5 MW is an appropriate threshold. This is consistent with the letter that DNOs sent to their generation customers requesting modification of the settings.

4.1.65 This threshold may need reconsidering in the future if the response to the DNO letters indicates that a significant amount of generation in this category cannot modify its settings.

4.1.66 The proposed text is included in appendix 2.

Other issues

4.1.67 G59 protection applies to Generators and can be embedded within their system or installed at the interface point. Often DNOs choose to install similar protection on their side of the interface connection. Group members noted that the settings would need to discriminate to ensure the desired operation. Members agreed that the frequency setting of both protection relays could be the same, but a longer trip time at the upstream relay could be used to meet the protection objectives.

4.1.68 NGET raised the issue that as the volume of embedded generation increases, its importance in operating the total system will increase in terms of management of system frequency. Consequently better information on the expected and actual operation of this generation will be required in operational timescales. The group concluded that the mechanisms already exist in the codes to allow NGET to obtain the data. It was agreed that NGET will pursue the issue further with DNOs and generators outside of the group.

4.1.69 NGET suggested that a requirement on DNOs could be included in the Grid Code, requiring the application by the DNOs of the group's proposals to their generation customers, on the basis that this would support the link between the proposed Distribution Code requirement and the requirement on transmission system connected generation, emphasising the total system security aspect. The group did not believe that this would be beneficial at this time, but noted that a requirement could be considered separately in the future.

Working Group report

4.1.70 This report has been authored by NGET on behalf of the Working Group. Draft 0.1 was commented on by group members. Draft 0.2 was discussed at the final Working Group meeting. The final version, which includes comments from the final Working Group meeting, has not been considered by the Working Group prior to submission to the DCRP and GCRP due to the short time between the final Working Group meeting and the panel meetings.

5.0 WORKING GROUP RECOMMENDATIONS

5.1 The Working Group recommends that the Distribution Code text proposals described in section 4 and appendix 2 are consulted on within the industry along with the proposals of the G59 working group, with the intention of implementing the proposals in the Distribution Code. The proposals are considered by the majority of the group to be the most economic and appropriate means of improving total system resilience to abnormal frequency incidents, whilst at the same time maintaining a sufficient level of protection within the DNO networks.

5.2 The text proposals included in appendix 2a are for the case where the recommendations of the Small Embedded Generation Working Group and the G59 Review Group are consulted on jointly, as recommended by the Small Embedded Generation Group.

5.3 The text proposals included in appendix 2b are for the case where the recommendations of the Small Embedded Generation Working Group are consulted on independently.

5.4 The Working group also recommends that the DCRP should formally monitor progress on the DNO letter to their generation customers, and take a view on whether further action is required on the basis of the responses.

Environmental Assessment

5.2 The Working Group believes that the proposals will not have any significant environmental impact. However, if the proposals are not implemented and it becomes necessary to hold additional response, this may result in increased CO_2 emissions. This impact has not been considered by the Working Group.

6.0 INITIAL VIEW OF NGET

6.1 NGET agrees with the Working Group recommendations and supports consulting on these proposals within the industry.

7.0 IMPACT ON GRID CODE

7.1 The proposed changes do not impact on the Grid Code.

8.0 IMPACT ON INDUSTRY DOCUMENTS

Impact on Core Industry Documents

8.1 The proposals of the group directly affect the Distribution Code.

Impact on other Industry Documents

8.2 The proposals of the Working Group have no impact on other Industry Documents.

9.0 IMPACT ON GB TRANSMISSION SYSTEM

9.1 The Working Group's recommendation will improve system resilience and hence security and reliability in the most economic manner.

10.0 IMPACT ON GRID CODE USERS

10.1 The proposals apply to all new Small Embedded Generation and existing Generation greater than 5MW in England, Wales and Scotland. They will require DNOs to liaise with their generation customers in applying the requirements.

11.0 ASSESSMENT AGAINST GRID CODE OBJECTIVES

11.1 The proposed changes outlined in the Working Group would better facilitate Grid Code Objectives:

iii) to promote the security and efficiency of the electricity generation, transmission and distribution system in Great Britain

by ensuring that the total electricity system robustness is improved. Specifically this is achieved by preventing embedded generation from unnecessarily disconnecting following a system frequency excursion.

Appendix 1 – WORKING GROUP TERMS OF REFERENCE

Grid Code & Distribution Code EC3 (Small Embedded Generation Frequency Obligations) Working Group

Terms of Reference

On the 27th May 2008, a frequency excursion occurred on the GB Transmission System which resulted in a significant amount of generation being disconnected (both directly connected and embedded) from the electricity grid.

Objectives
The purpose of the Working Group is to review the resilience of small embedded generation to large frequency excursions, resulting in both low and high frequencies, and to investigate options for improvements.

1. Work with AEP and other relevant organisation to gather further data on existing small embedded generation performance to establish as far as possible the timing and causes of the losses that occurred during the 27th May 2008 incident. Consideration of more formal arrangements for the collection of performance data for operational purposes.

2. For existing generating plant establish the current frequency operating range requirements in the Grid Code.

3. For existing small embedded generation establish the current frequency operating range requirements in the Distribution Code and the associated Engineering Recommendations.

4. Establish the current practice amongst DNOs regarding the implementation of these requirements.

5. Establish the current practice amongst existing small embedded generation in respect of protection settings that may determine the resilience of plant to frequency deviations.

6. Review the impact of limited frequency operating range of small embedded generation on Transmission System security, providing a cost benefit analysis where reasonably practicable.

7. Establish how small embedded generation can avoid adversely affecting the security of the Total System, taking into account the continual increase of small embedded generation.

8. Work with the industry to establish the generic performance capabilities of existing and future small embedded generation that could be incorporated into the Code(s) with minimal additional cost to Users, and identify the incremental capability that could be provided at additional cost.

9. Review the potential to modify, where reasonably practicable and cost effective, the frequency range settings on existing small embedded generation to improve their resilience to large frequency excursions.

10. Review and align, if necessary, the Grid and Distribution Codes (inclusive of applicable engineering recommendations[1]) as far as reasonably practicable and where cost effective, considering both the way it is set out in the Distribution Code and how it is implemented to improve resilience of future small embedded generation to large frequency excursions.

11. Provide regular updates and report findings to the Energy Emergency Executive Committee.

Governance
The joint Working Group has been convened and will operate and be managed under the remit of the Grid Code and Distribution Code governance frameworks.

Membership
The membership of the Working Group will be drawn from the GCRP/DCRP or their nominated representatives and the Authority.

Deliverables
The Working Group will produce a report outlining its analysis, findings and recommendations which will be submitted to the GCRP and DCRP.

Where applicable, other relevant 'industry working groups' will be informed of the Working Group's recommendations such that the proposals may be progressed within the appropriate governance framework.

Timescales
The Working Group will aim to present its findings and recommendations to November 2009 GCRP and DCRP meeting.

[1] Relevant engineering recommendations are as follows: G59/1, G75/1 etc

APPENDIX 2 – PROPOSED GRID CODE CHANGES

Proposed Changes to Connection Conditions

Proposed Legal Text Change to the Distribution Code to Enhance the Resilience of Embedded Small Power Stations to Large Frequency Excursions

Appendix 2a – proposals taking account of proposals from G59 review group

Black text *– current draft text proposed by G59 Review Working Group, based on Distribution Code Issue 11, 24 June 2009*

Blue text *– new text to cover performance requirements on new and existing plant proposed by Small Embedded Generation Frequency Obligations Working Group*

DPC7.4.1 **Generating Plant Performance Requirements**

For **Embedded Generating Plant,** which does not constitute or contain **BM Units** that are active (ie submitting bid-offer data) in the **Balancing Mechanism**, the electrical parameters required to be achieved at the **Generation Set** terminals are defined according to the connection method and will be specified by the **DNO** with the offer for connection. A **Generation Set** or **Power Station** must be capable of supplying its **Registered Capacity** within the **System** Frequency range 49.5 to 50.5 Hz. The output power should not be affected by voltage changes in the permitted operating range.

In exceptional circumstances, the **Frequency** of the **Distribution System** could rise above 50.5 Hz or fall below 49.5 Hz. **Generation Sets** in **Embedded Small Power Stations** shall be capable of continuing to operate in parallel with the **Distribution System** in accordance with the following:

47 Hz – 47.5 Hz	Operation for a period of at least 20 seconds is required each time the **Frequency** is within this range
47.5 Hz – 51.5 Hz	Disconnection by over or under frequency **Protection** is not permitted in this range
51.5 Hz – 52 Hz	Operation for a period of at least 90 seconds is required each time the **Frequency** is within this range

These frequency operating range requirements also apply to **Generation Sets** in **Embedded Small Power Stations** already existing on or before [*the date of the implementation of the **Distribution Code** change*], unless the **Registered Capacity** of the **Embedded Small Power Stations** is below **5 MW.**

For the avoidance of doubt, the above requirements do not preclude disconnection of **Generation Sets** by **Protection** agreed with the **DNO**, or when necessary to protect **Plant** or **Apparatus** from being damaged.

Embedded Medium Power Stations additionally have to comply with DPC 7.5.

DPC7.4.3.6 The settings in DPC7.4.3.4 apply to all ~~cases.~~ **Embedded Small and Medium Power Stations** first connected after [*the date of the implementation of the **Distribution Code** change*]. ~~For the avoidance of doubt it is expected that all **Generating Plant** will remain connected whilst the **Frequency** is in the range 47.0Hz to 52.0Hz.~~ In exceptional circumstances **Generator**s have the option to agree alternative ~~more sensitive~~ settings with the DNO if there are valid justifications in that the **Generating Plant** may become unstable or suffer damage with the settings specified in DPC7.4.3.4. The agreed settings should be recorded in the **Connection Agreement**.

The under and over frequency protection settings set out in DPC7.4.3.4 will also apply to **Generation Sets** in **Embedded Small Power Stations** already existing on or before [*the date of the implementation of the **Distribution Code** change*] with a **Registered Capacity** at or above **5 MW,** except where single stage **Frequency Protection** relays are used, in which case the following settings apply. In exceptional circumstances **Generator**s have the option to agree alternative settings with the DNO if there are valid justifications in that the **Generating Plant** may become unstable or suffer damage with these settings. The agreed settings should be recorded in the **Connection Agreement**.

Protection	Trip Setting	Time setting
Under frequency	47.5Hz	0.5 s
Over frequency	51.5Hz	0.5 s

Appendix 2b – proposals for independent consultation

Black text *– Existing Distribution Code text*
Blue text *– new text to cover performance requirements on new and existing plant proposed by Small Embedded Generation Frequency Obligations Working Group*

DPC7.4.1 **Generating Plant Performance Requirements**

For **Embedded Generating Plant,** which does not constitute or contain **BM Units** that are active (ie submitting bid-offer data) in the **Balancing Mechanism**, the electrical parameters required to be achieved at the **Generation Set** terminals are defined according to the connection method and will be specified by the **DNO** with the offer for connection. A **Generation Set** or **Power Station** must be capable of supplying its **Registered Capacity** within the **System** Frequency

range 49.5 to 50.5 Hz. The output power should not be affected by voltage changes in the permitted operating range.

In exceptional circumstances, the **Frequency** of the **Distribution System** could rise above 50.5 Hz or fall below 49.5 Hz. **Generation Sets** in **Embedded Small Power Stations** shall be capable of continuing to operate in parallel with the **Distribution System** in accordance with the following:

47 Hz – 47.5 Hz	Operation for a period of at least 20 seconds is required each time the **Frequency** is within this range
47.5 Hz – 51.5 Hz	Disconnection by over or under frequency **Protection** is not permitted in this range
51.5 Hz – 52 Hz	Operation for a period of at least 90 seconds is required each time the **Frequency** is within this range

These frequency operating range requirements do not apply to **Generation Sets** in **Embedded Small Power Stations** already existing on or before [*the date of the implementation of the **Distribution Code** change*] where the **Registered Capacity** of the **Embedded Small Power Stations** is below **5 MW.**

For the avoidance of doubt, the above requirements do not preclude disconnection of **Generation Sets** by **Protection** agreed with the **DNO**, or when necessary to protect **Plant** or **Apparatus** from being damaged.

Embedded Medium Power Stations additionally have to comply with DPC 7.5.

APPENDIX 3 – PAPER ON REQUIREMENTS ON GENERATORS AND DNO PRACTICES

Frequency Operating Range Requirements of Small Embedded Power Stations

1 Introduction

This short note attempts to address two of the objectives of the Grid Code & Distribution Code EC3 (Small Embedded Generation Frequency Obligations) Working Group as recently approved by GCRP/DCRP.

Objective 2
For existing generating plant establish the current frequency operating range requirements in the Grid Code.

Objective 3
For existing small embedded generation[2] establish the current frequency operating range requirements in the Distribution Code and the associated Engineering Recommendations.

Objective 4
Establish the current practice amongst DNOs regarding the implementation of these requirements.

Below are relevant extracts taken from the Grid Code, Distribution Code and the associated Engineering Recommendations in so much as they relate to the frequency and voltage operating range requirements and the interface protection settings expected of Small Embedded Power Stations.

In addition, details are provided regarding the relevant obligations relating to voltage as it is both voltage and frequency protection which are to considered the key control and protection issues at the interface.

2 Objective 2 - Current Requirements of the Grid Code

2.1 Grid Code

The performance requirements for Power Stations are set out in the Grid Code Connection Conditions. CC.3.1 states that the Connection Conditions apply to NGET and to Users. In relation to the CC, Users are defined as being:

(a) Generators (other than those which only have Embedded Small Power Stations)
(b) Network Operators;
(c) Non-Embedded Customers;
(d) DC Converter Station owners; and
(e) BM Participants and Externally Interconnected System Operators in respect of CC.6.5 only.

Hence the Grid Code Connection Conditions do not apply to Embedded Small Power Stations

2.1.1 CC6.1.3

It is however worth mentioning CC.6.1.3, as the settings applied to frequency related protection relays associated with Embedded Small power Stations align with the operational requirements for larger power stations. However this alignment does not imply a mandatory requirement. CC.6.3.1 recognises that the System Frequency could rise to 52Hz or fall to 47Hz in exceptional circumstances. Design of

[2] As per the Distribution Code an Embedded Generator is defined as being a Generator including a Customer with Own Generation whose Generation Sets are directly connected to the DNO's Distribution System or to an Other Authorised Distributor connected to the DNO's Distribution System. In the context of this working group 'small' is defined as including Small Power Stations, excluding G83 generators.

User's Plant and Apparatus must enable operation of that Plant and Apparatus within that range in accordance with the following:-

Frequency Range	Requirement
47.5Hz - 52Hz	Continuous operation is required
47Hz - 47.5Hz	Operation for a period of at least 20 seconds is required each time the Frequency is below 47.5Hz.

2.1.2 Summary

In summary the Grid Code does not place any technical conditions on Small Power Stations. Grid Code CC3.4 and CC3.5 sets out the obligations for Embedded Medium Power Stations. Large power Stations need to comply fully with the Grid Code.

2 Objective 3 - Current Requirements of the Distribution Code

3.2 Distribution Code

The Distribution Code places requirements on embedded generators as detailed in the Distribution Planning and Connection Code (DPC) section 7 - DPC7 Requirements for Embedded Generators[3]. The following subsections are considered relevant:

3.2.1 DPC7.2 General Requirements

Embedded Generators connected at or below 20kV and with an output not in excess of 5MW shall, as a minimum requirement, comply with the requirements of Item 3, DGD Annex 1 Engineering Recommendation G59/1, "Recommendations for the connection of private generating plant to the Public Electricity Suppliers' distribution systems".

Embedded Generators connected at a higher voltage or of a larger capacity shall comply with the general principles of Item 4, DGD Annex 1 Engineering Recommendation G75/1 "Recommendations for The Connection of embedded generating plant to public distribution systems above 20kV or with outputs over 5MW", subject to the particular requirements of the DNO necessitated by the adjacent DNO's Distribution System conditions, which will be made known by the DNO during the connection application process DPC7.3 "Provision of Information".

Given that these two documents are both Distribution Code Annex 1 documents compliance with them is considered to be mandatory[4] rather than 'recommendations'.

3.2.2 DPC7.4 Technical Requirements

DPC7.4.1 Generating Plant Performance Requirements

For Embedded Generating Plant, which does not constitute or contain BM Units that are active (ie submitting bid-offer data) in the Balancing Mechanism, the electrical parameters required to be achieved at the Generation Set terminals are defined according to the connection method and will be specified by the DNO with the offer for connection. A Generation Set or Power Station must be capable of supplying its Registered Capacity within the System Frequency range 49.5 to 50.5 Hz. The output power should not be affected by voltage changes in the permitted operating range.

Embedded Medium Power Stations additionally have to comply with DPC 7.5 but this is out of scope of this Working Group.

DPC7.4.3 Co-ordination with Existing protection

It will be necessary for the Protection associated with Embedded Generating Plant to co-ordinate with the Protection associated with the DNO's Distribution System as follows:-

(b) The settings of any Protection controlling a circuit breaker or the operating values of any automatic switching device at any point of connection with the DNO's Distribution System shall be

[3] Should be noted that DPC7.1.3 excludes G83 generators from the DPC7 requirements

[4] It should be noted that recommendations may be varied with agreement to suit the specific characteristics of the generator and/or network.

agreed between the DNO and the User in writing during the connection consultation process. The Protection settings or operating values shall not be changed without the express agreement of the DNO.

3.2.3 DPC7.4.6 Frequency Sensitive Relays (Islanding)

It is conceivable that a part of the DNO's Distribution System, to which Embedded Generators are connected can, during emergency conditions, become detached from the rest of the System. It will be necessary for the DNO to decide, dependent on local network conditions, if it is desirable for the Embedded Generators to continue to generate onto the islanded DNO's Distribution System. If no facilities exist for the subsequent resynchronisation with the rest of the DNO's Distribution System then the Embedded Generator will under DNO instruction, ensure that the Generating Plant is disconnected for resynchronisation. Under emergency conditions there is an expectation that some generation will continue to operate outside the statutory frequency limits. However, for Embedded Generators connected to the DNO's Distribution System at a voltage level less than 132kV it is likely that this could mean connection within an automatic low frequency load disconnection zone. Consequently, Embedded Generators should ensure that all Protection on Generating Plant should have settings to co-ordinate with those on the automatic low frequency load disconnection equipment which will be detailed by the DNO on request of the User.

3.3 Engineering Recommendation G75/1 Recommendations for the Connection of embedded generating plant to public distribution systems above 20kV or with outputs over 5MW

3.3.1 Section 1 Introduction and Scope

Subsection 1.5
This recommendation should be read in conjunction with Engineering Recommendation G59/1. Although the current edition of G59/1 and its associated technical report ETR113 related to generating plant with outputs not exceeding 5MW connected to systems with voltages at or below 20kV, many of the principles they contain are applicable at all Distribution system voltage levels.

This means that many of the principles contained in G59/1 apply to all generators of any size, save where G75/1 or the G Code supplies different parameters.

3.3.2 Section 4 General Unit Parameters

Subsection 4.5
DNOs' systems are subject to the "Statutory Instruments (Electricity Regulations)". The regulations require the frequency of supply to consumers to be maintained within +/- 1% of the declared frequency. As the declared frequency is 50Hz in the UK, section DPC7.4.1 of the Distribution code requires that Generating plant must be capable of supplying its registered capacity within the range 49.5Hz to 50.5Hz.

Subsection 4.6
Under abnormal conditions automatic low-frequency load-shedding provides for load reduction down to 47Hz. Therefore all generating units shall be encouraged to remain in parallel with the Distribution system until the system frequency falls to 47Hz.

Note: Subsection 4.6 goes on to provide further details of operating performance requirements for generators other than Small generators (ie Medium and Large) or those explicitly excluded by the Grid Code.

Subsection 4.7
In accordance with DPC7.4.1 of the Distribution Code, the rated power output of a Generating unit should not be affected by voltage changes within statutory limits declared by the DNO in accordance with the "statutory Instrument (Supply Regulations)" unless otherwise agreed with the DNO.

Subsection 4.9

If the Generating Plant is remote from the point of DNO connection, or is remote from the transformation point to the next higher voltage system, it should be able to withstand voltage changes in excess of statutory limits. In these circumstances, immunity of the Generating Plant to voltage changes +/-10% of the declared voltage is recommended, subject to the design appraisal of individual installations.

Subsection 6.9
Co-ordination with existing protection equipment and auto close schemes is achieved by compliance with (DPC) 7.4.3 of the Distribution Code.

3.4 Engineering Recommendation G59/1 Recommendations for the connection of private generating plant to the Public Electricity Suppliers' distribution systems

3.4.1 Section 6.4 Protective Equipment

Subsection 6.4.1
In addition to any generating plant protection installed by the Embedded Generator for his own purposes, the PES requires protective equipment to be provided by the Embedded Generator to achieve the following objectives:

(b) to disconnect the generator form the system when a system abnormality occurs that results in an unacceptable deviation in either voltage of frequency at the point of supply,

Subsection 6.4.2 – Protective equipment for HV Supply arrangements
Suitable protective arrangements and settings for an HV installation will depend upon the particular Embedded Generator installation and the requirements of the PES local system. These individual requirements must be ascertained in discussion with the PES. To achieve the objectives of Section 6.4, the protection must include the detection of:

a Over Voltage
b Under Voltage
c Over Frequency
d Under Frequency
e Loss of Mains

The settings of relays should be agreed with the PES and it is a requirement of the Electricity Supply regulations 1988 that the settings shall not be altered without the express agreement of the PES.

Subsection 6.4.3 – Protective equipment for LV Supply arrangements
Table 1 indicates the recommended protection settings normally appropriate to small asynchronous plant (<150kVA).

In some instances alternative schemes and settings may be applied subject to agreement between the embedded generator and the PES.

For synchronous and self excited asynchronous generating plant, the protection set out in Table 2 may not be sufficient to achieve the objectives……and additional protection to detect loss of mains will be required a described for the HV Supply arrangement in Section 6.4.2.

TABLE 1 - PROTECTIVE EQUIPMENT AND SETTINGS FOR LV SUPPLY ARRANGEMENTS

Protection	Phases	Trip Setting	Total * Tripping Time
Under Voltage	All	- 10% (phase-neutral)	0.5s
Over Voltage	All	+ 10% (phase-neutral)	0.5s
Under Frequency	One	- 6%	0.5s
Over Frequency	One	+ 1%	0.5s

* The total tripping time includes any integration or timing period of the protection relay as well as relay and circuit-breaker operating time.

b) Large Generating Plant Exceeding 150kVA

As the generating plant size increases, its likely adverse effects on the distribution system also increase. Additional protection to that stated above may be required similar to that suggested for HV installations. Engineering Technical Report 113 gives advice on protection systems for these higher power installations.

Table 1 above provides details for the settings of protection devices for LV connected generators. Section 3 provides clarification on the interpretation of these settings.

3.5 Engineering Technical Report no. 113 - Notes Of Guidance For The Protection Of Embedded Generating Plant Up To 5Mw For Operation In Parallel With Public Electricity Suppliers' Distribution Systems.

Section 5.7.1 (Protection settings for LV installations) states that the total tripping times (for o/v, u/v, o/f and u/f protection) stated in G59/1 Table 1 were revised down to 0.5s from 1.0s in a previous document G47, to align with the dead time (normally 1s) associated with some 11kV pole mounted reclosers (this is also covered in section 6 – Implications of Remote Auto Switching).

Section 5.7.2 (Protection settings for HV installations) explains the possibility of extending the total tripping time (up to 6s is stated) for voltage protection for HV connected generators not associated with fast reclosers.

Appendix 4 of ETR113 details typical Site Commissioning Tests (SCT) sheets for both HV and LV connected synchronous generating plant which clearly indicates a requirement for plant to be tested for Under/Over Frequency settings. Over frequency being 50.5Hz and under frequency is 47Hz.

3.6 Summary of current frequency operating range requirements

A summary of the requirements of the Grid code, Distribution Code, ER G75/1 and ER G59/1[5] is provided below:

1. Section DPC7.2 General Requirements of the Grid Code states that all generation shall, as a minimum requirement, comply with Engineering Recommendations G75 and/or G59 as applicable.

[5] It should be noted that G59/1 was introduce circa 1991 replacing G59. The U/F requirement in G59 was 49Hz.

2. Embedded Generators connected above 20kV or with outputs over 5MW shall, as a minimum requirement, comply with the general principles of ER G75/1.

3. All generating plant must be capable of supplying registered capacity within the range 49.5Hz to 50.5Hz. (DPC7.4.1 and G75 4.5).

4. G75 subsection 4.6 states that all generating units shall be encouraged to remain in parallel with the Distribution system until the system frequency falls to 47Hz.

5. Embedded Generators connected at or below 20kV and with an output not in excess of 5MW shall, as a minimum requirement, comply with the requirements of ER G59/1.

3.7 Summary of current protection requirements

A summary of the requirements of the Grid code, Distribution Code, ER G75/1 and ER G59/1 is provided below:

1. DPC7.4.3 of the Dcode calls for the co-ordination with existing protection such that the settings of any Protection controlling a circuit breaker or the operating values of any automatic switching device at any point of connection with the DNO's Distribution System shall be agreed between the DNO and User.

2. Subsection 4.7 of G75/1 requires the rated power output of a Generating unit to not be affected by voltage changes within statutory limits unless otherwise agreed with the DNO.

3. Subsection 6.9 of G75/1 requires co-ordination with existing protection equipment and auto close schemes.

4. Subsection 6.4.1 of G59/1 requires that in addition to any generating plant protection installed by the Embedded Generator for his own purposes, protective equipment be provided by the Embedded Generator to disconnect the generator form the system when a system abnormality occurs that results in an unacceptable deviation in either voltage of frequency at the point of supply.

5. Subsection 6.4.2 of G59/1 provides details of the protective equipment requirements for HV Supply arrangements. Protection settings shall be agreed between the DNO and the User and shall not be changed without the agreement of the DNO.

6. Subsection 6.4.3 of G59/1 provides details of the protective equipment requirements for LV Supply arrangements. "Table 1 indicates recommended protection settings normally appropriate to small asynchronous generating plant" (<150 kVA). Alternative schemes and settings may be applied subject to agreement between the embedded generator and the PES.

7. ETR113 Appendix 4 details typical Site Commissioning Tests (SCT) sheets for both HV and LV connected synchronous generating plant.

4 Objective 4 - Current DNO Practice

It should be noted that the settings articulated in G59/1 Table 1 are by 'common practice' applied to generators connected at all voltages. G59/1 subsection 6.4.3a states that the purpose of these settings is to disconnect equipment at times of system abnormalities and are not the back up limits of the generating unit.

4.1 Current Practice In ENW

Internal policies and procedures have been developed to draw out the specific requirements placed on embedded generators in the DCode. Namely EPD259, CP259 and ES259 - Generation Connected to the Electricity North West Distribution Network. In all cases appropriate references are given to the above documents and CP259 includes information on typical generator protection settings.

Any generation connecting to ENW's distribution network is required to comply with ENW Engineering Specification ES259. Technical requirements outlined in ES259 make appropriate references to the national documents as outlined in objective 3 above.

Before commencing operation of the Generation, the Generator and ENW shall complete a Technical & Operating Agreement and Responsibility Schedule.

In some instances ENW may agree to a variation within an acceptable range for protection settings for certain protection such as voltage and loss and mains. However, in all cases ENW insists on the over and under frequency relay settings as per G59/1.

ES259 subsection 7.8.3.1 states that it is the responsibility of the Generator to determine the correct protection settings and submit them to the appropriate person in ENW. In some instances it is ENW themselves who have advised the generator on the appropriate settings. In all instances the setting must comply with G75 or G59.

Full tests on the protective equipment shall be carried out to the satisfaction of ENW. These tests are the responsibility of the Generator and shall be carried out by him. The tests shall be witnessed (but not approved) by a representative of ENW, unless, in any particular case, ENW has notified the Generator that such witnessing is not required. Commissioning tests and forms used shall be as described in ENA ER G59/1 and ENA ETR113.

ENW provides recommendations regarding the periodic testing of protection by the Generator, intervals not exceeding two years is currently recommended in ES259.

4.2 Current Practice In CE Electric UK

Any generator connecting to either the NEDL or YEDL distribution network is required to comply with CE Electric UK policy IMP/001/007 – Code of Practice for Connection of Distributed Generation which includes a requirement to comply with the Grid Code, Distribution Code and Engineering recommendations G59 & 75.

The protection scheme for each generator is designed on an individual basis in accordance with the Code of Practice for The Protection of High Voltage Networks (DSS/007/001). This policy lists the specific protection required for normal parallel operation and short term paralleling. DSS/007/001 requires over / under frequency and over / under voltage to be installed. Protection settings will be agreed and discussed with the generator although it is standard practice that the settings on the voltage and frequency relays will be in accordance with Table 1 in ER G59/1.

As part of the commissioning process, CE Electric UK witness the protection commission tests of all embedded generators connected at 11kV and above. This includes witness testing of the frequency and voltage protection provided by the generator. CE Electric UK owned protection at the DNO / generator interface including, ovecurrent, reverse power, neutral voltage displacement protection etc is included in the commissioning tests together with an inspection to ensure that the installation complies with the electrical design and that all the operational interfaces, e.g. synchronising, interlocks etc and that the interface documentation are in place.

Witness testing for generators connected to the low voltage system is discretionary, but where tests are not witnessed generators are required to submit a completed test proforma similar to that included as part of the draft ER G59/2 for comment.

4.3 Current Practice in Central Networks (CN)

CN apply internal policies and procedures for Embedded Generation that are specifically associated with our D-Code obligations.

The policies and procedures cover all aspects as follows:-

Customer application process to include:

- Distribution Network studies.
- Formal Offer.
- Connection Agreement.
- Site Responsibility Schedule.

Distribution Network connection strategy advice to Customers and CN employees.

- Specification for cables, plant and equipment at the "Boundary Interface".
- ER G59/2 Customer witness testing only – 11kV and above.

With regard to the interface switchgear protection i.e. overcurrent and earth fault, this complies with the CN Protection Manual. For the generator connections CN expect compliance with ER G59/2 . With regard to LV generator connections CN do not carry out witness testing for very small generators i.e. less than 10 kW per phase, but require the Customer to provide information on request. Larger LV generators may also be treated this way with prior agreement between the Customer and CN.

There is no provision for CN to consult with the Customer after initial witness testing has been undertaken as it is considered that the Customer has responsibility to maintain their ER G59/2 obligations.

CN are presently consolidating the internal policy and procedures in an Embedded Generation Manual of Procedure, which will be available for both internal and external publication when completed - estimated issue date 1st September 2009.

4.4 Current Practice in SSE

South

Generation connections are dealt with on the basis that protection will normally comply with the requirements of G59 or post 1990 G59/1 and where appropriate with G75 – G75/1. In addition some sites have additional generator protection not regarded as being part of the protection required by G59 or G75 which has been set to operate at other frequencies usually in the range 49 to 49.5Hz. SSE witness the testing of the protection prior to allowing the generator to operate on the network but take no futher to steps to ensure that the protection is maintained as this is reqarded as the responsibility of the owner of the protection. In a small number of cases the G59 protection has been

fitted to and operates the interface CB owned by SSE in conjunction with intertripping from a remote SSE site, in these cases SSE will maintain the protection as part of its routine maintenance.

North

Generation connection protection is laid down in a policy document currently TG-PS-575 (compliant with G59 and G75). This specifies the settings which should be applied for embedded generators. These have changed over the years, with the current recommendation being 52Hz for 2 seconds, 47 Hz for 2 seconds and 47.5Hz for 20 seconds. Variations have ranged recently between 51.5Hz and 52Hz for over frequency and 47 and 47.5Hz for under frequency.

4.5 Current Practice in WPD

WPD require generator connections to comply with G59 and G75 (as amended). The Generator is expected to install, own and maintain the G59 protection. The only exception is where neutral voltage displacement (NVD) protection is required and the generator does not own any HV switchgear, in which case, WPD will provide NVD protection. The voltage and frequency settings listed in Table 1 of G59 are applied to both LV and HV generators. Settings for loss of mains and NVD protection are specified in accordance with Engineering Technical Report 113.

WPD witness G59 commissioning tests for all HV generators and the vast majority of LV generators. The only exception is for small embedded generators (up to 50kW) that have been type tested (for example small scale embedded generators type tested in accordance with G83/1). Where tests are not witnessed the installer must provide WPD with copies of their commissioning test results.

4.5 Current Practice in EDF

Connection of new embedded generation is to be in accordance with EDF Energy Engineering instruction EI 08-0106. This requires that all generation connections should be designed to comply with requirements of the:-

- Distribution Code
- Grid Code
- ESQCR
- And where appropriate ER G59/1, ETR 113 and ER G75/1

Protection settings have traditionally been set in accordance with those in table 1 of G59/1. In some recent windfarm connections, where the customer has installed a 2 Stage relay, settings been set in accordance with figures published for G59/2.

Witnessing is normally carried out on all HV generators and the majority of LV connected Generators. EDF are currently recommending the use of 51.5hz over frequency setting 0.5 S as default for sites which have long term parallel operation but only have single stage relays. This position is not currently formalised and will be an interim solution until the publishing of G59/2 which will require the installation of 2 stage relays. At that time full 2 stage settings can be implemented.

Sites within the SPN licensed area have previously been fitted with a second stage of G59 backup relay installed to trip the DNO circuit breaker. These settings would be graded with the customers G59 protection, EPN and LPN sites have not included this facility.

4.6 Current Practice in SPD (North)

The Connection Agreement between SPD and the generator includes Schedule 3 which includes additional technical requirements. These are a relaxed version of Grid Code requirements covering

the requirements for fault ride through and voltage control (including reactive range, as well as an additional requirement on power ramp rate limits at start-up following a trip. The requirements normally result in the generators obtaining wind turbines with the same options fitted as would be required to meet the Grid Code requirements. However, the relaxed voltage control requirements do not require a STATCOM to be fitted, as is common on Large wind farms using certain DFIG turbines, in order to meet the speed of response requirement of the Grid Code.

Consequently, it is thought that most wind farms should be able to meet the full Grid Code frequency operating range. However, since the start of the working group, an additional clause has been added based on the proposed revision to G59 requiring the following:-

47 – 47.5 Hz Operation for at least 20 seconds required.
47.5 – 51.5 Hz Continuous operation required.
51.5 – 52 Hz Operation for at least 90 seconds required.

SPD normally fits G59 protection to its breaker in addition to the G59 protection installed by the generator. To provide discrimination between the two sets of G59 protection, the generators protection can have narrower operating ranges or shorter time delays than the values specified in G59.

4.5 Summary of DNO approach

This section summarises the overall approach adopted by DNOs in respect of frequency requirements:

- All generators less than 50MW have protection settings from G59/1.
- G59 table 1 provides details on required protection settings for LV connected generators. In practice these settings are applied to all Small generators
- All generators must be capable of supplying its registered capacity within the range 49.5Hz to 50.5Hz.
- Generators are generally encouraged to remain in parallel below 49.5Hz down to 47Hz.

5 Draft amendments in G59/2

Engineering recommendation G59/1 is currently undergoing revision. The current draft G59/2 replaces the current frequency protection setting requirements and are summarised below.

In order to prevent the unnecessary disconnection of a large volume of smaller Generating Plant for all LV and HV connected Generating Plant, a 2-stage protection is to be applied as follows[6]:

Over Frequency

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

[6] The new settings are still intended to be recommendations, to minimise unnecessary tripping. Section 10.5.1 says: "It is not the intention that this Section specifies the performance requirements of Generating Plant...". Section 10.5.10 says: "The settings in table 10.5.8 are the settings which should be applied although Generators should have the option to agree more sensitive settings with the DNO if there are valid concerns regarding relay settings."

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

Under Frequency

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

Stage 2 of 47.0 Hz (time delayed by 0.5s) which are in line with the Grid Code requirements[7].

7 Stage 2 lines up with Grid Code requirements for larger generators. It is a deliberate alignment rather than a reflected obligation.

APPENDIX 4 – GENERIC VERSION OF DNO TO GENERATOR LETTER

Note – the green and blue text are alternatives, depending on whether the DNO wishes to be involved in the process of modifying the settings.

[To be sent out on DNO headed paper as a DNO letter]

The purpose of this letter is to seek your assistance to help improve the resilience of the Great Britain (GB) electricity supply system by reviewing the settings of the high and low frequency protection on your generating plant. Depending on these settings, the security of the electricity supplies to end users could be affected. This letter results from work within the industry following a system incident in May 2008 that resulted in the loss of supply to a large number of customers. Appendix 2 describes the incident and the work that has been undertaken to date to investigate the causes of the incident.

You are requested to:

- confirm the present frequency trip settings of your generating plant (ie. the ER G59 protection settings and / or any other protection or control settings that would have the effect of tripping the generator during a frequency excursion);

- advise whether, following further discussion with us, you are able to modify the protection settings to either: modify the protection settings, where you are able, to either:

Protection	Trip Setting	Tripping Time
Under frequency (1st stage)	47.5Hz	20 s
Under frequency (2nd stage)	47Hz	0.5 s
Over frequency (1st stage)	51.5Hz	90 s
Over frequency (2nd stage)	52Hz	0.5 s

or, if these cannot be implemented because only single stage relays are installed,

Protection	Trip Setting	Total Tripping Time
Under frequency	47.5Hz	0.5 s
Over frequency	51.5Hz	0.5 s

and advise us whether the settings have been revised.

- advise whether there are any issues (technical, commercial, bilateral agreement conditions, impact on associated industrial processes, or otherwise) that prevent the settings being changed to those indicated above or might prevent these settings being used on an enduring basis.

Whilst we appreciate that assessing the capability of your existing system and reviewing and potentially changing the protection settings will require resource and will incur some costs, we believe that improving the resilience of generation to frequency excursions and therefore improving the security of the wider system is in the interest of the whole industry and all consumers. Additionally there may be a benefit to individual generators in a reduction in nuisance tripping if frequency trip settings are widened.

Given the importance of these issues, I would appreciate a response by the end of October. A pro-forma for submission of settings information is attached in appendix 1. If you are able to change your frequency relay settings we will contact you to discuss the process that we will need to follow.

The information that you provide to us will form an important part of further discussions within the industry concerning the resilience of the system to frequency excursions.

If you have any queries please contact [name of DNO contact]….

Appendix 1: Pro-forma for submission of settings *

Site Name				
Generating plant reference				
Contact name and details				
Protection type				
	Current setting		Revised settings. If unchanged mark 'Unchanged' Settings that can be implemented. If no change is possible mark "No change"	
	Trip Setting (Hz)	Tripping Time (s)	Trip Setting (Hz)	Tripping Time (s)
Under frequency Stage 1 (or single stage)				
Under frequency Stage 2 (where applicable)				
Over frequency Stage 1 (or single stage)				
Over frequency Stage 2 (where applicable)				
Issues, if any, with implementing revised settings:				

* One table to be completed for each set of protection relays

Appendix 2: Background describing the frequency incident and resulting work

On May 27th 2008 there was an incident on the GB transmission system that resulted in the electricity supplies to some 550,000 customers across GB being disconnected for approximately 30 minutes, although some customers were affected for longer than this. The incident occurred as a result of the loss of large generators connected to the system which led to the automatic shedding of demand as system frequency fell. Following this incident the Government's Energy Emergency Executive Committee (E3C) placed a number of actions on the Grid Code Review Panel (GCRP) and Distribution Code Review Panel (DCRP) to further investigate the causes of the incident including the performance of small generators connected to distribution systems, and to make any reasonably practicable recommendations that would reduce the risk of a similar incident occurring in the future.

As a result of these actions an industry working group was established, comprising representatives of Generators, Distribution Network Operators (DNOs), National Grid, and OFGEM, with the specific actions, as recommended by the E3C, to:

1. Modify, where reasonably practicable, the frequency range settings on small embedded generation plant to improve their resilience to frequency excursions.

2. Address the lack of an explicit frequency range requirement on small embedded generation plant in the Distribution Code. Review and align the Grid and Distribution Codes as far as reasonably practicable.

Whilst the recommendations arising from the E3C investigation were focussed on the performance of generating plant at low frequencies, the GCRP and DCRP both agreed that the working group should consider the performance of generating plant under low and high frequency conditions. This change was as a result of work reported to the panels highlighting that a significant amount of small embedded generation plant, over 6000MW in aggregate, may trip if the system frequency increases to 50.5 Hz. The loss of these generators could be sufficient for the system frequency to drop rapidly leading to unnecessary widespread electricity supply loss to customers. A rise of system frequency to 50.5 Hz is permitted within National Grid's licence standards and must be considered to be within the normal range of operation.

The working group is discussing a number of options to address the above two actions, taking account of international practices and views from plant manufacturers on their current and future generation plant designs.

In recent years there has been a substantial increase in the total capacity of small generation plant connected to DNOs' networks and a consequent increase in the significance of the performance of this generation on the overall performance of the GB system. In September 2006, a working group under the auspices of the DCRP was set up to review the Distribution Code and the associated Engineering Recommendations (ER G59/1 and ER G75/1) with the objectives of enhancing and improving the clarity of the

requirements on small embedded plant. This group has proposed introducing two stage frequency protection settings, as detailed in Appendix 3, into the Distribution Code and the associated Engineering Recommendations. These proposals will be subject to formal industry consultation, however they are already in the public domain and have been adopted by some DNOs and applied to new generation connections.

Because the work of these two working groups is linked there is common membership to ensure that the output from them is co-ordinated and compatible.

Given this background, the E3C GCRP/DCRP Distribution Generation Working Group invited plant manufacturers, with help from the Association of Electricity Producers (AEP), to a meeting to discuss the proposed revised settings. Those who attended represented a range of, but not all, generating plant types. They expressed support for the change to improve the resilience of small embedded generation plant and their view was that there will not be any major technical problem on existing and future generation plant.

In respect of action 1 above, each DNO is writing to all of its small generation customers with an installed capacity above 5MW. The purpose of this is to:

- Establish current protection settings that will result in the tripping of DNO connected generation during frequency excursions

- Improve the resilience of the whole GB system to frequency excursions by modifying these settings where possible and necessary.

Action 2 above is currently being discussed by the E3C GCRP/DCRP Distribution Generation Working Group. These discussions may lead to a requirement for further work by DNOs and their generation customers. We will contact you should this be the case.

Appendix 3 - Existing and proposed frequency relay settings

Protection	G59/1 (current) Trip setting	G59/1 (current) Trip time	Proposed Distribution Code and G59/2 Trip setting	Proposed Distribution Code and G59/2 Trip time
Under Frequency (1st stage)	-	-	47.5 Hz	20s
Under Frequency (2nd stage)	47 Hz	0.5s	47 Hz	0.5s
Over Frequency (1st stage)	-	-	51.5 Hz	90s
Over Frequency (2nd stage)	50.5 Hz	0.5s	52 Hz	0.5s

APPENDIX 5 – PAPER ON INTERNATIONAL GRID CODES AND DESIGN STANDARDS

E3C Small Embedded Generation Frequency Obligations Working Group

Items for consideration following meeting no. 5 (9/7/09)

Review of existing Grid Code requirements

1. Grid Code frequency requirements are separated between the following two sections of the Grid Code Connection Conditions:

   CC.6.1 NATIONAL ELECTRICITY TRANSMISSION SYSTEM PERFORMANCE CHARACTERISTICS

   CC.6.3 GENERAL GENERATING UNIT REQUIREMENTS

   (nb This is not particularly helpful to users as it separates the frequency range/duration requirements from the related frequency range/active power requirements. Both of these are performance requirements and it would be preferable to keep them together in CC.6.3.)

2. Section CC.6.1 is primarily informative – it advises users of the technical, design and operational criteria with which the parts of the transmission system at connection sites must comply. CC.6.3 sets out the technical and design criteria and performance requirements for generators and DC converters.

3. Key requirements from CC.6.1 – frequency range/duration requirements:

   CC.6.1.2 The Frequency of the National Electricity Transmission System shall be nominally 50Hz and shall be controlled within the limits of 49.5 - 50.5Hz unless exceptional circumstances prevail.

   CC.6.1.3 The System Frequency could rise to 52Hz or fall to 47Hz in exceptional circumstances. Design of User's Plant and Apparatus must enable operation of that Plant and Apparatus within that range in accordance with the following:-

Frequency Range	Requirement
47.5Hz - 52Hz	Continuous operation is required
47Hz - 47.5Hz	Operation for a period of at least 20 seconds is required each time the Frequency is below 47.5Hz.

   nb CC.6.1.2 reflects the statutory requirements.

4. Is CC.6.1.3 relevant to any other users other than generators and DC converters?

5. NGET's normal operational control range is 50Hz +/- 0.2Hz.

6. Original CC.6.1.3 clause (from Grid Code Issue 1 Rev 1):

   CC.6.1.3 The System Frequency could rise to 52Hz or fall to 47Hz in exceptional circumstances. Sustained operation outside the range 47 - 52Hz need not be taken into account in the design of Plant and Apparatus.

   i.e. this was an advisory clause – there was no performance requirement here. It did not mean that sustained operation across the entire 47 - 52Hz range was required.

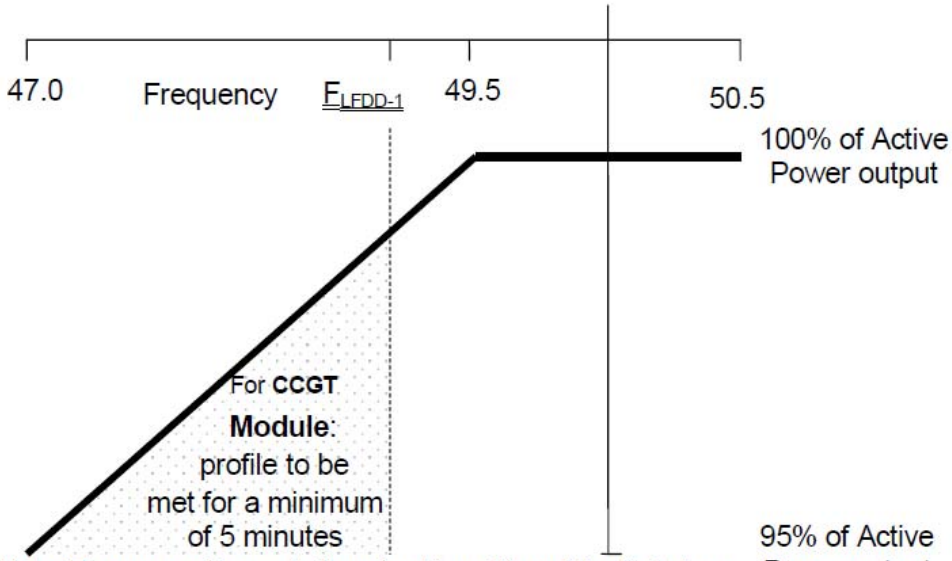
   This old text is of interest for comparison with the present Distribution Code requirement.

7. Key requirements from CC.6.3 – frequency range/active power requirements:

   CC.6.3.3 Each Generating Unit, DC Converter, Power Park Module and/or CCGT Module must be capable of

   (a) continuously maintaining constant Active Power output for System Frequency changes within the range 50.5 to 49.5 Hz; and

   (b) (subject to the provisions of CC.6.1.3) maintaining its Active Power output at a level not lower than the figure determined by the linear relationship shown in Figure 2 for System Frequency changes within the range 49.5 to 47 Hz, such that if the System Frequency drops to 47 Hz the Active Power output does not decrease by more than 5%. *(plus some extra qualifications for CCGTs)*



Note: **Frequency** F_{LFDD-1} is the relay trip setting of the first stage of the Automatic Low **Frequency Demand Disconnection** Scheme

Figure 2

Review of existing Distribution Code requirements

8. Distribution Code frequency requirements are also separated into two sections:

   DPC4 Design Principles and Standards

   DPC7 Requirements for Embedded Generators

9. Key requirements from DPC4 :

   DPC4.2.2 Frequency and Voltage

   DPC4.2.2.1 The DNO's Distribution System and any User connections to that System shall be designed to enable the Normal Operating Frequency and voltages supplied to Customers to comply with the ESQCR.

   DPC4.2.2.2 The Frequency of the DNO's Distribution System shall be nominally 50 Hz and shall normally be controlled within the limits of 49.5 - 50.5 Hz in accordance with principles outlined in the ESQCR.

   DPC4.2.2.3 In exceptional circumstances, System Frequency could rise to values of the order of 52 Hz or fall to values of the order of 47 Hz. Sustained operation outwith the range 47 - 52 Hz is not taken into account in the design of Plant and Apparatus.

   Note that DPC4.2.2.3 is similar to the original CC.6.1.3.

10. Key requirements from DPC7:

   DPC7.4.1 Generating Plant Performance Requirements

   For Embedded Generating Plant, which does not constitute or contain BM Units that are active (ie submitting bid-offer data) in the Balancing Mechanism, the electrical parameters required to be achieved at the Generation Set terminals are defined according to the connection method and will be specified by the DNO with the offer for connection. A Generation Set or Power Station must be capable of supplying its Registered Capacity within the System Frequency range 49.5 to 50.5 Hz. The output power should not be affected by voltage changes in the permitted operating range.

   Embedded Medium Power Stations additionally have to comply with DPC 7.5.

   This is similar to CC.6.3.3 (a). However, it is not identical as it does not require the capability to maintain constant active power output levels, at all output levels between min and max, independent of frequency across the range 49.5 to 50.5Hz.

Options for frequency obligations for small embedded generators

Option 1 – Distribution Code frequency range performance requirement

11. This would be in the form of an explicit requirement e.g. small embedded generators must remain connected across specified frequency ranges, for specified durations.

12. A requirement to simply "remain connected" for specified frequency ranges and durations, e.g. as per CC.6.1.3, would not be a fully specified requirement. It would be necessary to also specify what is required in terms of variation of active power output with frequency, across the whole frequency range, not just across the 49.5 to 50.5Hz statutory range.

13. Advantages of this option are likely to include:

- the requirements can be specified in a clear and simple form
- it should provide a good level of confidence that plant is designed and built to provide a clearly defined capability to meet the system needs (subject to any plant capability issues)

14. Disadvantages of this option may include:

- difficulty in determining the exact requirements (frequency ranges, durations, and permitted active power variation with frequency)
- uncertainty regarding plant capability e.g. insufficient evidence and operating experience for abnormal frequency conditions.

15. Appropriate frequency ranges and durations can be considered based on:

- plant capabilities as specified in international standards
- prime mover capabilities
- system characteristics as specified in international standards
- European Grid Codes and technical specifications
- GB system needs

16. BS EN 60034-1:2004 Rotating electrical machines – Part 1: Rating and performance

(Note: Steam turbine and gas turbine driven synchronous generators are covered by part 3 of the standard).

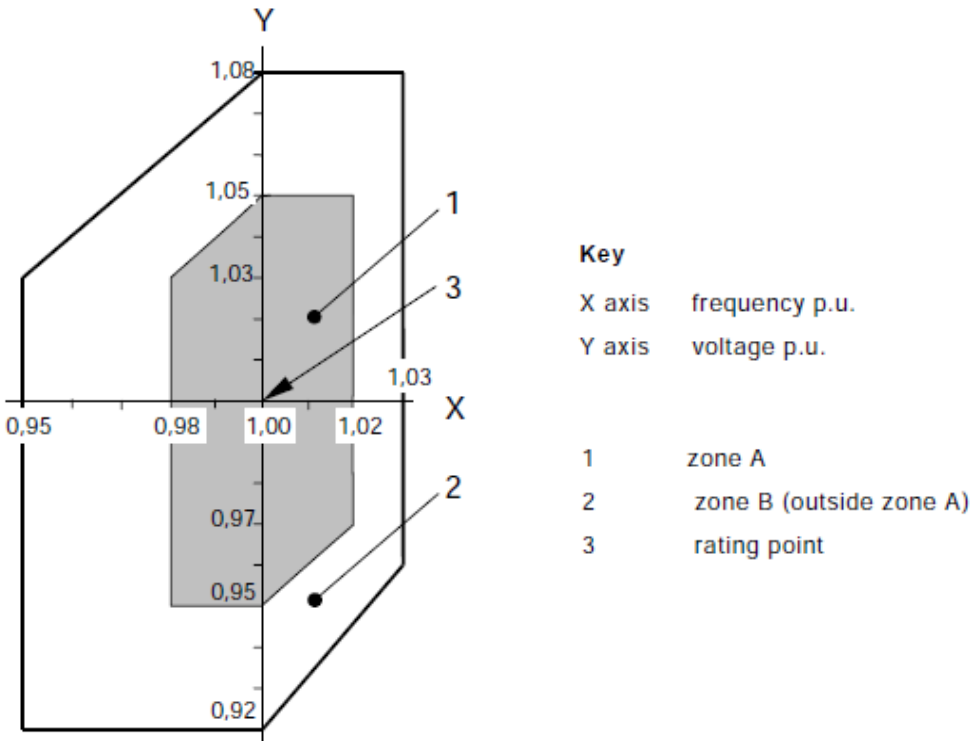
The rated performance of the machine applies at the rating point, defined as rated voltage and rated frequency (50Hz for GB). Machine capability at voltages and frequencies away from the rating point is defined in terms of zone A (from 49 to 51 Hz for GB) and zone B (outside of zone A, from 47.5 to 51.5Hz for GB). These zones are shown in the figure below. It should be noted that the corners are clipped at high and low voltages.

AC generators shall be capable of rated kVA at rated power factor continuously within zone A, but need not comply fully with performance requirements at rated voltage and frequency and may exhibit some deviations.

The temperature-rise limits or temperature limits in accordance with this standard apply at the rating point and may be progressively exceeded as the operating point moves away from the rating point. For conditions at the extreme boundaries of zone A, the temperature rises and temperatures typically exceed the limits specified in this standard by approximately 10 K.

A machine shall be capable of performing its primary function within zone B, but may exhibit greater deviations from its performance at rated voltage and frequency than in zone A. Temperature rises may be higher than at rated voltage and frequency and most likely will be higher than those in zone A. Extended operation at the perimeter of zone B is not recommended.

In practical applications and operating conditions, a machine will sometimes be required to operate outside the perimeter of zone A. Such excursions should be limited in value, duration and frequency of occurrence. Corrective measures should be taken, where practical, within a reasonable time, for example, a reduction in output. Such action may avoid a reduction in machine life from temperature effects.



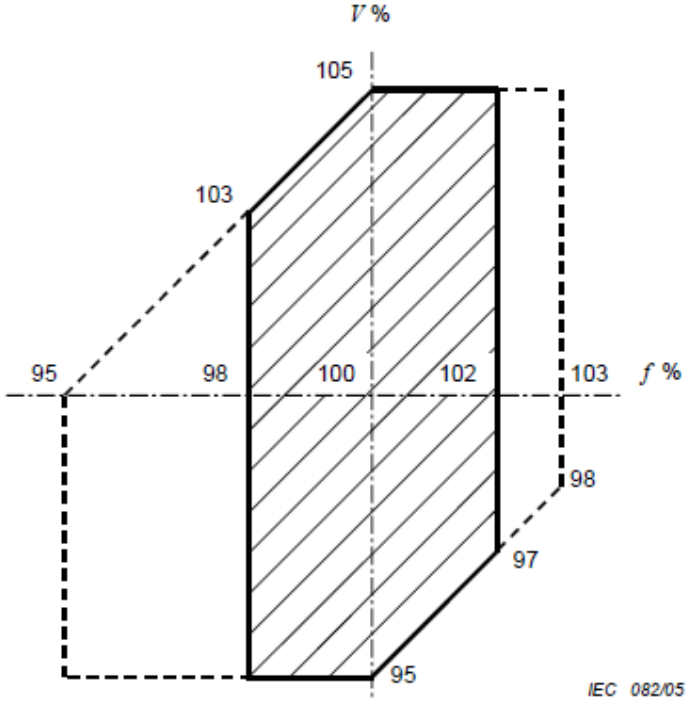
Capability outside zone A (whether at rated or reduced output) is not quantified and should be regarded as infrequent and short-term.

17. BS EN 60034-1:2008 Rotating electrical machines – Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines

This standard is applicable to the specific types of generator and prime mover as per the title. It uses similar principles to BS EN 60034-3, as shown in the figure below (though the zone A and zone B terminology is not used). Generators shall be capable of continuous operation at rated output and power factor for voltages and frequencies as defined by the shaded area (i.e. 49 to 51Hz for GB).

Generators will also carry output at rated power factor within the ranges of ±5 % in voltage and 47.5 to 51.5Hz in frequency, as defined by the outer boundary of the figure, but temperature rises will be further increased. Therefore, to minimize the reduction of the generator's lifetime due to the effects of temperature or temperature differences, operation outside the shaded area should be limited in extent, duration and frequency of occurrence. The output should be reduced or other corrective measures taken as soon as practicable.

It is considered that overvoltage together with low frequency, or low voltage with over-frequency, are unlikely operating conditions. The former is the condition most likely to increase the temperature rise of the field winding. The figure shows operation in these quadrants restricted to conditions that will cause the generator and its transformer to be over- or under-fluxed by no more than 5 %. Margins of excitation and of stability will be reduced under some of the operating conditions shown. As the operating frequency moves away from the rated frequency, effects outside the generator may become important and need to be considered. As examples: the turbine manufacturer will specify ranges of frequency and corresponding periods during which the turbine can operate; and the ability of auxiliary equipment to operate over a range of voltage and frequency should be considered.



18. Prime mover capabilities

Steam and gas turbines are normally designed to run continuously within a narrow speed range, in synchronism with the grid frequency. Turbine capabilities are normally defined by the manufacturer specifically for each turbine. Operation at abnormal frequencies will usually be covered by caveats, which specify, for example, maximum durations and increased inspection and maintenance requirements. Operation away from the design frequency often gives rise to blade resonance problems and it is considered that prolonged and cumulative operation away from the statutory frequency range (49.5Hz to 50.5Hz) could significantly increase the risk of blade failure.

19. BS EN 50160:2007 Voltage characteristics of electricity supplied by public distribution networks

This standard defines characteristics of the supply to users of public LV and MV distribution networks (defined as below 35kV).

The standard gives the following frequency ranges for large interconnected systems:

50 Hz ± 1 %	(i.e. 49.5 Hz to 50.5 Hz)	during 99.5 % of a year
50 Hz + 4 % / - 6 %	(i.e. 47 Hz to 52 Hz)	during 100 % of the time

20. European Grid Codes

A comparison of the requirements in various Grid Codes was presented in the following paper at EWEC 2008:

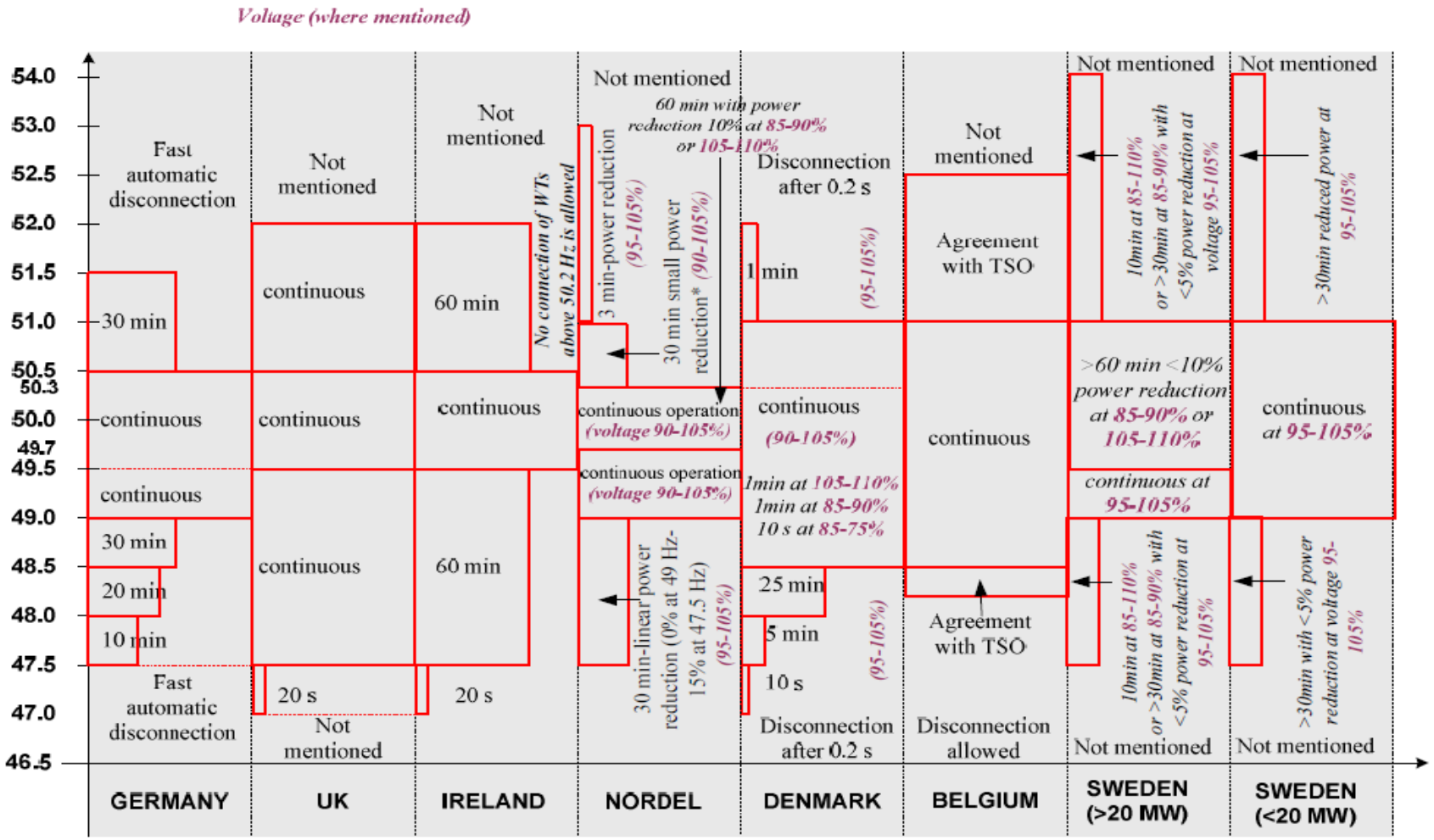
Grid Code Requirements for Large Wind Farms: A Review of Technical Regulations and Available Wind Turbine Technologies

by M. Tsili, Ch. Patsiouras, S. Papathanassiou, School of Electrical & Computer Engineering, National Technical University of Athens (NTUA)

http://www.ewec2008proceedings.info/index2.php?page=info2&id=133&id2=144&ordre=2&tr=&searchin=&what=&searchtext=&day=&top=&fil1=&fil2=&fil2&ord1=&sess=103#top

The following figure from this paper illustrates the frequency operating range requirements from various European Grid Codes.

As noted in the paper, the most stringent requirement for continuous operating frequency range is specified in the GB Grid Code. Other codes, including Ireland, specify narrower frequency ranges for continuous operation together with short-term operating requirements for the abnormal frequency bands.



* the total duration of these operating conditions must not exceed 10 hours/year

21. E.ON Netz Grid Code

The E.ON Netz code (Germany) is a good example showing how the duration is reduced for more extreme frequency bands. This is shown in more detail below. In this figure, both the active power and related duration requirements are shown across the frequency range. Duration requirements are also shown related to voltage.

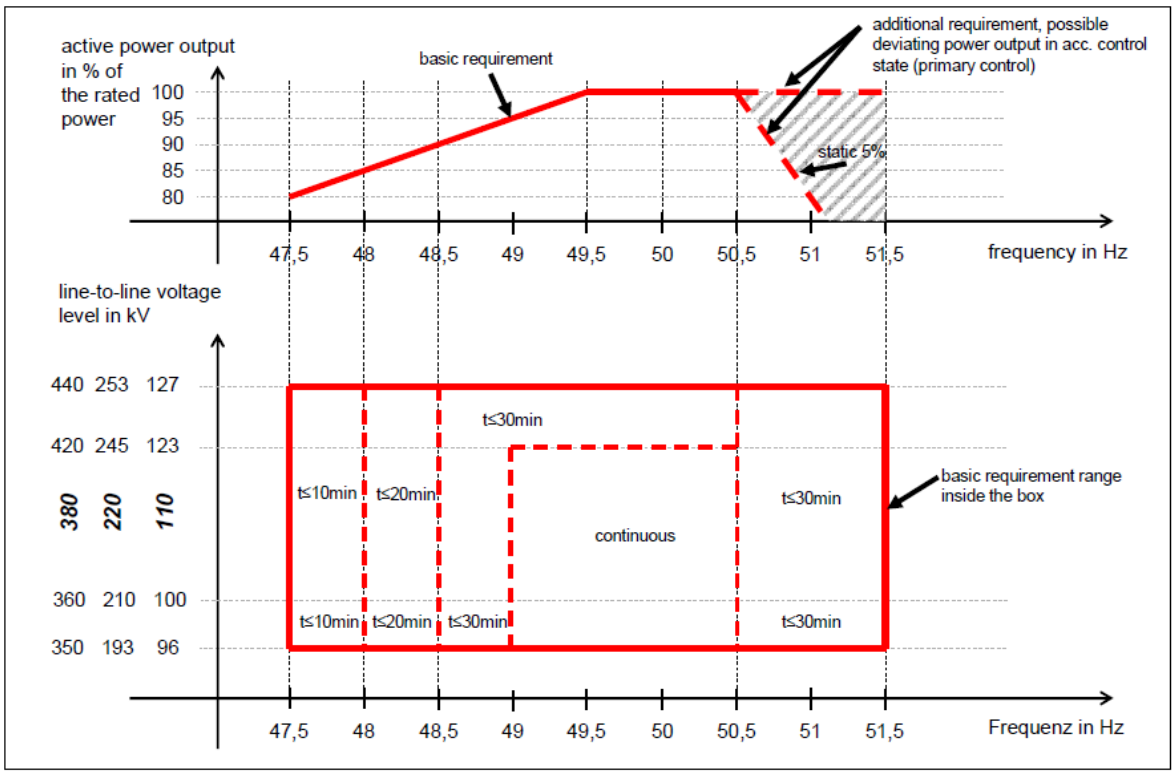


Figure 3 Requirements placed on the output power of a generating plant to the grid for certain periods, as a function of grid frequency and grid voltage (quasi-stationary observation, i.e. frequency gradient < 0.5% / min., voltage gradient 5% / min.)

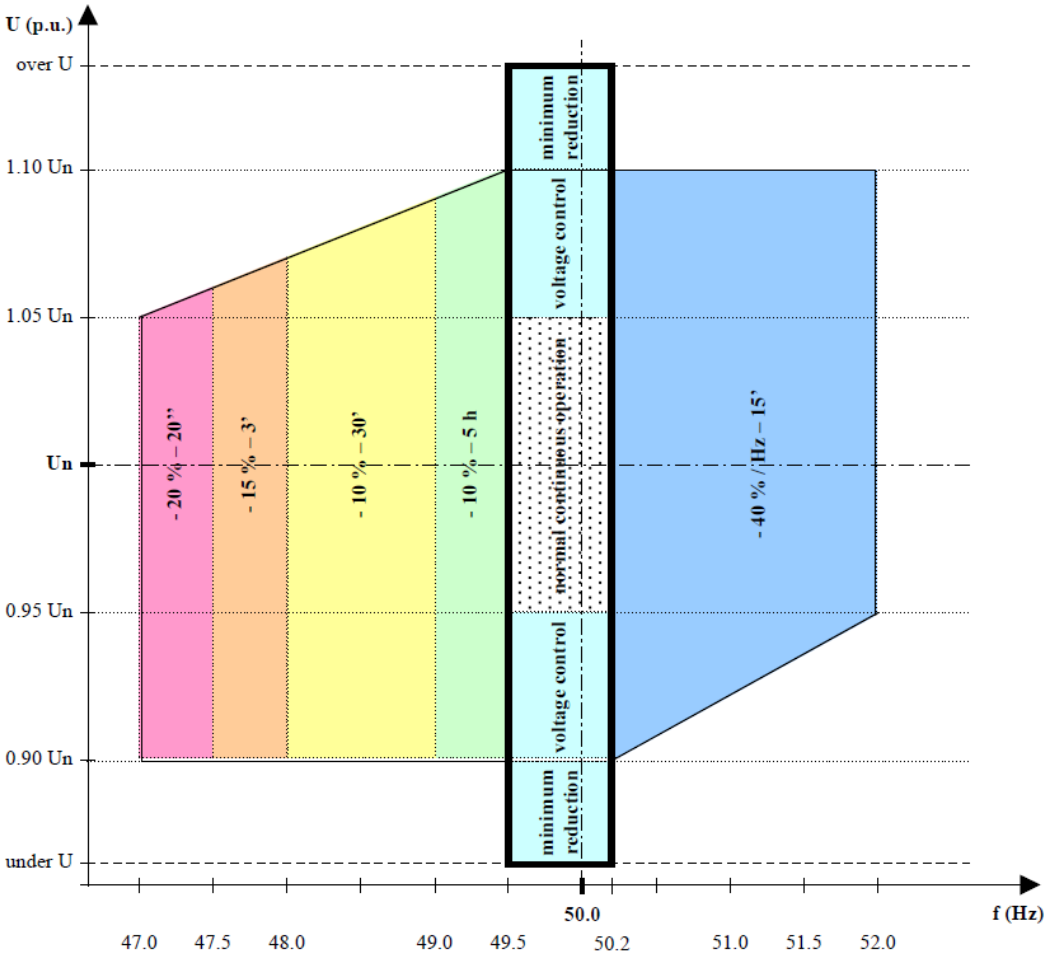
22. CENELEC working group TC8X WG3

This working group has produced a draft technical specification entitled:

“Requirements for the connection of generators above 16 A per phase to the LV distribution system or to the MV distribution system”.

The UK is represented on this working group by EA Technology Limited and the Energy Networks Association. This draft technical specification has also been recently considered by the DCRP G59/G75 working group.

The current draft (14 October 2009) of this technical specification includes the following requirements with regards to active power output, frequency range, voltage range and duration:



Frequency range at the PCC f [Hz]	Operating time t [sec. / min.]	Power reduction [%]
f < 47.0 Hz	Stay connected until under frequency trip	No requirements
47.0 ≤ f ≤ 47.5	> 20.0 sec.	< 20%
47.5 < f ≤ 48.0	> 3 min	< 15%
48.0 < f ≤ 49.0	> 30 min	< 10%
49.0 < f ≤ 49.5	> 5 hours	< 10%
49.5 < f ≤ 50.2	Continuous	None
50.2 < f ≤ 52.0	> 15 min	Automatic reduction of at least 40% per Hz
f > 52.0 Hz	Stay connected until over frequency trip	No requirements

It can be seen that there is a narrow frequency band for continuous operation, plus increasingly short duration operating requirements for the more abnormal frequency bands.

23. GB System Needs

The normal operation control range is 49.8 to 50.2Hz.

To manage frequency deviations, National Grid hold frequency reserves for 'significant' and 'abnormal' events such that:

Significant event (sudden imbalance greater than 300MW and up to 1000MW): the system frequency should not deviate by more than 0.5Hz.

Abnormal event (sudden imbalance greater than 1000MW and up to 1320MW): the system frequency should not deviate by more than 0.8Hz (hence the frequency should not drop below 49Hz).

For both significant and abnormal events any frequency deviation below 49.5Hz should not persist for more than 60 seconds, and system frequency should return to between operational limits within 10 minutes.

24. GB historical data presented by National Grid – summary of incidents of frequency excursions outside statutory limits:

Low frequency incidents (14 years from 1995 to 2008):

- Number of incidents, f < 49.5Hz: 7
- Total time below 49.5Hz: ~19 minutes
- Number of incidents, f < 49Hz: 1

- Worst single low frequency incident (27 May 2008):
  - minimum frequency: 48.8Hz
  - time below 49Hz: ~90 seconds
  - time below 49.5Hz: 9 minutes

Low frequency incidents (20 years to 1996/7)

- Number of incidents, f < 49.5Hz: 41
- Number of incidents, f < 49Hz: 1*

High frequency incidents f > 50.5Hz:

- 1972
- 1981 (5 August)*

* system split resulting in frequencies of 47.3Hz and 50.7Hz

(Sources: NGET presentation to manufacturers, 28/5/09 and NGC's "Technical and Operational Characteristics of the NGC Transmission System", Issue 1 June 1998)

Note that the 27 May 2008 event was initiated by the total loss of 1582MW of large transmission connected generating units, within 2 minutes, and is considered to be beyond the maximum secured loss.

25. Given the system needs as indicated by historical data, plant performance capabilities and requirements as specified in various standards and codes, and concerns about the implications for risk of plant failure, it appears difficult to justify the requirement for continuous operating capability across the wide frequency range of 47.5 to 52Hz as written in the GB Grid Code. The capability to withstand such extreme frequency abnormalities continuously would appear to provide very little value to grid operation and security.

It would appear that the threat to grid security due to inadequate capability of small embedded generation to ride through short term frequency abnormalities is a valid concern and hence this should be the subject of further consideration.

Option 2 – Distribution Code and/or G59 protection requirements

26. The DCRP G59/G75 working group has proposed revised so-called 'G59' protection settings as part of the work to produce a new revision of Engineering Recommendation G59.

27. The protection systems and revised settings in the draft G59/2 document (and also currently proposed for incorporation in the Distribution Code) have been proposed based on the following:

"The main function of the protection systems and settings described in this document is to prevent the Generating Plant supporting an islanded section of the Distribution System when it would or could pose a hazard to the Distribution System or customers connected to it. The settings recognize the need to avoid nuisance tripping and therefore require a two stage approach where practicable, ie to have a long time delay for smaller excursions that may be experienced during normal Distribution System operation, to avoid nuisance tripping, but with a faster trip for greater excursions."

"The protection systems and settings can have an impact on the behaviour of Generating Plant when the Total System is in distress. Where Generating Plant has the capability to operate at the extremes of the possible operating range of the Total System, it would be inappropriate to artificially impose protection settings that would cause Generating Plant to be disconnected where it would otherwise be capable of remaining connected and helping to maintain the

integrity of the Total System. It is not the intention that this Section specifies the performance requirements of Generating Plant connected to Distribution Systems, only that protection settings do not aggravate the stress on the Total System by tripping before there is a definite need in those circumstances. (For Medium Power Stations and Large Power Stations, performance requirements are specified in the Grid Code)."

(G59/2, v10, Jun 09 , sections 10.1.1 and 10.5.1)

28. The changes to the under and over frequency 'G59' settings presently introduced by the draft G59/2 are summarised in the following table:

	G59/1 (current)	G59/2 (draft)
U/F (1st stage)	-	47.5Hz, 20s
U/F (2nd stage)	47Hz, 0.5s	47Hz, 0.5s
O/F (1st stage)	-	51.5Hz, 90s (n/a to Medium PS)
O/F (2nd stage)	50.5Hz, 0.5s	52Hz, 0.5s

Thus, resilience is improved with regards to high frequency by means of less sensitive settings, but is marginally reduced with regards to low frequency (through the introduction of an additional, slightly more sensitive, stage).

29. It is important to note that there are likely to be other protection relays installed in addition to the designated 'G59' relays. These may include protection installed and owned by the DNO, effectively used as back-up protection for the distribution network, and protection installed at each generating unit. The latter may typically be installed as part of a standard generator product (e.g. protection included in individual wind turbines) for the purpose of protecting the generating unit as opposed to protecting the network. The 'G59' protection may be combined with the generating unit protection (at each generator) and this will often be the case for units embedded in an industrial site, so that the 'G59' protection will trip only the generating units and not the site load. However, some projects with multiple generating units (e.g. wind farms) may have a single set of designated 'G59' protection at the connection point substation such that it is in a secure, immediately accessible location and so as to avoid witness inspection and testing of protection at each generating unit.

30. Ideally, protection will be graded so that disconnection takes place closest to the generator. This will avoid unnecessary loss of supply to generator auxiliaries or unnecessary tripping of the DNO's circuit breaker. The design of a properly co-ordinated protection scheme, to meet a variety of opposing requirements, can

therefore become very complicated and compromised if too many protection devices are installed.

31. If any of the protection devices has more sensitive settings than the recommended 'G59' settings, then the resilience of the plant to frequency excursions will be reduced. This is a potential problem for grid security which needs to be given special attention in any protection-based solution.

32. The present Distribution Code and G59/2 drafting (which must be regarded as work in progress, not finalised) proposed by the DCRP G59/G75 working group includes several clauses which give scope for variation of settings and permit other protection with more sensitive settings to be installed. These need to be considered further against the requirements for grid security, for example:

Distribution Code (draft):

DPC7.4.3.2 Specific Protection Required for Embedded Generating Plant

In addition to any protection installed by the Generator to meet his own requirements and statutory obligations on him, the Generator must install protection to achieve the following objectives.....

Suitable protection arrangements and settings will depend upon the particular Generator's installation and the requirements of the DNO's Distribution System. These individual requirements must be ascertained in discussions with the DNO.

DPC7.4.3.5 The settings in DPC7.4.3.3 apply although in exceptional circumstances Generators have the option to agree more sensitive settings with the DNO if there are valid justifications in that the Generating Plant may become unstable or suffer damage with the settings specified in DPC7.4.3.3. The agreed settings should be recorded in the Connection Agreement.

G59/2 (draft):

10.3 Loss of Mains

10.3.1 To achieve the objectives of Section 10.1.1, in addition to protection installed by the Generator for his own purposes, the Generator must install protection to achieve (amongst other things) disconnection of the Generating Plant from the Distribution System in the event of loss of one or more phases of the DNO's supply.

10.5 Protection Settings

10.5.9 Generating Plant may become unstable or suffer damage with the settings specified in 10.5.8 or when Distribution System configuration

requires different settings. The agreed settings should be recorded in the Connexion Agreement. The settings in table 10.5.8 are the settings which should be applied although Generators should have the option to agree more sensitive settings with the DNO if there are valid concerns regarding relay settings. The specific earthing requirements for LV connected Generation Plant are described in DPC 7.4

(compare with draft DPC7.4.3.5 clause above).

Other considerations

- What would be required of Generators and DNOs in terms of demonstrating, checking and approving compliance, for whatever options are proposed?
- The proposals for further investigation of problems and options for existing plant need to be identified.
- There does appear to be a concern over the G59 over frequency setting. However, given that the G59 under frequency setting is 47Hz, what is the evidence that small embedded generation is actually more susceptible to low frequency than to say rate of change of frequency, and that this is therefore the main problem that needs to be addressed?
- How can the expected degree of improvement of any proposed changes to frequency obligations be estimated and quantified, in order to justify those changes?