Grid Code CC.6.3.3 Review Working Group

Report to Grid Code Review Panel

Review Of Grid Code Connection Condition Clause 6.3.3 Requirements For Frequencies Below 49.5Hz

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SUMMARY

In April 2000, Ofgem received a request from a Generator for a derogation from the Grid Code clause CC.6.3.3, stating that the technical design of its new technology and more efficient CCGT renders it unable to comply with these requirements at frequencies below 49.5Hz. In May 2000, Ofgem issued a consultation paper with three possible ways to approach the Generator's request. In June 2000, Ofgem issued responses to the consultation paper, and confirmed that Ofgem will request NGC to review the Grid Code with a view to establish the system requirements underlying CC.6.3.3 and incorporate only the minimum requirements in the Grid Code, with the remainder being purchased by the Generator. Ofgem also confirmed that it will grant a temporary derogation to the Generator while the Grid Code review is carried out.

The Grid Code Review Panel (GCRP) set up a Working Group to begin the review ahead of the anticipated request from Ofgem. The Working Group met on 22 March 2001, and the GCRP was informed on 17 May 2001 of the draft Terms of Reference for the Working Group. In April 2002, Ofgem formally requested National Grid to carry out the review, and confirmed that the draft Terms of Reference would meet the objective of the review.

The review has been carried out and is reported in this document. The review considered possible alternatives to the current requirement - power/frequency slope characteristics between the extremes of the existing slope requiring 95% of active power output at 47Hz, and a slope requiring 75% of active power output at 47Hz. It assessed the impact of alternative CC.6.3.3 slopes on frequency response and demand disconnection requirements. In addition, research was carried out to explore CC.6.3.3 equivalent requirements employed by overseas electric utilities.

The assessment showed that relaxing the CC.6.3.3 requirements would result in an increased system balancing cost due to an increase in the requirement for frequency response holding, an increase in the amount of customer and demand disconnection, and risk of island collapse under emergency system operating conditions. The estimated increase in system balancing costs incurred by the increased frequency response requirements due to relaxation of CC.6.3.3 can be substantial and cannot be justified.

Since complying with CC.6.3.3 involves special actions (overfiring, water injection, or other measures) which causes the plant to operate beyond its rated capacity, evidence emerged from CCGT plant manufacturers of the existence of a real risk to plant tripping for frequencies below 49Hz. The consensus is that the probability of tripping depends on the frequency itself, duration of operation and ambient conditions, but cannot be quantified analytically or empirically due to absence of any meaningful real life experience.

The minimum system requirement is based on the minimum risk to the security of customer demand. This minimum risk appears to be consistent with the need to reduce the risk of CCGT plant tripping under such conditions.

The minimum system requirements can be met by the following proposal:

a) For frequencies down to the relay trip setting of the first stage of the automatic low frequency demand disconnection scheme (currently 48.8Hz), the existing CC.6.3.3 requirements should be retained.

b) For frequencies below the relay trip setting of the first stage of the automatic low frequency demand disconnection scheme (currently 48.8Hz) where special action(s) may be required to meet existing requirements, CC.6.3.3 should be retained for a period of 5 minutes. Thereafter, a relaxation shall take place so that the gas turbine power output is reduced to follow the machine natural (inherent) characteristic with reduced shaft speed due to falling system frequency, and special action(s) may be discontinued if there is a materially increased risk of the gas turbine tripping.

For all stakeholders (Generators, NGC, DNOs and plant manufacturers) to obtain the benefits of this proposed relaxation, the proposal needs to be applied to all CCGT plant where there is a material increase in the risk of plant tripping during a prolonged period of operation below 48.8Hz

1 INTRODUCTION

General

1.1 This report reviews the Grid Code Connection Condition clause 6.3.3 requirement for frequencies below 49.5Hz. In the review, possible alternatives to the current requirement have been considered. These have included slope characteristics between the extremes of the existing slope requiring 95% of active power output at 47Hz, and a slope requiring 75% of active power output at 47Hz.

1.2 The impact of using different slopes has been assessed using dynamic simulations of the power system from the point of view of increased frequency response requirements and increased customer demand disconnection. Research was also carried out to compare CC.6.3.3 with equivalent information from overseas electric utilities. Various options for CC.6.3.3 were considered, and progress at different stages of the review, was presented and discussed at various meetings of the Grid Code Review Panel Working Group.

1.3 This document puts together all relevant information including background to the review, results of analysis, findings of research on overseas utilities, discussion of options for CC.6.3.3, and provides conclusions and recommendations.

Background

1.4 In April 2000, Ofgem received a request from a Generator for a derogation from the Grid Code clause CC.6.3.3, stating that the technical design of its new technology and more efficient CCGT renders it unable to fully comply with the requirement for frequencies below 49.5Hz.

1.5 In May 2000, Ofgem issued a consultation paper with three possible ways to approach the Generator's request. The approach that Ofgem minded to follow was to grant a temporary derogation to the Generator for the proposed plant, instigate a review of the true requirements underlying CC.6.3.3 and require the Generator to procure, to NGC's reasonable satisfaction, response equivalent to the proposed plant's shortfall from other plant on the system.

1.6 In June 2000, Ofgem issued responses to the consultation paper, and confirmed that Ofgem will request NGC to review the Grid Code with a view to establish the system requirements underlying CC.6.3.3 and incorporating only the minimum requirements in the Grid Code, with remainder being purchased by the Generator. Ofgem will also grant to the Generator a derogation for a reasonable time period which allows a shortfall from present Grid Code requirements while the Grid Code review is carried out, and which requires the Generator to procure, to NGC's reasonable satisfaction, response equivalent to the proposed plant's shortfall whenever it is operational.

1.7 In November 2000, National Grid presented a paper (GCRP 00/31) to the Grid Code Review Panel (GCRP) proposing a possible review of the Grid Code Connection Condition 6.3.3 requirements for frequencies below 49.5Hz.

1.8 The paper GCRP 00/31 gives the background to this review and sets out the current Grid Code CC.6.3.3 requirement as:

"Each Generating Unit and/or CCGT module must be capable of:

a) Continuously maintaining constant active power output for system frequency changes within the range 50.5Hz to 49.5Hz

b) Maintaining its active power output at a level not lower than the figure determined by the linear relationship shown in Figure 1 for system frequency changes within the range 49.5Hz to 47Hz, such that if the system frequency drops to 47Hz the active power does not decrease by more than 5%"

The derogation request (clause 1.4 above) received by Ofgem from the Generator asked for a replacement of clause 1.8(*b*) as follows:

"Maintaining its active power output at a level not lower than the figure determined by the linear relationship shown in Figure 1 for system frequency changes within the range 49.5 to 47 Hz, such that if the system frequency drops the active power occurring does not decrease with system frequency by a ratio of more than 5:1"

1.9 The GCRP set up a Working Group to begin the review ahead of the anticipated formal request from Ofgem (membership of the Working Group is shown in Appendix I). The constituted group met on 22 March 2001 and discussed in some detail the review terms of reference. The GCRP were informed of the Working Group agreed draft terms of reference at their meeting on 17 May 2001. The Terms of Reference are attached in Appendix II.

1.10 In April 2002, Ofgem formally requested NGC to carry out the review, and confirmed that the Working Group's draft terms of reference would meet the objectives of the review that Ofgem requires.

1.11 The review has been carried out based on National Grid's Security and Quality of Supply Standard. National Grid carried out the review in various stages. The first stage was based on a simple algebraic approach where response requirement was calculated from initial system demand, system frequency, and CC.6.3.3 slope. Demand disconnection requirement was calculated from initial generation deficit, system frequency, and CC.6.3.3 slope. The objective was to obtain a basic understanding of requirements and the relative importance of the factors affecting those requirements. Power system dynamics were not represented. The first stage was followed by several dynamic simulations which allowed the inclusion of the effect of dynamic models for generators, governors, excitation systems, and dynamic modelling of CC.6.3.3 slope. In addition, research was carried out to compare CC.6.3.3 with equivalent information from overseas electric utilities.

1.12 In the following sections, findings of the review of CC.6.3.3 for frequencies below 49.5Hz are reported. Frequency response and demand disconnection requirements are discussed. Also, the power system dynamic models, data, study approach, and results of dynamic simulations are presented. Findings are presented comparing CC.6.3.3 with similar information from overseas utilities. This is followed by discussion of various options for CC.6.3.3, conclusions and recommendations.

2 FREQUENCY RESPONSE REQUIREMENTS

General

2.1 For the maximum credible generation loss of 1320MW, the effect on frequency response of using two alternative power/frequency slopes for CC.6.3.3 is investigated: the existing slope requiring 95% power output at 47Hz (slope K=1), and an alternative slope requiring 75% power output at 47Hz (slope K=5) as shown in Fig. 1. The objective is to identify additional response requirements due to K=5 compared to the existing requirements for K=1.

2.2 Response requirements are identified to meet criteria for primary response and secondary response. Primary response is defined as the increase in active power delivered by automatic governor action from a generating unit (or decrease in active power demand initiated by low frequency relay) that will be available at 10 seconds after an event and can be sustained for a further 20 seconds. Secondary response is defined as the increase in active power delivered by automatic governor action from a generating unit (or decrease in active power demand initiated by low frequency relay) that will be available at 30 seconds after an event and can be sustained for a further 30 minutes.

Power System Model and Data

2.3 The power system dynamic model used represents a 2005/6 future generation background, typical plant mix and mix of response requirements.

2.4 The power system model as shown in Fig. 2 consists of generation in England and Wales (E&W), and Scotland and interconnection with France. The E&W generation comprises conventional thermal plant, e.g., coal, oil in responsive and unresponsive mode, CCGTs in responsive and unresponsive mode, and hydro units as a source of frequency response. The model for Scottish generation mainly consists of thermal responsive and unresponsive plant. The interconnection with France is a constant power infeed. In the calculation of response, plant loading and reserve margins are chosen in line with existing agreements such that about 90% of the total response would come from E&W and about 10% response from Scotland.

2.5 Generation background and the various plant mix assumed is that for the year 2005/06. Guidance is also taken from the Energy Management System real-time data snapshots to determine the proportions of plant mix, loading levels, and the amount of responsive and unresponsive generation. The data used is given in Table 1 and Table 2. The responsive generation shown in Table 2 represents initial loading level of the plant (pre-event). To make up the E&W system demand, the responsive and unresponsive components of E&W generation are added together with import from Scotland and France. Table 3 is a breakdown of the unresponsive CCGT generation (and its interpretation in terms of percentage non-compliant unresponsive CCGT generation studied).

2.6 A selection of automatic voltage regulator and governor models that are found on the E&W power stations has been used to represent those modelled in the present study.

2.7 The TRIP generator in Fig. 2 represents the 1320MW to be tripped. The HYDRO units have been used to assist frequency to return to 49.5Hz within 60 seconds (frequency must return to 49.5Hz according to NGC frequency containment and control policy). These units have been modelled to respond at 49.8Hz with a delay of 10 seconds, ramping to full output in 10 seconds (for simulation purposes, hydro units can be brought in with increased delay period if necessary).

2.8 For unresponsive thermal plants, the power/frequency variation given by CC.6.3.3 existing requirements (K=1) is modelled as an algebraic function, delayed by a boiler pressure time-constant, and applied at the turbine input. The responsive thermal plant provides response in the event of generation loss.

2.9 The single-shaft unresponsive CCGT module comprises 66% output from gas turbine(s) and 34% output from steam turbine. The power/frequency variation given by CC.6.3.3 requirements (K=1 and K=5) is modelled as an algebraic function and applied instantaneously (without a time-constant) to the gas turbine mechanical power. The responsive CCGT plant provides response in the event of generation loss.

2.10 The droop function for unresponsive thermal plant and unresponsive CCGTs provides constant mechanical power output between 49.5Hz and 50.4Hz, and a 10% droop between 50.4Hz and 52Hz (limited high frequency response). The CC.6.3.3 power/frequency function as described above is applied below 49.5Hz.

2.11 The droop function for responsive thermal plant and responsive CCGTs models a 4% droop below 50.5Hz, and 10% droop between 50.5Hz and 52Hz.

2.12 Demand variation with frequency is included (2%/Hz for active power and –1%/Hz for reactive power). The response from demand side is provided by disconnecting a total of 258MW demand in two stages (first stage at 49.7Hz and the second stage at 49.65Hz).

Study Approach

2.13 Based on the power system model of Fig. 2, dynamic simulations are carried out for UK system demands (E&W + Scotland) of 22GW, 45GW and 61GW using a power/frequency slope of K=1 (existing CC.6.3.3 requirements) and slope K=5 (assumed worst case CC.6.3.3). The CCGT unresponsive generation is split into two components: a compliant component with K=1 applied, and the non-compliant component with K=5 applied. For the 100% non-compliant case, all unresponsive CCGT generation has K=5 applied.

2.14 The component of non-compliant unresponsive CCGT generation (CCGTUN) is varied for each of the three system demand levels. The amount of non-compliance studied is 100%, 75%, 50%, 25% and 0% of the total CCGTUN, and the data is shown in Table 3.

2.15 In accordance with National Grid Security and Quality of Supply Standard, frequency containment and control policy, for any abnormal event involving the loss of more than 1000MW up to 1320MW of generation infeed, any frequency deviation below 49.5Hz should not persist for more than 60 seconds. In the dynamic simulations, the values of primary and secondary response delivered at the times specified under item 2.2 above have been derived.

2.16 Primary response is scheduled to contain the frequency deviation to 0.8Hz for a 1320MW generation loss. If the frequency were at the lowest operational limit of 49.8Hz, then this would result in a minimum frequency of 49Hz. The primary response and secondary response are evaluated for both K=1 and K=5 to prevent frequency falling below 49Hz and to be restored to 49.5Hz within 60 seconds. The additional response requirement is the difference between response values at K=5 and K=1.

Discussion of Results

2.17 Fig. 3 shows the additional primary response requirements. It can be seen that as system demand increases, the additional primary response requirements increase due to the increase in the amount of unresponsive plant. Fig. 3 also shows that additional primary response requirements increase with the increase in the amount of non-compliant plant. It is noted that if all CCGTs become non-compliant (100% non-compliance), 223MW of additional primary response would be required at a system demand of 61GW. Additional secondary response requirements (Fig. 4) follow a trend similar to that of additional primary response requirements. It is noted that if all CCGTs become non-compliant (100% non-compliance), 289MW of additional secondary response would be required at a system demand of 61GW.

2.18 The generation background and system operating practice as considered in these studies indicate that there would be a sufficient amount of plant to meet the identified additional response requirements. The additional response results presented are based on a forecast of future generation mix and CCGT component. An increase in this component accompanied by an increase in the amount of non-compliance would raise the requirements for additional response.

2.19 At average system demand of approximately 42GW, it is noted that about 180MW and 220MW of additional primary and secondary response respectively would be required system-wide for 100% non-compliant case. The cost of holding such additional response on generators is estimated in the region of £35m per annum, which is a central figure and is very dependent on conditions in the Balancing Market (prices and length).

2.20 Relaxation of the existing CC.6.3.3 requirement would incur a substantial additional cost in balancing the transmission system in order to maintain the same level of security. The costs of such a relaxation may be compared with the cost Generators incur in maintaining compliance with existing CC6.3.3 requirements. However, the later costs are not available.

Summary of Results

2.21 The amount of additional primary and secondary response increases as system demand increases, and it also increases as the amount of non-compliance increases. The worst case is when all unresponsive CCGT generation becomes non-compliant at the highest system demand of 61GW in which case a requirement of

223MW is identified for additional primary response and 289MW for additional secondary response.

2.22 The additional response required depends on the amount of non-compliant unresponsive CCGTs in the system, and is also very much dependent on future generation background. Larger amounts of non-compliant CCGTs would worsen the requirements, increase balancing costs, and may impact on the ability to operate the system in terms of the unavailability of sufficient levels of responsive plant.

2.23 At average system demand and based on present annual cost of holding response, the additional frequency response could cost around £35m per annum.

3 DEMAND DISCONNECTION REQUIREMENTS

General

3.1 The work reported here investigates the effect of alternative CC.6.3.3 slopes (K=1 and K=5) on automatic low frequency demand disconnection for frequencies below 49Hz. The low frequency demand disconnection (LFDD) scheme is called upon under extreme system conditions where the entire power network or power islands have an increased generation deficit that can lead to collapse of the system frequency. By automatically shedding load, there is an increased probability that the frequency can be stabilised. By avoiding total blackout in the case of an island situation, resynchronisation to other parts of the system and load restoration can be achieved much more quickly.

3.2 A scenario leading to a major and insecure generation deficit is a multiple loss of generation plant in quick succession in excess of the secured loss of 1320MW. Another more likely scenario which can cause the frequency to drop below 49Hz, is multiple transmission circuit tripping giving a split of a part of the system from the remainder. The generation deficit amount will vary depending on the magnitude of demand and generation in the island at the split instant. If this part (island) is a net power importer, and the island contains insufficient response, then the frequency will drop below 49Hz and stability will only be retained if demand disconnection and demand reduction with voltage and frequency balance the available generation. An island can consist of a single generating unit or several. It is impossible practically to predict all likely system split scenarios or be able to study all variations. Hence some simplifying assumptions have been made as discussed below to evaluate the effect of different CC.6.3.3 slopes on demand disconnection.

Power System Model and Data

3.3 The LFDD scheme used in the analysis is shown in Table 4. This is the scheme with the settings recently revised by National Grid. The Distribution Network Operators (DNOs) were informed of the new settings to implement in March 2002. It consists of 9 load shedding stages; the first three stages use a 0.2 second circuit breaker/relay operating time, and the remaining six stages use a 0.4 second operating time. The first load shedding stage activates when the frequency threshold of 48.8Hz is encountered; the last stage is set for 47.8Hz. Table 4 also shows the accumulated load shed; all the nine stages would shed 60% of the demand. The effect of using a possible future relay operating time of 0.2 seconds (when the relays are replaced by the DNOs with faster ones) for all load shedding stages has also been investigated.

3.4 The power system model is shown in Figure 5 and consists of a single generating unit, a single load, and a single power infeed (a single generating unit equivalent is formed assuming that all generators remain in step during transient). Loss of infeed is simulated by tripping the branch between the INFEED and LOAD nodes.

3.5 Because it is impossible to predict where system split boundaries will be, it is assumed that the island contains no responsive plant as this represents a likely and worst case scenario. The amount of unresponsive CCGT plant corresponds to the peak system demand condition, and for the generic case studies, it is taken to be 21000MW (see clause 3.14 below). Demand variation with voltage and frequency has been modelled.

Study Approach

3.6 Based on the power system model of Fig. 5 and LFDD scheme of Table 4, dynamic simulations were carried out for different amounts of generation deficits using K=1 (all CCGTs compliant) and then using K=5 (all CCGTs non-compliant). The difference between the two sets of results would represent the amount of additional demand disconnection required due to a change to K=5. Simulations were also carried out using a possible future relay operating time of 0.2 seconds.

3.7 The generation amount is kept fixed while the demand and infeed (import) are changed to obtain different percentage of generation deficits (generation deficit is the ratio of import to demand). Therefore, in the simulation, various levels of imports representing different generation deficits were tripped to cause the frequency to drop below 49Hz.

Discussion of Results

3.8 Results from dynamic simulations using the existing relay operating times are shown in Table 5. These results show for K=1 and K=5, and for different generation deficits, the number of load shedding stages used, minimum transient frequency after the load shedding, and the amount of load overshed. The additional amount of load shedding required using K=5 instead of K=1 is also shown in percent of demand and number of stages.

3.9 It is noted that generally there is one extra stage of load shedding required due to the worst case slope K=5 over the existing CC.6.3.3 slope of K=1. In one case for a very small generation deficit, two extra stages of load shedding have been identified (it is impossible to investigate a very large number of generation deficits, and it would be difficult to say if there is any other case of generation deficit where two additional stages might be involved).

3.10 For higher generation deficits, more load shedding stages are involved. For K=1, all nine stages are shed at 50% generation deficit while for K=5 all nine stages are shed at a slightly lower generation deficit of 47.5%.

3.11 For K=1, a generation deficit of 56.6% causes the frequency to drop to 47Hz and would result in island collapse (results in bold). For K=5, island collapse occurs at a slightly lower generation deficit of 52.1%. The difference between the generation deficits is about 4.5%, and the risk of island collapse is slightly increased for K=5.

3.12 Results for demand disconnection stages against initial generation deficit are shown plotted in Fig. 6 which shows no time dimension. It should be noted that in a transient time scale, the demand disconnection for K=5 would be happening slightly earlier than for K=1. Figure 7 shows a plot of minimum frequency observed against initial generation deficit. There is a gradual change in frequency with generation deficit except for very large generation deficits where island frequency is much more sensitive to generation deficit.

3.13 Demand is naturally overshed due to the discrete size of demand blocks in both cases of K=1 and K=5. Demand overshed is up to 10% for K=1, and up to 17% for K=5 depending on the size of generation deficit.

3.14 The model used is a generic one and would produce similar results if it is scaled down to represent a smaller island (low demand). The amount of additional demand disconnected in percentage terms and number of additional stages shed would be the same. However, in terms of MW, demand to be disconnected would be low in a smaller island than in a large island.

3.15 The use of a possible future relay operating time of 0.2 seconds for all load shedding stages was found to produce virtually the same requirements for additional load shedding stages as found with existing relay operating times.

3.16 For generation deficit cases of 4.5% to 50%, the following should be noted:

a) The period of time system frequency remains below 49Hz can be up to 10 sec.

b) The rate of frequency drop can be between 0.096 Hz/sec and 2.1 Hz/sec. These figures represent the initial part of the transients immediately after the event.

c) The frequency always stabilises above 50 Hz.

Summary of Results

3.17 For the worst case slope of K=5 compared to the existing slope K=1, one additional stage of load shedding has been identified in all cases except one where two additional load shedding stages have been identified.

3.18 The non-compliant CCGTs (K=5) result in a marginal increase in the risk of island collapse in the event of very large generation deficits above 52%. For K=5, the island would collapse with some 4.5% less generation deficit than that required for K=1.

3.19 The existing and future relay operating times produce the same requirements for additional load shedding stages.

3.20 The period of time system frequency remains below 49Hz can be up to 10 sec, and the quickest drop in frequency has a rate of 2.1 Hz/sec. The frequency always stabilises above 50 Hz after the demand disconnection has been accomplished.

4 OVERSEAS EQUIVALENT OF CC.6.3.3

4.1 Investigation has been carried out to explore key features pertaining to power/frequency characteristics, type of power plants, and operating practice of overseas electric utilities, and to find out if any utility has connection conditions similar to CC.6.3.3. The findings of this research and comparison with the UK are produced in Appendix III, and a summary of these findings is given below.

Summary of Findings

4.2 It is found that the power/frequency characteristics of generators used in the Grid Codes in Scotland, Northern Ireland and the Philippines are the same as those of CC.6.3.3. It is also noted that the proportion of conventional thermal plant in these utilities is higher than other type of plants. NGC has a significant proportion of CCGT plant while Northern Ireland and the Philippines are reported to have no CCGT plant.

4.3 It is noted that the power/frequency characteristics of utilities in Finland and Germany (DVG) require full power output down to 49Hz compared to NGC which is down to 49.5Hz. These utilities also allow more power drop below 49Hz than CC.6.3.3. The major difference appears to be in the type of generating plant between these utilities and NGC - these utilities have no CCGT plant while NGC has a significant proportion of CCGT plant. Also, Finland has less conventional thermal plant than NGC (plant composition is not available for Germany RWE/DVG utilities).

4.4 It is recognised that sufficient details about overseas electric utilities are not available to reach any firm conclusions or to determine conditions under which some overseas utilities can allow more power drop than that permitted by CC.6.3.3. Also, some utilities make no explicit power/frequency requirement in their Grid Codes or connection requirements.

5 CONSIDERATION OF OPTIONS FOR CC.6.3.3

5.1 The work carried out and reported in the previous sections shows increased frequency response and demand disconnection requirements due to an alternative power/frequency slope (K=5) compared to the existing slope (K=1). It is to be noted that carrying additional frequency response above 49Hz will not increase the risk of demand disconnection. Another option of carrying additional response is via low frequency demand tripping.

5.2 Five options were considered for CC.6.3.3 review. These options and their implications are described in Table 6 and discussed from the point of view of Generators (both existing and new), Distribution Network Operators and Suppliers, National Grid, and DTI/Ofgem (it should be noted that all implications described including those under the DTI/Ofgem column are the views of the Working Group).

5.3 The options considered are:

Option 1 - Leave the existing CC.6.3.3 unchanged (slope K=1).

Option 2 - Change CC.6.3.3 to 25% power drop between 49.5Hz - 47Hz (slope K=5).

Option 3 - Leave the existing CC.6.3.3 unchanged above 49Hz, but change to 25% power drop between 49Hz - 47Hz.

Option 4 - Leave existing CC.6.3.3 unchanged above 49Hz (as option 1 and option 3), but remain silent for frequencies below 49Hz. Maintain obligation on Generators to provide data on power/frequency characteristics down to 47Hz.

Option 5 – Leave the existing CC.6.3.3 unchanged above 48.8Hz (K=1). Also, retain K=1 below 48.8Hz for 5 minutes, then allow a gradual reduction of output in line with natural characteristics with shaft speed.

Some implications pertaining to these options have already been described in Table 6, and further discussion is provided below.

5.4 Option 1

a) CCGT plant has an inherent power/frequency characteristics of K>1 depending on the gas turbine technology used. The latest technology has K=5. In order to increase the power output up to the K=1 level, the gas turbine will be required to operate at internal temperatures in excess of those known to be prudent in long term operation. Thus while this plant would be able to meet the requirements of K=1 during a grid emergency, it would be achieved at a likely cost in terms of requirements for inspection, early parts replacements, and degradation of performance. In addition, there is a small but finite probability of plant tripping whenever a plant is in unfamiliar operating conditions. The nearly complete absence of applicable operational experience makes it impossible to quantify this judgement regarding increased probability of tripping. Such operating conditions are not amenable to testing.

b) Generators on the Working Group who do own and operate CCGT plant support the view that the plant trip risk would be present, and that whilst this risk was expected to be small, it was not possible to quantify.

c) International CCGT manufacturers have also confirmed that there is a risk of tripping for operation at system frequencies below 49Hz, and this risk will increase significantly with prolonged operation at low frequencies, and increased ambient temperatures.

5.5 Option 2

a) Above 49Hz, existing Generators state that they may be able to operate with ‘increased efficiency’ by avoiding pre-emptive over-firing which is currently used at higher frequencies to ensure that the current characteristics can be met. On the other hand, this option would make it easier for new CCGT technology to comply. However, the relaxation of CC.6.3.3 would require more response to be carried at all times, and the cost of carrying such additional response may be greater than any possible savings which might accrue to Generators. It should be noted that any fuel savings due to new efficient CCGT technology have not been identified here. Overall, the discussions at the Working Group, including the views of new CCGT developers, concluded that relaxation of CC.6.3.3 requirements above 49Hz cannot be justified given the substantial additional frequency response costs and the fact that the existing requirement can be met by existing and new CCGT technologies without risk to plant operation.

b) Below 49Hz, the relaxation of CC.6.3.3 would result in at least one additional stage of load shedding, and a marginal increase in the risk of island collapse for an extreme islanding event (case of a very large generation deficit). This could be avoided by retaining K=1 requirement and assuming no risk of CCGT plant tripping in the island when having to operate below 49Hz. However, as discussed above, the CCGT plant manufacturers, owners, and operators agree that this risk is very real, and is increased when plant variables are taken outside proven operational limits in order to maintain compliance with K=1 requirement.

c) The DNOs and Suppliers wish to see minimum risk of customer demand disconnection due to CC.6.3.3 requirement. It should be emphasized that the effect of generation tripping (due to K=1) in an island could be much more severe than one additional stage of LFDD (due to K=5). Loss of generation could cause a number of LFDD stages to operate, and in the extreme, cause the whole island to collapse. The objective should therefore be to present a minimum risk to customer demand both in terms of disconnection magnitude and disconnection duration.

5.6 Option 3

Above 49Hz, this option represents the existing CC.6.3.3. There is no increased cost of system operation, and requirements can be met by all CCGT technologies. For frequencies below 49Hz, this option is similar to option 2 as far as pros and cons are concerned, and therefore comments for option 2 also apply to option 3..

5.7 Option 4

Above 49Hz, this option represents the existing CC.6.3.3 as option 1 and option 3. For frequencies below 49Hz, no requirements are specified. There would be an obligation on Generators to provide data on their plant power/frequency characteristics. However, this could lead to impractical requirement to re-design/reset the LFDD scheme, and slightly more difficult prediction of system performance under emergencies.

5.8 Option 5

a) This option is a slightly modified form of option 3. The only difference is that the existing CC.6.3.3 (K=1) is extended to 48.8Hz instead of 49Hz (note 48.8Hz is currently the relay trip setting of the first stage of the automatic low frequency demand disconnection scheme). The benefit of extending K=1 to 48.8Hz is to remove the initial risk of additional low frequency demand disconnection that could occur if the requirements were relaxed at 49Hz and an event leading to a small generation deficit takes place activating the first stage of LFDD at 48.8Hz. It is therefore beneficial that K=1 should be extended to 48.8Hz as it presents a lower risk to customer demand disconnection.

b) Below the relay trip setting of the first stage of the automatic low frequency demand disconnection scheme (currently 48.8Hz), the retention of K=1 for a short period removes the risk of additional demand disconnection without subjecting the generation plant to a new risk of tripping.

The time period after which CC.6.3.3 may be relaxed depends on whether the relaxation should take place immediately after the formation of an island or after some period of time. From the study results, it is evident that LFDD would be carried out very fast and system frequency would not remain below 48.8Hz for more than 10 seconds, and would stabilise to around 50Hz in about a minute or so. It is agreed that CCGTs have no compliance problem for a short period of time, but there is always a risk of CCGT tripping despite the fact that CCGTs are designed to comply by overfiring. After island formation, scenarios that might lead to frequencies stabilising below 48.8Hz are very unlikely but theoretically may be due to consequential loss of generation, increase in demand balanced by the demand/frequency sensitivity in the island. Also, some relays may fail to operate with the system stabilising at very low frequencies. In all these scenarios, operators would need at least some time to understand what has happened, what emergency measures should be taken, and the system to settle after the initial automatic period. From operators' point of view and consistent with the need to reduce the plant trip risk duration, the time period for relaxation from K=1 to the natural (inherent) power/frequency characteristic with shaft speed should be no longer than 5 minutes.

For frequencies below 48.8Hz (or 49.5Hz depending on the CCGT manufacturer) where special actions (overfiring, water injection, or other measures) may be required to meet existing CC.6.3.3 requirements, such actions shall be discontinued after a period of 5 minutes if there is a material increased risk of gas turbine tripping. The need for special action is linked to the inherent power reduction caused by reduced shaft speed due to falling system frequency.

c) The relaxation may require additional control/ time delay/mode switching functions to facilitate smooth transitions between modes of operation. The implementation of such facilities must not introduce new unacceptable risks.

6 CONCLUSIONS

6.1 The review of Grid Code Connection Condition clause 6.3.3, as far as its application to CCGT plant is concerned, has been carried out for frequencies below 49.5Hz between the extremes of the existing power/frequency slope requiring 95% of active power output at 47Hz, and a slope requiring 75% of active power output at 47Hz.

6.2 Option 5 appears to provide a minimum risk alternative overall. The existing CC.6.3.3 requirements above the relay trip setting of the automatic low frequency demand disconnection scheme (currently 48.8Hz) should be retained, resulting in no additional system response costs, no risks to system operation, and that existing and new CCGT plant can comply with this requirement. There is no benefit for relaxing the existing CC.6.3.3 requirement above 48.8Hz.

6.3 Relaxation of CC.6.3.3 requirement below the relay trip setting of the automatic low frequency demand disconnection scheme (currently 48.8Hz) would result in at least one additional stage of load shedding and a marginal increase in the risk of island collapse for an extreme islanding event. The DNOs and Suppliers do not wish to see increased risk of customer demand disconnection.

6.4 On the other hand, retaining the existing CC.6.3.3 requirement below 48.8Hz on a continuous basis presents a risk of plant tripping which may be greater than the risk under 6.3 above. The risk of plant tripping is real, but cannot be quantified as there is no operating experience available. It is also recognised that, in order to comply with existing requirements below 48.8Hz, the effect of generation tripping in an island could be much more severe than one additional stage of LFDD (when requirements relaxed). Loss of generation could cause a number of LFDD stages to operate, and in the extreme, cause the whole island to collapse.

6.5 In view of the above, it is therefore imperative to present a lower risk to customer demand disconnection whilst maintaining the security and stability of the power system. The existing CC.6.3.3 requirements below 48.8Hz should be retained for a period of 5 minutes. Thereafter, the requirement would be relaxed to allow the gas turbine in a CCGT plant to gradually reduce its power output in line with the natural (inherent) machine power/frequency characteristic with reduced shaft speed.

For frequencies below 48.8Hz (or 49.5Hz depending on the CCGT manufacturer) where special action(s) may be required to meet existing CC.6.3.3 requirements, such action(s) shall be discontinued after the period of 5 minutes if there is a material increased risk of gas turbine tripping. The need for special action is linked to the inherent power reduction caused by reduced shaft speed due to falling system frequency.

6.6 The relaxation of requirement may require additional control/ time delay/mode switching functions to facilitate smooth transitions between modes of operation. The implementation of such facilities must not introduce new unacceptable risks.

6.7 For all Generators, NGC, DNOs and plant manufacturers to obtain the benefits of the proposed relaxation, the proposal needs to be applied to all CCGT plant where there is a material increase in the risk of plant tripping during a prolonged period of operation below 48.8Hz.

6.8 Research on overseas electric utilities provided useful information on some utilities for comparison with CC.6.3.3 but sufficient details were not available to reach any firm conclusions.

7 RECOMMEMDATIONS

7.1 The Grid Code Review Panel is invited to note the following recommendations.

a) For frequencies down to the relay trip setting of the first stage of the automatic low frequency demand disconnection scheme (currently 48.8Hz), the existing CC.6.3.3 requirements should be retained.

b) For frequencies below 48.8Hz where special action(s) may be required to meet existing requirements, CC.6.3.3 should be retained for a period of 5 minutes. Thereafter, a relaxation shall take place so that the gas turbine power output is reduced to follow the machine natural (inherent) characteristic with reduced shaft speed due to falling system frequency, and special actions may be discontinued if there is a materially increased risk of the gas turbine tripping.

c) The relaxed CC.6.3.3 requirements should be applied to all CCGT plant where there is a material increase in the risk of plant tripping during a prolonged period of operation below 48.8Hz.

Figures

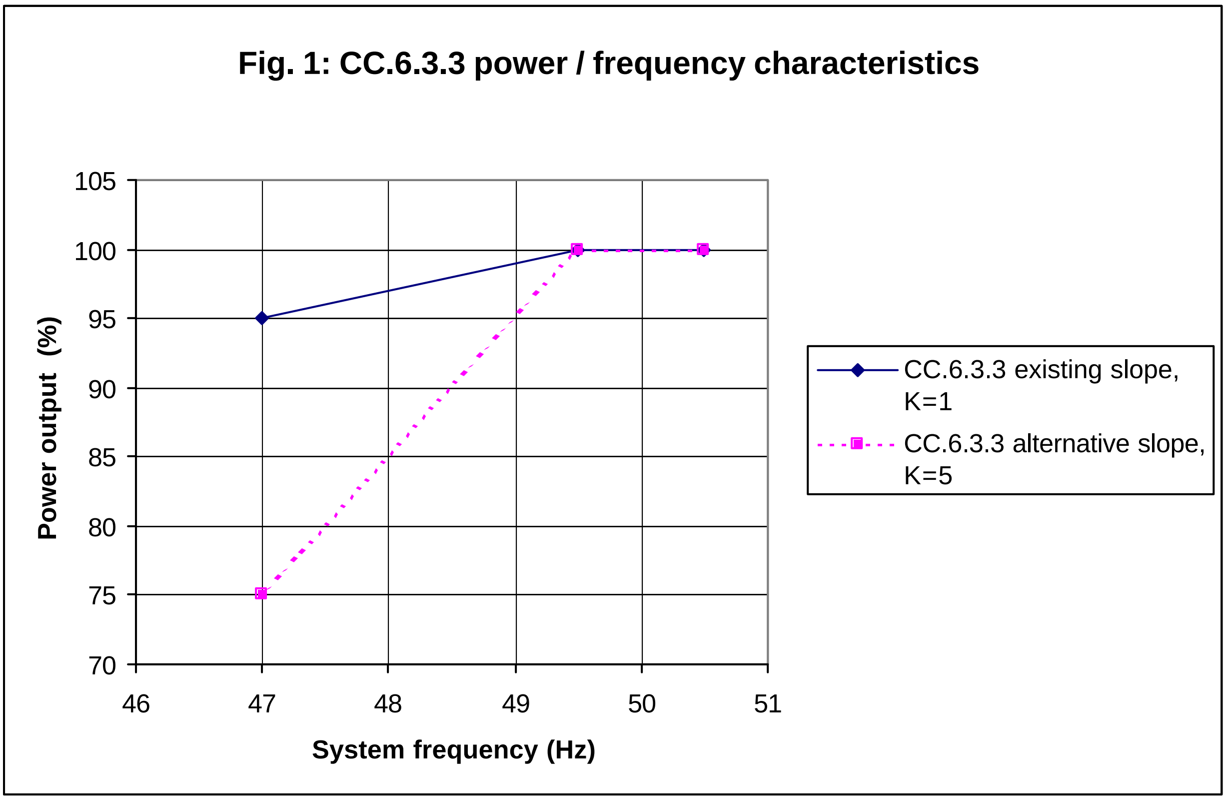
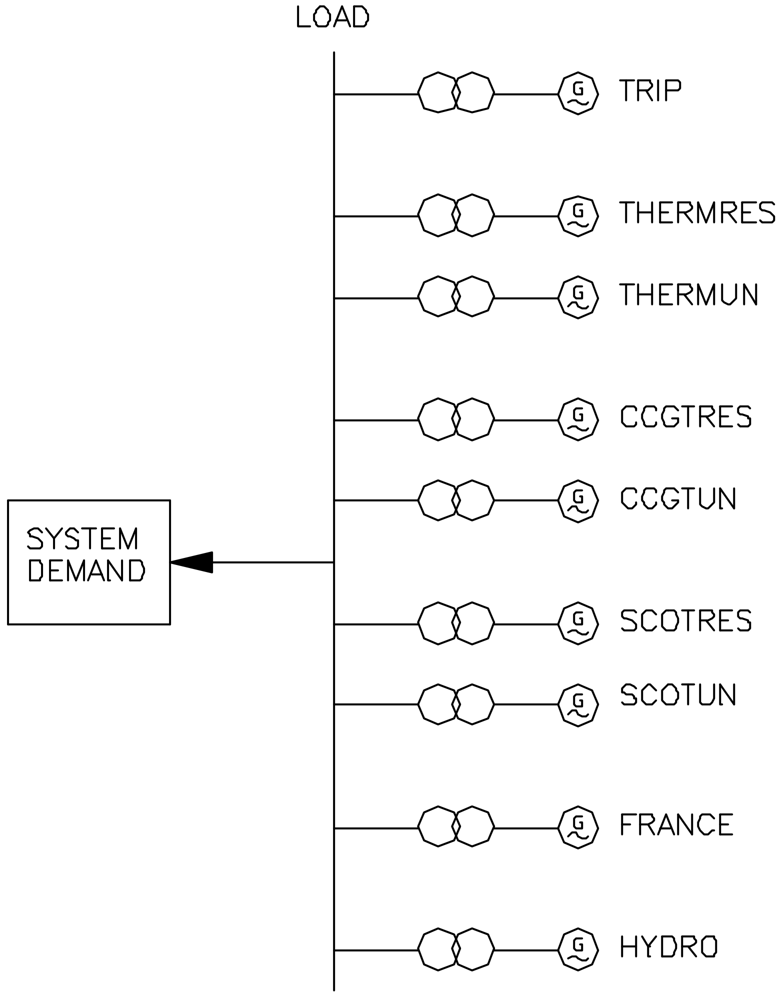


Fig. 1: CC.6.3.3 power / frequency characteristics
105
100
95
90
85
80
75
70
Power output (%)
46
47
48
49
50
51
System frequency (Hz)
CC.6.3.3 existing slope, K=1
CC.6.3.3 alternative slope, K=5

A4 | CAD | **National Grid**



KEY

LOAD – EHV BUSBAR
TRIP– SINGLE GENERATOR OF 1320MW OUTPUT (ENGLAND & WALES)
THERMRES – RESPONSIVE THERMAL GENERATION (ENGLAND & WALES)
THERMUN – UNRESPONSIVE THERMAL GENERATION (ENGLAND & WALES)
CCGTRES – RESPONSIVE CCGT GENERATION, SINGLE SHAFT (ENGLAND & WALES)
CCGTUN – UNRESPONSIVE CCGT GENERATION, SINGLE SHAFT (ENGLAND & WALES)
SCOTRES – RESPONSIVE THERMAL GENERATION (SCOTLAND)
SCOTUN – UNRESPONSIVE THERMAL GENERATION (SCOTLAND)
FRANCE – IMPORT FROM FRANCE
HYDRO – HYDROELECTRIC GENERATION
P_L = DEMAND ON BUSBAR 'LOAD'

ISSUE	A	
DRAWN	N.M.	04-11-02
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FIGURE 2
POWER SYSTEM MODEL
FREQUENCY RESPONSE ASSESSMENT

Station
Circuit
ISSUE A
Drg No. 41/44566 | Sht No 1 | No of Shts 1
SCALE:– | Work Ref

Fig. 3: 1320MW generation loss, frequency falls to 49Hz then recovers
Varying %age of non-compliant unresponsive CCGT generation
Additional primary response

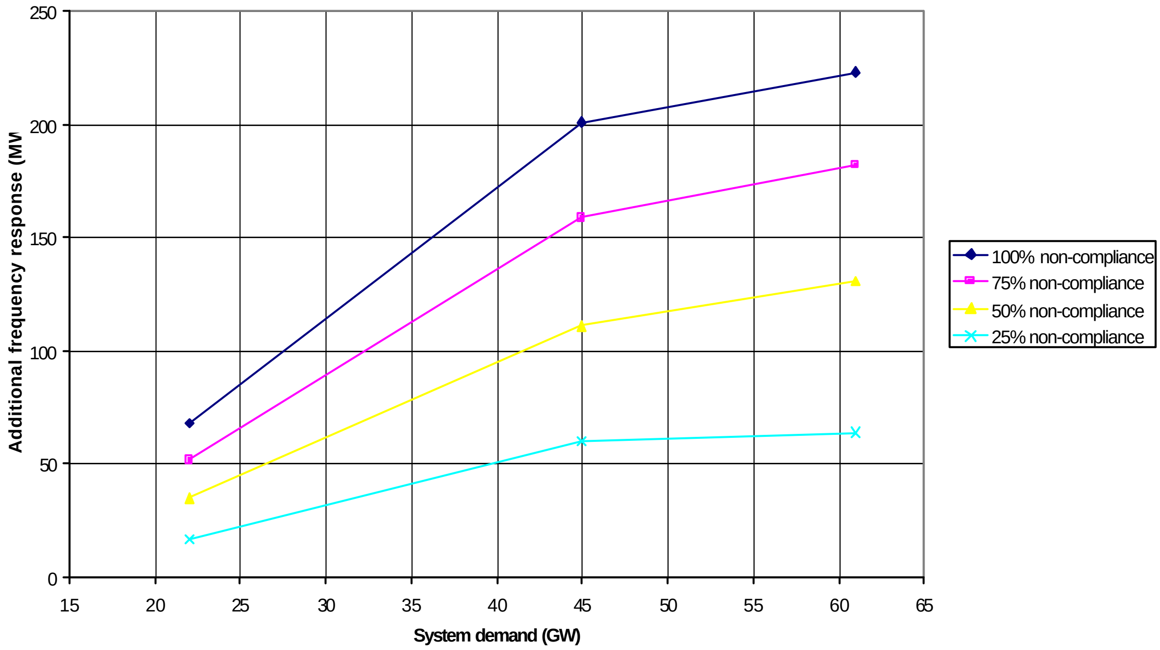
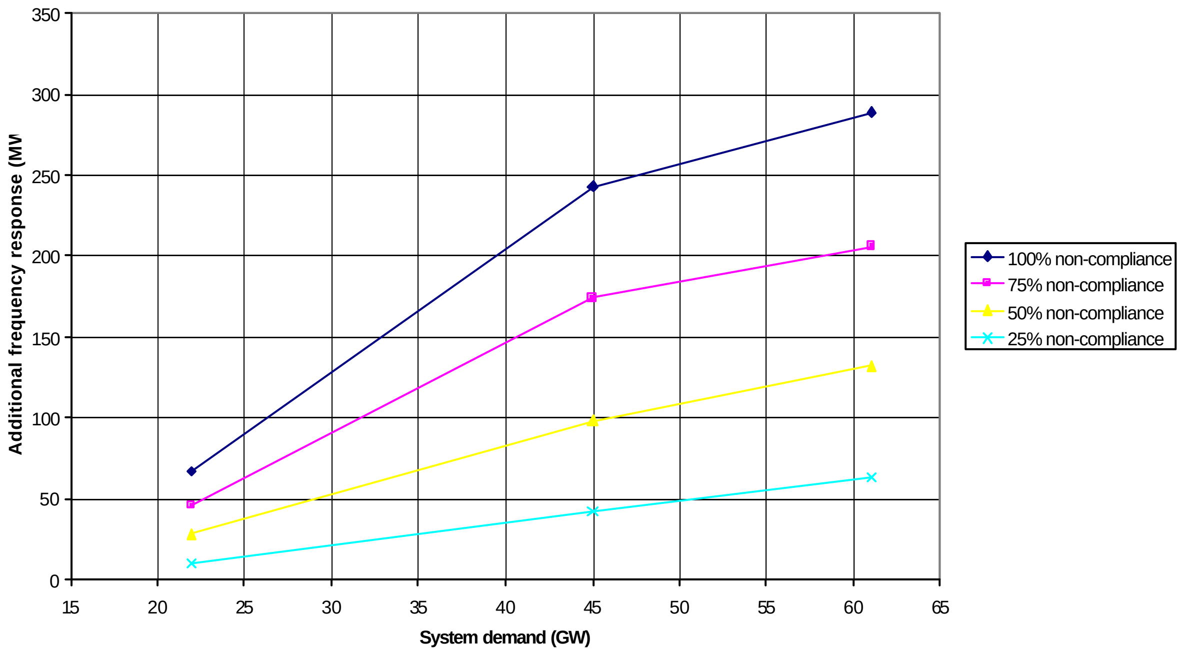


Fig. 4: 1320MW generation loss, frequency falls to 49Hz then recovers
Varying %age of non-compliant unresponsive CCGT generation
Additional secondary response



A4	CAD	National Grid

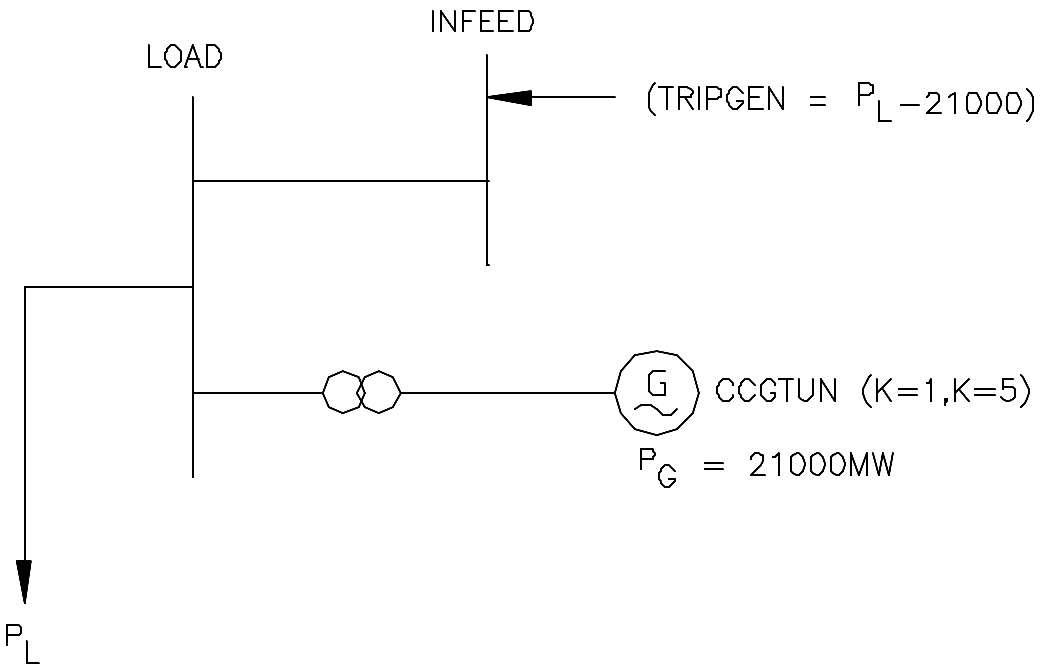


FIG.5 - POWER SYSTEM MODEL
DEMAND DISCONNECTION ASSESSMENT

ISSUE	A	
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Circuit					A
Drg No.	41/44565	Sht No	1	No of Shts	1
SCALE:-		Work Ref			

Fig.6 - LFDD:Demand disconnection versus generation deficit - Generic study
Operation of LFDD scheme with K=1 and K=5

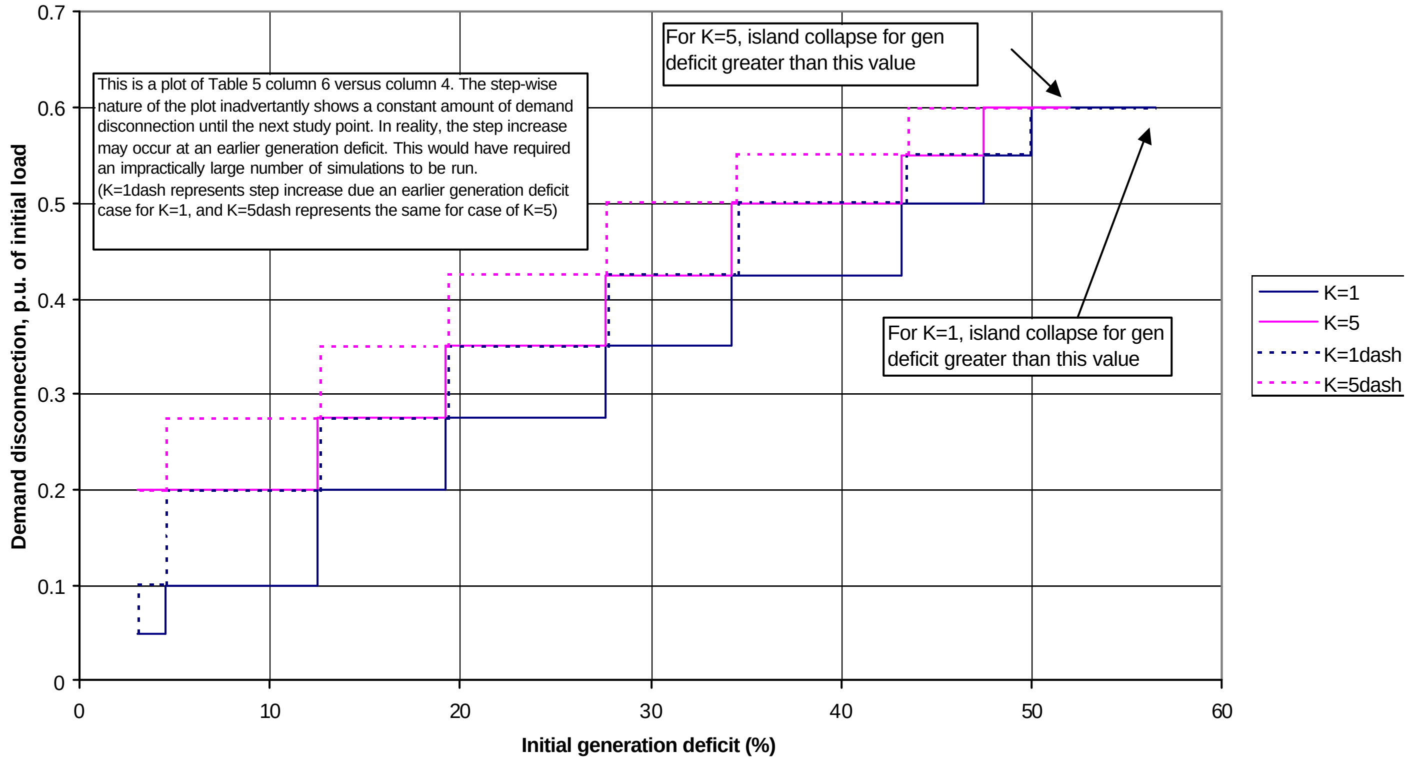
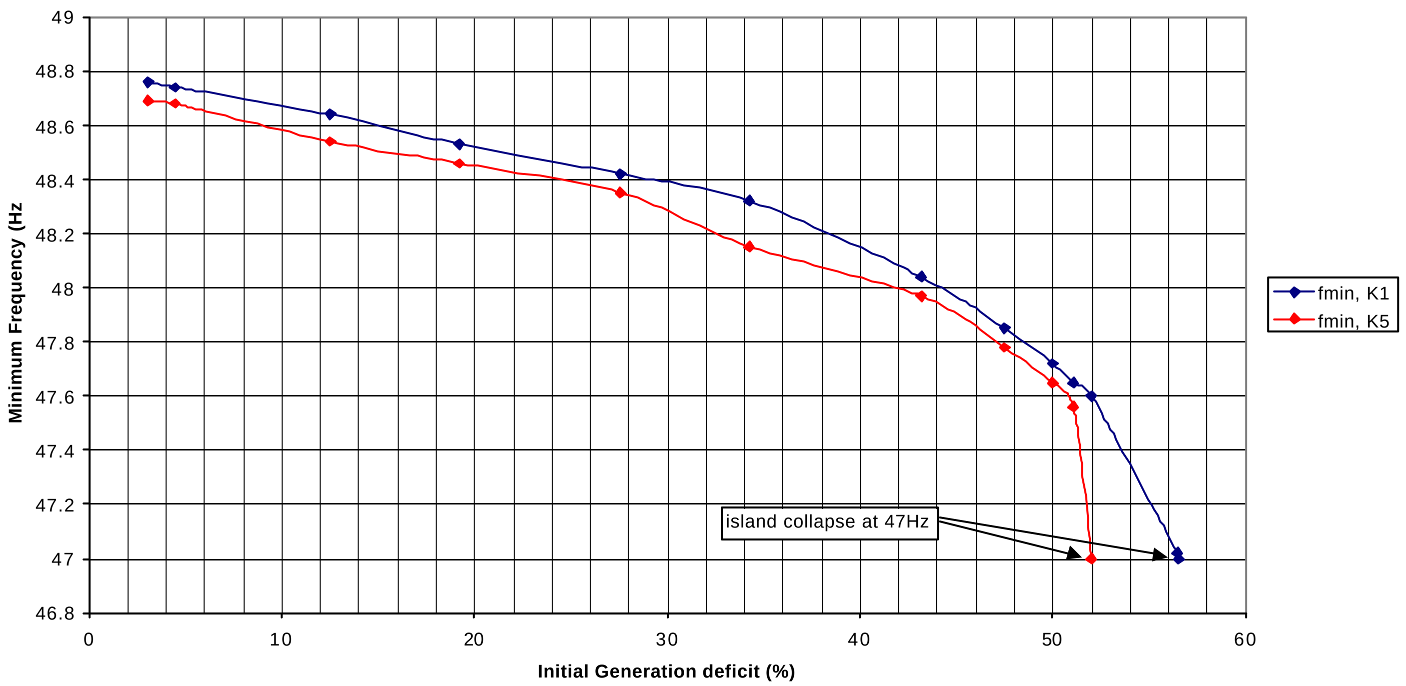


Fig.7 - LFDD: frequency versus generation deficit - Generic study
Operation of existing LFDD scheme with K=1 and K=5



Tables

Generating Plant Data

Table 1: Plant mix

UK System demand (MW)	England and Wales generation (MW)		Scottish generation (MW)	Import from France (MW)
	Nuclear,coal,oil	CCGT	Nuclear,coal	
61000 (E&W:55215)	27937	23072	8035 (exports 2250MW to E&W)	1956
45000 (E&W: 41274)	18425	20034	5652 (exports 1926MW to E&W)	889
22000 (E&W: 19480)	7117	10796	3465 (exports 945MW to E&W)	622

Table 2: Responsive and unresponsive plant in E&W

System demand (MW)	Total responsive Generation (MW) used in E&W	Unresponsive Thermal (MW) used in E&W	Unresponsive CCGTs (MW) used in E&W
UK: 61000 E&W:55215)	9500 (75% coal, 25% ccgt)	20812 (nuclear,coal,oil)	20697
UK: 45000 (E&W: 41274)	9245 (69% coal, 31% ccgt)	12045 (nuclear,coal)	17169
UK: 22000 (E&W: 19480)	7000 (ccgt)	7117 (nuclear,coal)	3796

Table 3: Non-compliance (%) verses MW of unresponsive CCGT generation

Non-compliant CCGT (%)	at 61GW		at 45GW		at 22GW	
	K=1	K=5	K=1	K=5	K=1	K=5
0%	20697	0	17169	0	3796	0
25%	15523	5174	12877	4292	2847	949
50%	10349	10348	8584	8585	1898	1898
75%	5174	15523	4292	12877	949	2847
100%	0	20697	0	17169	0	3796

Table 4

The LFDD Scheme

Stage	Load shed (%)	Operating time (sec)	Cum. Load shed (%)	Frequency threshold (Hz)
1	5	0.2	5	48.80
2	5	0.2	10	48.75
3	10	0.2	20	48.70
4	7.5	0.4	27.5	48.60
5	7.5	0.4	35	48.50
6	7.5	0.4	42.5	48.40
7	7.5	0.4	50	48.20
8	5	0.4	55	48.00
9	5	0.4	60	47.80

Table 5

Island with generation deficit - A Generic Study (relays with existing operating times)

Low Frequency Demand Disconnection (LFDD) - comparison between existing CC633 (slope K=1) and new CC633 (slope K=5)

1 Generation (MW)	2 Import (MW)	3 Demand (MW)	4 Import/Demand %age loss (Gen. Deficit %)	5 CC633 Slopes	6 Demand Shed (%)	7 (MW)	8 Demand Disconnection	9 Minimum Freq (Hz)	10 Overshed (%)	11 Additional (%)	12 Loadshed No of stages
21000	685	21685	3.1	K=1	5	1084	1 stage	48.76	1.9		
	685	21685	3.1	K=5	20	4337	3 stages	48.69	16.9	15.0	2
	1000	22000	4.5	K=1	10.0	2200	2 stages	48.74	5.5		
	1000	22000	4.5	K=5	20.0	4400	3 stages	48.68	15.5	10.0	1
	3000	24000	12.5	K=1	20.0	4800	3 stages	48.64	7.5		
	3000	24000	12.5	K=5	27.5	6600	4 stages	48.54	15.0	7.5	1
	5000	26000	19.2	K=1	27.5	7150	4 stages	48.53	8.3		
	5000	26000	19.2	K=5	35.0	9100	5 stages	48.46	15.8	7.5	1
	8000	29000	27.6	K=1	35.0	10150	5 stages	48.42	7.4		
	8000	29000	27.6	K=5	42.5	12325	6 stages	48.35	14.9	7.5	1
	11000	32000	34.3	K=1	42.5	13600	6 stages	48.32	8.2		
	11000	32000	34.3	K=5	50.0	16000	7 stages	48.15	15.7	7.5	1
	16000	37000	43.2	K=1	50.0	18500	7 stages	48.04	6.8		
	16000	37000	43.2	K=5	55.0	20350	8 stages	47.97	11.8	5.0	1
	19000	40000	47.5	K=1	55.0	22000	8 stages	47.85	7.5		
	19000	40000	47.5	K=5	60.0	24000	9 stages	47.78	12.5	5.0	1
	21000	42000	50.0	K=1	60.0	25200	9 stages	47.72	10.0		
	21000	42000	50.0	K=5	60.0	25200	9 stages	47.65	10.0	0	0
	22000	43000	51.1	K=1	60.0	25800	9 stages	47.65	8.9		
	22000	43000	51.1	K=5	60.0	25800	9 stages	47.56	8.9	0	0
	22800	43800	52.1	K=1	60.0	26280	9 stages	47.6	7.9		
	22770	43770	52.0	K=5	60.0	26262	9 stages	47.03	8.0	0	0
	22800	**43800**	**52.1**	**K=5**	**60.0**	**26280**	**9 stages**	**47.0**	**7.9**	0	0
	27300	48300	56.5	K=1	60.0	28980	9 stages	47.02	3.5		
	27350	**48350**	**56.6**	**K=1**	**60.0**	**29010**	**9 stages**	**47.0**	**3.4**		

Note: such import losses are not currently practically realisable, nonetheless similar results will be obtained for additional load shedding in percentage terms if the same generation deficit exists for these cases as noted above.

Columns:

(10) Difference between column (6) and (4)

(11) Derived from column (10) as difference between K=5 and K=1

(12) Derived from column (8) as difference between K=5 and K=1

Table 6

Options for CC.6.3.3

Option No.	Option	Implications for:				
		Generators		DNOs/Suppliers	National Grid	Country (DTI/Ofgem)
		New	Existing			
1	Leave unchanged. (5% power drop from 49.5Hz to 47Hz, i.e., K=1)	If using new generation technology, may be costly to make plant comply or to provide shortfall from elsewhere. Risk of plant tripping is real but unquantifiable.	Status quo. Risk of plant tripping is real but unquantifiable.	Status quo. Unaware that risk to demand security may be higher.	Status quo. Risk taken to system operation may not be minimum.	Status quo, but may discourage new technologies. Risk of plant tripping and system collapse. Risk not quantifiable.
2	Change to 25% power drop from 49.5Hz to 47Hz, i.e., K=5	Can comply	May have spent money to comply.	Risk of one extra stage of LFDD for an islanding event. Increased risk of collapse for extreme islanding event.	Increased cost of response holding.	Increased risk of collapse for extreme islanding event. Reduced risk of plant tripping and system collapse.
3	Leave unchanged above 49Hz, (K=1 above49Hz). Change to 25% power drop from 49Hz to 47Hz.	May be some cost to comply above 49Hz, either due to modifications to plant or to purchase shortfall from elsewhere. Can comply below 49 Hz	Status quo above 49Hz. Below 49Hz as Option 2.	As Option 2	None	As Option 2
4	Leave unchanged above 49Hz, (K=1 above49Hz). Silent below 49Hz. Obligation to provide data on power drop with frequency.	As Option 3 above 49Hz.	Status quo above 49Hz.	Status quo above 49Hz. Below 49Hz, impractical requirement to reset LFDD scheme. May or may not increase risk of extra stage of LFDD or system collapse.	Status quo bove 49Hz. Below 49Hz, loss of coordination, and impractical requirement to redesign LFDD scheme.	Status quo above 49Hz. Below 49Hz, slightly more difficult prediction of system performance under emergencies.
5	Leave unchanged above 48.8Hz. (K=1 above 48.8Hz). Also, retain K=1 below 48.8Hz for 5 minutes, then allow a gradual reduction of output in line with natural characteristic with shaft speed.	As Option 3 above 48.8Hz. Below 48.8Hz, limited duration at K=1 then relaxation is preferable.	As option 3 above 48.8Hz.	Risk of additional LFDD or system collapse removed.	Appear to give minimum system security risk.	Reduced risk of plant tripping and system collapse. Encourage new generation technologies. Minimum risk to security of supply.

Appendices

Appendix I

Working Group Membership

Member	Representing	
Nasser Tleis	National Grid	
Geoff Charter	National Grid	
Khadim Hussain	National Grid	
Patrick Hynes	National Grid	
John Norbury	Innogy	
Graham Trott	British Energy	
John France	Powergen	
Chris Motley	Seeboard	(DNO)
Brian Sequeira	Centrica	(Supplier)
Patrick Ohene-Djan	General Electric	
John Undrill	General Electric	

Appendix II

Review of Grid Code CC.6.3.3 requirements for frequencies below 49.5Hz

Terms of Reference

1. To consider possible alternatives to the current requirements of Grid Code Connection Condition CC.6.3.3 for frequencies below 49.5Hz. The review will consider alternative slope characteristics between the extremes of the existing slope (requiring 95% of Active Power output at 47Hz) and a slope requiring 75% of Active Power output at 47Hz.

2. Within the framework of NGC operational Licence security standards and frequency containment and control policy, the review will assess the impact of alternative slope requirements on:

    a. the amount of increased primary/secondary response requirement;

    b. the amount of increased customer demand disconnection, the security and stability of island system operation for various generation deficits; and

    c. the design settings of the existing revised automatic low frequency demand disconnection scheme. In particular, the review will consider whether changes to the scheme could counteract a reduced CC.6.3.3 requirement.

3. To consider, where possible, any CC.6.3.3 equivalent (or similar) information, requirement or practices employed by overseas utilities for comparison with the NGC Grid Code requirement.

4. To identify the minimum system requirements under Grid Code Connection Condition CC.6.3.3, taking into account the above issues and any other relevant technical, operational, or economic aspects.

5. To consider whether any changes to the identified minimum technical requirements may place constraints on commercial issues.

Appendix III

CC.6.3.3 and its overseas equivalent

This research is carried out to explore key features pertaining to power/frequency characteristics and type of generation plant of UK and overseas utilities. This is also to find out if other utilities have connection condition similar to CC6.3.3. The findings from this research are produced below:

Information on of power / frequency relationships is taken from Grid Codes.
Generation plant composition is taken from Union of the Electricity Industry 'eurelectric' report of November 2001, internet and SYS documents. Some data taken previously from World Energy Council report has been retained as no latest data was available.

UK:

NGC – full output between 49.5% - 50.5Hz, and 5% power output change between 49.5Hz – 47.0Hz (between 47Hz – 47.5Hz, plant to operate for a period of at least 20 seconds each time the frequency is below 47.5Hz).

Year	Plant type and MW composition (from SYS document)									Total (MW)
	Nuclear	Conv. steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Renew	Not specif.	
2001	10109 16.2%	28451 45.5%	1193 2%	22711 36.3%		*				62464
2005	9869	28451	1478	40129		*				79927

(excluding pumped storage, and scottish/Edf import. * CHP are very small amount and are included under CCGT)

Scottish Power / Scottish and Southern Electric - full output between 49.5Hz - 50.5Hz, and 5% power output change between 49.5Hz – 47.0Hz.

Year	Plant type and MW composition (from SYS document)									Total (MW)
	Nuclear	Conv. steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Renew	Not specif.	
2000	2735 27.2%	4146 41.2%		1155 11.5%			1886	130		10052

Northern Ireland – full output between 49.5Hz-50.5Hz, 5% power output change between 49.5Hz-47Hz.

Year	Plant type and % composition (from World Energy Council report)									Total
	Nuclear	Conv. steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Rene	Not specif.	
2000	5%	60%	25%				5%		5%	

Overseas:

Canada (Ontario Hydro) – full output between 59.4Hz – 60.6Hz (99%-101%), full output for a limited time between 59.4Hz – 58.8Hz (99%-98%). Generators to trip immediately below 57Hz (95%). No power change data between 58.8Hz and 57Hz.

Year	Plant type and MW composition (from internet)									Total (MW)
	Nuclear	Conv. Steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Renew	Not specif.	
2001	7648 31%	9700 39.3%	*				7309			24657

* about 2.8% gas plant was mentioned in World Energy Council report, but the latest data from internet did not show that.

Finland – full output between 49Hz-51Hz, 30 minutes operation at full output between 49Hz-47.5Hz followed by 15% power output change between 49Hz-47.5Hz.

Year	Plant type and MW composition									Total (MW)
	Nuclear	Conv. Steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Renew	Not specif.	
2000	2640 16.2%	3350 20.6%	1362 8.3%		83	5907	2882	38	0	16262
2005	2640	3350	1362		83	6411	2950	150	0	16946

Germany (RWE)

- constant power output down to 48.5Hz then no more than 5% drop at 47.5Hz for thermal plants.

- constant power output down to 49Hz then no more than 5% drop at 47.5Hz for nuclear plants

Germany (DVG)

- constant power output down to 49Hz then no more than 10% drop at 47.5Hz

(Note: Euroelectric produced this statistics for Germany, and is not clear how does it apply to RWE or DVG utilities)

Year	Plant type and MW composition									Total (MW)
	Nuclear	Conv. Steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Rene	Not specif.	
2000	22391 18.7%	56014 46.9%	4157 3.5%			21200	8855	6850		119467

The eurelectric report shows data on CHP and conv. thermal plants moved to under 'not specified' plant. But according to an earlier World Energy Council report, data on CHP and thermal was retained under their relevant columns. The above table adopts the World Energy Council position.

Philippines - full output between 49.5Hz-50Hz, 5% power output change between 49.5Hz-47Hz.

Year	Plant type and % composition (from internet)									Total
	Nuclear	Conv. steam therm	Gas turbine	CCGT	Int. Comb.	CHP	Hydro	Rene	Not specif.	
2000		58.6%					19.5%		21.9%	100%

New Zealand (TransPower)
Normally frequency maintained between 49.8Hz – 50.2Hz.
For a contingent event (e.g. sudden loss of the largest infeed), frequency may drop to 48Hz, but operator to return frequency to within normal limits.
For frequency drop below 48Hz to 47.5Hz, generator sets must be able to provide at least 80% of rated output indefinitely. This level of output is to be available for 30 seconds while the frequency is below 47.5Hz.

(plant composition not available for TransPower)

Comments:

Power/frequency characteristics of Scotland, Northern Ireland, and Philippines are found to resemble with CC.6.3.3.

Finland shows K=5 between 49Hz – 47.5Hz. Finland installed generation is about ¼ of that of NGC, and no CCGTs in Finland.

Germany shows K=3.3 between 49Hz – 47.5Hz. Germany installed generation is about double the size of that of NGC, percentage amounts of conventional thermal plant and nuclear are slightly higher in Germany, and no CCGTs in Germany.

NewZealand shows 20% power drop between 48Hz – 47.5Hz, but how power changes between these frequencies is not known.

Canada shows full power output (for limited time) between 59.4Hz – 58.7Hz (corresponds to UK 49.5Hz – 49Hz). No power change information available below 58.8Hz (corresponds to UK 49Hz). Generators trip below 57Hz (corresponds to UK 47.5Hz). No CCGTs.

France power/frequency characteristics are unknown. No CCGTs.

Finland and Germany allow full power output down to 49Hz. Canada allows full power output down to 49.5Hz.

Information obtained on Lativa, Orissa, Netherlands, New England, Brazil, India, Italy, Australia and France was lacking of the required information.