A REPORT TO THE AUTHORITY

Pursuant to Paragraph 2 of Condition C14 of the Transmission Licence

Grid Code Short Circuit Ratio requirements in respect of very Large Synchronous Generating Units

The purpose of this document is to assist the Authority in its decision of whether to implement the proposed Grid Code Modification

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DISTRIBUTION

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Authority	Ofgem
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SUMMARY OF PROPOSALS

0.1 The proposed changes to the Grid Code, were developed by National Grid after the issue was raised at the Grid Code Review Panel (GCRP) in May 2008. At this meeting, a number of Generators expressed concern at their ability to utilise new and evolving technology, some of which is dependant upon the use of single Generating Unit sizes of up to 2000MVA. The concern arises from the need to meet the Short Circuit Ratio (SCR) requirement of 0.5 or above.

0.2 National Grid has 10 signed Connection Agreements, in which Generators have committed to using this technology with the earliest completion dates scheduled for 2017. To this end, a number of Generators have already committed substantial investment to these projects. This is on the basis of the long design, procurement and construction phases of these nuclear generation projects to which the timescales are already very tight. The purpose of this review has therefore been to investigate the impact on the Transmission System of reducing Short Circuit Ratio solely in respect of very Large Generators so as to minimise delays to these projects and prevent restrictions on competition amongst Generators and equipment suppliers.

0.3 In conducting this initial review, National Grid is conscious of the potential impact that a wholesale reduction of SCR could have on the operation of the Transmission System, in terms of Security of Supply, potential discrimination between Users and promotion of competition amongst Generators and Suppliers. However it should be stressed that the scope of this review has been limited to the threshold at which SCR should be relaxed for very Large Synchronous Generators, to allow the impact on the Transmission System and the on developer's projects to be assessed whilst preventing unnecessary delays to those projects under development.

0.4 The intention of the proposals is to lower the Short Circuit Ratio (SCR) obligations in respect of very Large Synchronous Generating Units greater than 1600MVA. This is intended to better facilitate new generation technologies and increase the range of suppliers available to Generators. The proposals were discussed at the GCRP meeting on 17th September 2009 and the Panel agreed that they should be taken to industry consultation.

0.5 National Grid has consulted Authorised Electricity Operators on this issue. All respondents were broadly supportive of the proposals, although one respondent suggested that the proposals should be extended to generation of all sizes. Some text changes intended as clarifications were suggested and have been taken into account in the final proposals.

0.6 The final proposal is to lower the minimum SCR obligation in the Grid Code from 0.5 to 0.4 for Generating Units greater than 1600MVA.

0.7 National Grid recommends the adoption of the proposals but would also suggest that a full and thorough review of SCR, (whilst noting the proposals of this paper), is placed on the Grid Code Review Panel issues list for further consideration by an industry Working Group. National Grid would welcome the opportunity to engage in such a group but recognises that such a review may take up to a minimum of a year and needs to be assessed alongside the other priorities of the Grid Code Review Panel.

0.8 National Grid also also recommend that any future review of SCR is considered in the context of the outcome of EU activity which is currently focussed on drafting harmonised European requirements for Generators

(scoped by ERGEG/ACER and drafted by ENTSO-E). Notwithstanding this, National Grid notes that such a review needs to be undertaken in a timely manner. This is to ensure that any such Grid Code change which may result from a future review, is implemented at an early stage, takes into account the views of all User's so there is no element of undue discrimination and minimises uncertainty to future projects which aim to utilise Generating Units of below 1600MVA in the future.

0.9 Based on its analysis of the impact on the system performance, NGET does not consider that current or future Generators who install plant of below 1600MVA will be adversely affected in terms of costs or system security from the lowering of the minimum SCR of very Large Synchronous Generators of above 1600MVA".

0.10 National Grid recommends to the Authority that these proposals be approved.

A. INTRODUCTION

1. Paragraph 2 of Condition C14 of the Transmission Licence granted to National Grid Electricity Transmission plc ("National Grid") provides that National Grid shall, in consultation with Authorised Electricity Operators liable to be materially affected thereby, periodically review the Grid Code and its implementation. That paragraph also requires National Grid, following such review, to send to the Authority:-

   (a) a report on the outcome of such review;

   (b) any proposed revisions to the Grid Code as National Grid (having regard to the outcome of such review) reasonably thinks fit for the achievement of the objectives set out in sub-paragraph (b) of Condition C14 of the Transmission Licence; and

   (c) any written representations or objections from authorised electricity operators (including any proposals by such operators for revisions to the Grid Code not accepted by National Grid in the course of the review) arising during the consultation process and subsequently sustained.

2. This review examines proposed amendments to the existing Grid Code provisions relating to the Short Circuit Ratio Requirement in respect to very Large Synchronous Generating Units. The proposals were developed through industry consultation.

3. The proposed changes to the Grid Code were discussed with the Grid Code Review Panel (GCRP) on 17th September 2009. Panel Members agreed that National Grid should issue a Consultation Paper regarding the proposed changes.

4. National Grid, in accordance with its obligations under its Transmission Licence, consulted Authorised Electricity Operators by including Consultation Paper G/09 on the National Grid Industry Information website. This paper contained an explanation of the proposed amendments to the Grid Code and a copy is attached to this Report as Appendix B. National Grid informed interested parties that a copy of the Consultation Paper had been placed on its website to ensure its wide availability.

5. Comments were invited from all such Authorised Electricity Operators by 10th December 2009. National Grid received three responses from Authorised Electricity Operators.

6. The proposed revisions to the Grid Code are explained below.

B. DESCRIPTION OF THE PROPOSED AMENDMENTS, THE NEED FOR CHANGE, THEIR EFFECTS ON THE TRANSMISSION SYSTEM AND TRANSMISSION SYSTEM USERS

7. Background

7.1 At the May 2008 Grid Code Review Panel, the issue of new generation technologies including nuclear and supercritical coal was discussed. With regard to new nuclear, single synchronous generating unit sizes with a Rated MW output of up to 1800MW have been proposed and for supercritical coal,

values of up to 1000MW have been suggested.

7.2 The Grid Code places minimum requirements on the capabilities of synchronous generating units. One such parameter is the SCR which under section CC.6.3.2 of the Grid Code is required to be not less than 0.5.

7.3 The largest synchronous generator currently connected to the National Electricity Transmission System is in the order of 660 MW (776MVA). With the introduction of new generation technologies where individual machine size increases to a rated Apparent Power of 2000MVA, supplying a synchronous generator with an SCR of 0.5 or above becomes more challenging.

7.4 The conclusions presented in a 2001 IEEE paper[1] state "Increasing a generator SCR from 0.4 to 0.5 results in an increase in the total volume of about 5 to 10% depending on the type of the generator". The consequence of which being that designing a Synchronous Generator with a higher SCR, will result in a larger machine size.

7.5 Based on the data available, to date, the maximum achieved SCR of a 2000MVA synchronous Generator is in the region of 0.41 - 0.46. The current Grid Code drafting would prohibit the use of these machines in Great Britain.

7.6 Designing and building a generator of this size with a SCR of 0.5 or above would result in a larger generator than currently considered achievable. Information received from manufacturers indicates the increase in size necessary would not be possible due to restrictions on manufacturing capability (machining / casting) and equally, transport of component parts taking National infrastructure (e.g. road bridge loading etc) into account. Putting it another way, Generators with units above 1600MVA have no choice, a machine with an SCR of 0.5 or above is not physically available.

7.7 To date, National Grid has 10 signed offers for the next generation of new nuclear power stations, all off which are potentially considering using the above generation technology. The first of these has a contracted completion date of 2017 for which detailed design work by these developers has already concluded, and the specification issued to manufacturers for tendering purposes (reactor / turbine and generator).

8. Scope

8.1 In view of the time frame associated with these large projects, Consultation G/09 only considered the Grid Code SCR requirement in respect of very large Synchronous Generating Units and the threshold at which a relaxation (if any) should be applied. This is on the basis that is not currently possible to procure and be supplied with a synchronous generator of 2000MVA with a SCR of 0.5 or above. This report therefore assesses what measures need to be put in place to manage the impact on the Transmission System and its Users arising from these very large Synchronous Generating Units.

8.2 National Grid is conscious that the scope of this review was restricted to a certain size of generator equipment. SCR was last considered as part of the

[1] Specifying a Turbogenerator's Electrical Parameters guided by Standards and Grid Codes – C-E Stephan and Z Baba 2001 – Ref 0-7803-7091-0/01/$10©2001 IEEE.

Reactive Power Working Group[2] report in 2001. Any future review would need to undertake a complete reassessment of the current and future Generation and Transmission System background. It is estimated that such a piece of work would take a minimum of a year causing significant delays for a number of projects.

8.3 It is recommended that the wider SCR requirement (whilst noting the recommendations of this report) is placed on the Grid Code Review Panel issues list with a view to holding a full industry working group and wider consultation. It is also recommended that any such review is considered in the context of the outcome of EU activity which is currently focussed on drafting harmonised European requirements for Generators (scoped by ERGEG/ACER and drafted by ENTSO-E).

9. Introduction - Short Circuit Ratio

9.1 The SCR of a synchronous generator is defined in IEC34-4 as "The ratio of the field current for rated armature voltage on open–circuit to the field current for rated armature current on sustained symmetrical short circuit, both with the machine running at rated speed". The SCR is a key design parameter of a synchronous machine. Its minimum value is specified in IEC 60034-3:2005 which states the "the value of the short-circuit ratio at rated conditions shall be not less than 0.35. Higher minimum values may be specified and agreed upon (for example by grid demand), but, for a given cooling system, these usually require an increase in machine size and higher losses". Thus the existing requirement for SCR is based on i) the minimum requirements of IEC standards and ii) historical, design, and operational experience gained through the Nationalised Electricity industry prior to 1990 which led to its inclusion in the Grid Code at vesting.

9.2 A generator with a higher SCR requires a larger field winding which as indicated in paragraph 6.4 above requires an increase in the size of the machine. At 2000MVA, a synchronous machine is constrained by its physical size and based on current manufacturing techniques and transport issues can only be designed with an SCR below 0.5. It is for this reason that very large generators may struggle to achieve an SCR of 0.5 or greater.

9.3 The implications of reducing the SCR of a synchronous generator are further clarified (see footnote 1) but in summary, the SCR has a direct impact on the machine's stability performance. This is likely to result in more onerous excitation system requirements, for example higher ceiling voltages and /or faster rise times. In addition, it also affects the machine's reactive capability in the underexcited mode of operation (i.e. leading capability). It should also be noted that CC.6.3.15 of the Grid Code places obligations on Generating Units to remain transiently stable for a range of Transmission System faults which may require additional measures or enhanced excitation systems to be employed.

10. Manufacturer Capabilities

10.1 Having discussed the impact of short circuit ratio on machine design, it is important to establish if the manufacturers of generating plant with Apparent Power ratings of up to 2000MVA can design, build and supply a machine with a SCR of 0.5 or greater.

[2] Grid Code Reactive Power Sub-Group – Report to the Grid Code Review Panel. Available at:- http://www.nationalgrid.com/NR/rdonlyres/D9A1B2C1-20BB-4D1C-8F29-39DFA51081C6/3165/reactwgrep.pdf

10.2 With this in mind, National Grid contacted five major turbo Generator manufactures to establish:-

i) Their ability to manufacture a machine with a rated Apparent Power of 2000 MVA
ii) The limit in terms of size, at which a 0.5 SCR can no longer be achieved
iii) The type of excitation system available.
iv) Limitations on reactive capability

10.3 Of the five manufactures contacted, some provided a full response, some provided limited information, some provided no information, and in some cases, the data was obtained via alternative sources[3].

10.4 Due to confidentiality issues, National Grid is unable to publish the responses received; however general trends can be presented which are considered to be sufficient to draw some conclusions from this work.

10.5 For those manufacturers who currently supply machines with a rated Apparent Power of 2000MVA, the SCR ranges between 0.41 – 0.46. The limitation on SCR is determined largely by manufacturing capability (casting / machining) but also the ability to transport component parts taking National Infrastructure (eg road bridge loading etc) into account. Based on the Generator Saturated Reactance values (footnote 3, figure 16), the SCR at best of the 2000MW Turbogenerator described is 0.43.

10.6 Of those manufacturers questioned, a number do not supply machines with a rated Apparent Power of 2000MVA, but the majority of them advised that the maximum limit at which an SCR of 0.5 could be achieved would be in the order of 1600 MVA.

10.7 With regard to reactive capability, it would appear a reactive range of 0.95 lead to 0.85 lag at the Generator Unit terminals on a rated Apparent Power of 2000MVA is achievable, although the cooling water temperature would need to be limited.

10.8 With regard to excitation, some manufacturers promote rotating systems whilst others use static. Each type is limited on excitation ceiling voltage to about 2 p.u. It would appear from the research carried out that both systems can be employed although it is envisaged that a manufacturer supplying a static system would be reluctant/unable to use a rotating system and vice versa due to changes of an authorised design. Both systems can incorporate a power system stabiliser.

11. <u>The impact of Reducing Short Circuit Ratio for very Large Synchronous Generators on the Transmission System and Users of the Transmission System</u>

11.1 SCR is effectively the inverse of its saturated reactance. It is a key parameter used by all Generator manufacturers in the design of synchronous machines with a minimum value specified under IEC 60034-3:2005 as described in section 9.1 above. Whilst affecting the machine's stability performance it also

[3] Type Testing a 2000MW Turbogenerator K Sedlazeck, C Richter, S. Strack, Siemens Energy, Mulheim, Germany, S Lindholm, J Pipkin, F Fu, B Humphries, L. Montgomery, Siemens Energy Orlando, FL, USA – IEEE paper reference 978-1-4244-4252-2/09/$25.00 © 2009 IEEE.

affects the fundamental design of the machine in terms of size and other performance characteristics such as reactive capability in the leading mode of operation. Notwithstanding this, SCR is only one of a number of parameters which can influence system stability, others include the inertia constant, generating transformer reactance, excitation performance and network strength at the point of connection. Whilst SCR will affect these parameters, it should not be seen as a replacement for other Grid Code requirements such as reactive capability (CC.6.3.2), excitation performance requirements (CC.6.3.8) and Fault Ride Through (CC.6.3.15). They are all fundamental performance requirements which cannot be replaced or amalgamated. In general terms, the Grid Code is based on a set of functional performance requirements, in terms of capability rather than minimum Generating Unit parameters. This also has the advantage of catering for the full range of Synchronous Generating Units irrespective of type or size. This approach allows National Grid to define the requirements of Generating Units based on the minimum needs of the Transmission System and to monitor plant through the compliance process. SCR is therefore unusual in this respect but its value is fundamental to the design of the machine.

11.2 Following the connection applications of a number of Generators interested in utilising very large synchronous generator technology, National Grid has held detailed discussions with both the Generators and manufacturers, to understand any Grid Code Compliance issues. With regard to Reactive Capability as defined in CC.6.3.2(a) confirmation has been received that the full reactive capability range of 0.95 Power Factor lead to 0.85 Power Factor lag at rated MW output at the Generating Unit terminals can be achieved provided the cooling water temperature is limited.

11.3 As indicated above, reducing SCR in isolation will consequently reduce system stability. However system stability can be improved by a number of factors including, but not limited to, enhanced fast acting excitation systems, fast valving, faster protection operating times, higher machine inertia, variations in generator construction (eg a divided winding) or breaking resistors.

11.4 In terms of impact on the Transmission System, each generator connection is assessed on an individual basis at the connection application stage. This involves detailed modelling based on data submitted by the Generator including the SCR. This process has been applied to all 10 developers seeking to utilise very Large Synchronous Generator technology and who have signed Bilateral Connection Agreements with National Grid. The results of stability studies are used to set Excitation Performance requirements as outlined in Grid Code CC.6.3.8 and Grid Code Connection Conditions Appendix 6. These include requirements for excitation ceiling voltage, rise time, a power system stabiliser including tuning studies, under and over excitation limiters and submission of models for analysis purposes. Further detailed stability studies are conducted following offer signature well in advance of the construction phase, to ensure the integrity of the Transmission System and prevent interference to other Users.

11.5 Once commissioning has commenced, tests are witnessed at site to ensure the models and data received from the developer are a true and accurate reflection of the plant as built. These are subsequently used by National Grid for modelling the Transmission System in both the operational and design phase. By specifying these requirements at the application stage and by operating a detailed compliance process, the connection of these generators can be managed without causing a negative impact on the design and

operation of the Transmission System or indeed to other Users of the Transmission System.

11.6 So far as the developers seeking to use this technology are concerned, there may be a need for them to install an enhanced excitation system, with for example a higher excitation ceiling voltage or faster rise time, for which there would be an increased cost. However, by undertaking detailed studies at the design stage and managing these projects through the compliance process, together with the ongoing liaison with manufacturers, the effect of reducing SCR, even for the 10 Generator applications received can be managed. National Grid also consider this process to be robust going forward should further applications be received.

11.7 National Grid does not expect there to be any direct impact on existing Users of the Transmission System. For new User's who choose to employ a synchronous generator rated at less than 1600MVA, they would need to utilise a generator with an SCR of 0.5 or above as is currently stipulated. Notwithstanding this, National Grid would recommend that a full and thorough review of SCR (whilst noting the proposals of this paper) is placed on the Grid Code Review Panel issues list for further consideration by an Industry Working Group. Whilst the priorities of the Grid Code Review Panel will need to be assessed, it is considered that such a review will enable any concerns raised by User's with smaller Generating Units to be addressed in a timely fashion.

12 Qualitative Assessment of Costs, Benefits and Impacts

12.1 If the Grid Code SCR requirement is not relaxed from 0.5 to 0.4 for plant in excess of 1600MVA, the consequences are that either:

i) the Generating Unit would have to be de-rated resulting in significant loss of revenue;
ii) the developer would have to install two smaller units at considerably higher capital cost or
iii) the developer would choose not to build in Great Britain

12.2 National Grid recommends reducing the required SCR for Generators in excess of 1600MVA to facilitate competition in the provision of generation facilities. There may be a requirement for mitigation measures such as the specification of an enhanced excitation system as stated in paragraphs 10.5 and 10.6, but these costs would be small in comparison to either de-rating the plant or the installation of duplicate smaller units.

12.3 It should also be noted that significant work has been completed by a number of generators seeking to develop this technology, the first of which is scheduled to connect in 2017. To reject this proposal, or delay it until the outcome of a further review, will present risks for those projects.

12.4 For Generators which are rated at less than 1600MVA, it is possible to procure a generator with a SCR of 0.5 or above. It is acknowledged that the Grid Code will remain unchanged for such units until a wider review has been conducted. Any such review will need to consider whether the cost of purchasing a machine with a higher SCR is cheaper than procuring one with a lower SCR but fitted with an enhanced excitation system, especially as the natural SCR tends to increase as machine size reduces.

13 Conclusions

13.1 The work undertaken has enabled an assessment of the size limits to which manufacturers are capable of supplying a machine which would be compliant with the SCR requirements of the Grid Code.

13.2 Based on the work completed to date, and discussions held, it is concluded that manufacturers can produce and supply a machine of up to a rated Apparent Power of 1600MVA with a short circuit ratio of 0.5 or above. It is clear from the evidence available that manufacturing and supplying a machine with an SCR in excess of this value would become increasingly difficult.

13.3 To manage the reduced stability margin as a result of the lower SCR, excitation systems may need to be specified with a higher performance than would have been required on a higher SCR machine. National Grid undertakes stability studies at the connection application stage and during the compliance process which would identify and verify any such requirement. National Grid considers this process to be robust in managing the impact of the proposed change going forward.

13.4 National Grid would welcome a wider review of SCR for all Generating Units below 1600MVA and recommend this should be placed on the Grid Code Review Panel issues list for consideration. It is also recommended that any such review is considered in the context of the outcome of EU activity which is currently focussing on drafting harmonised European requirements for Generators (scoped by ERGEG/ACER and drafted by ENTSO-E).

13.5 National Grid supports this proposal as it removes a restriction on entry to generation equipment supply in Great Britain without detriment to the operation of the Transmission System and its Users.

14 The proposed Grid Code changes are to:

14.1 Amend the requirements for synchronous generators with an Apparent Power rating of more than 1600 MVA to be designed with a short circuit ration of not less than 0.4.

15 Impact on the National Electricity Transmission System

15.1 In National Grid's opinion, the impact of the proposed changes can be managed through the existing connection application and compliance process. In view of these safeguards, it is not considered that these proposals will have an adverse affect on the National Electricity Transmission System.

16 Impact on Grid Code Users

16.1 The proposed changes will remove the restriction on the use or output of very Large Synchronous Generators above 1600MVA. The Users concerned may face additional costs due to the requirement to install an enhanced excitation system but this cost would be low compared to either de-rating or using smaller Generating Units. These proposals will therefore result in greater efficiency and competition amongst generation equipment suppliers.

16.2 Developers using Generating Units below 1600MVA will still be required to meet an SCR of 0.5 rather than the SCR of 0.4 proposed for very large Synchronous Generators. This difference in treatment is necessary at this

time, as a machine rated at 1600MVA or above with a SCR of 0.5 or above is not physically available. National Grid estimate that the wider review required to assess a uniform requirement would take a minimum of a year, with a considerable impact in costs, uncertainty and delays to those Users who are in the development phase of those projects.

17 Assessment against Grid Code Objectives

17.1 The proposed changes outlined in G/09 Report to the Authority will better facilitate and maintain the following Grid Code Objectives:

i) to permit the development maintenance and operation of an efficient, coordinated and economical system for the Transmission of electricity.
ii) to facilitate competition in the generation and supply of electricity;
iii) to promote the security and efficiency of the electricity generation, transmission and distribution system in Great Britain

17.2 Taking these in turn: The proposed change would not have an adverse affect on objective i), to permit the development, maintenance and operation of an efficient, co-ordinated and economical system for the transmission of electricity as the lowering of the Short Circuit Ratio limit for very large machines will not adversely affect system stability through specific management in the connection and compliance process.

17.3 Objective ii) is better met as Users will have a greater choice in the generating equipment available to them, thereby potentially increasing competition in generation and the choices available to Suppliers.

17.4 Through a greater choice amongst generator manufacturer's, the consequential increased variation in Generating Units available to the GB market, and the economies of scale achieved through such Generator technology will thereby promote greater security and efficiency, in the generation, transmission and distribution of electricity in Great Britain better meeting objective iii).

17.5 Based on the discussions with developers and manufacturers, if the proposals are rejected, it would mean that developers would have the choice of de-rating their plant resulting in reduced income for a fixed capital investment, considering the installation of two smaller Generating units at higher capital cost, or to cease development altogether. National Grid consider that the cost of mitigation measures necessary from a Transmission System perspective such as specifying an enhanced excitation system are small when compared to the other choices available to Users.

17.6 With regard to User's who wish to install Generating Units of below 1600MVA, for which the SCR requirement remains unchanged, National Grid recommend this issue will be placed on the Grid Code Review Panel issues list for further consideration and management in a timely fashion.

17.7 In view of these points, especially those described in 17.2 – 17.4, National Grid considers that as a whole all the Grid Code Objectives, as defined in 17.1, are better met by the proposals presented in this paper.

18 Impact of Core Industry Documents

18.1 Grid Code Report to the Authority G/09 has no impact on Core Industry

Documents.

19 Impact on other Industry Documents

19.1 Grid Code Report to the Authority G/09 has no impact on other Industry Documents.

20 Environmental Impact Assessment

20.1 Grid Code Report to the Authority G/09 is anticipated to have zero environmental impact. That withstanding, one of the Consultation Respondents (G/09-CR-02) stated that the lowering of the Short Circuit Ratio obligation from 0.5 to 0.4 will allow the use of very Large Synchronous Machines that can be designed with lower losses and therefore will have a positive carbon benefit.

C. CONSULTATION RESPONSES

21. National Grid has consulted Authorised Electricity Operators on this issue. Three responses were received. All three respondents supported the proposed relaxation of the SCR obligations although one respondent believe it should be applied more widely to all generation. All responses, along with National Grid's replies, are included as Appendix C.

22. Respondent G/09-CR-01 (E.On) was supportive of the change and agreed that it is unnecessary to apply the proposed wording offshore at this time, given the size of units connecting offshore.

23. Respondent G/09-CR-02 (EDF) agrees that it becomes more challenging to design larger generator units at the 0.5 rating. It was also suggested that it may be more appropriate for a lower threshold to be investigated in a further review and this could be based on generating unit ratings greater than 1000MVA. National Grid agreed that such an investigation could be included onto the Grid Code Review Panel Development Issues list for further consideration.

24. Respondent G/09-CR-03 (RWE) acknowledges the reasons put forward for reducing the SCR for units above 1600MVA but feels that this may be considered discriminatory for smaller units. A proposal was made to lower the SCR for all generating units which was suggested to move obligations in line with international standards. The proposer also requested clarification from National Grid on whether obligations would change relating to excitation performance Grid Code obligations.

25. Minor suggested revisions to the legal drafting were also made within G/09-CR-03 concerning the final paragraph of CC.6.3.2:
    - Second line – insert "of" after "rating" and before "less"; and
    - Use the term "a Rated MVA" rather than "an Apparent Power rating".

26. National Grid acknowledge that the scope of the Consultation analysis had been limited to very Large Synchronous Generators but this was in order to prevent unnecessary delays and increased costs for imminent projects that anticipate using such equipment. This was not perceived to be undue discrimination as the proposed future review on whether such revised SCR obligations can be applied to all size generators will ensure appropriate consistency is achieved.

27. In regards to requirements on excitation performance, National Grid clarified that the requirements would need to be determined on a site specific basis and within the framework of the Grid Code, as last debated at length under Grid Code Consultation G/06. The current Grid Code requirements as detailed in Appendix 6 of the Connection Conditions allow excitation system performance requirements to be tailored to the needs of a specific connection and detailed in the site specific Bilateral Agreement following completion of Transmission System stability studies.

28. National Grid agreed with the first alternative drafting suggestion and this has been included in the final proposals. National Grid noted the second suggestion to use the term "Rated MVA" instead of "Apparent Power rating" but concluded that neither are defined terms. Alternatively, National Grid confirmed the final proposals would use the phrase: "Generating Units with a rated Apparent Power of 1600MVA…" as "Apparent Power" is a defined term.

D. LEGAL TEXT AND RECOMMENDATIONS

29. Connection Conditions

29.1 It is proposed to amend the existing clause CC.6.3.2 to allow the use of Synchronous Generators greater than 1600MVA with a Short Circuit Ratio not less than 0.4.

- Modify CC.6.3.2

APPENDIX A: PROPOSED GRID CODE CHANGES

The proposed legal text is reflective of the current Grid Code baseline as specified in Issue 4 Revision 2

Proposed Changes to ..

CC6.3.2 (a) When supplying **Rated MW** all **Onshore Synchronous Generating Units** must be capable of continuous operation at any point between the limits 0.85 **Power Factor** lagging and 0.95 **Power Factor** leading at the **Onshore Synchronous Generating Unit** terminals. At **Active Power** output levels other than **Rated MW**, all **Onshore Synchronous Generating Units** must be capable of continuous operation at any point between the **Reactive Power** capability limits identified on the **Generator Performance Chart**.

In addition to the above paragraph, where **Onshore Synchronous Generating Unit(s)**:

(i) have a **CEC** which has been increased above **Rated MW** (or the **CEC** of the **CCGT module** has increased above the sum of the **Rated MW** of the **Generating Units** compromising the **CCGT module**), and such increase takes effect after 1st May 2009, the minimum lagging **Reactive Power** capability at the terminals of the **Onshore Synchronous Generating Unit(s)** must be 0.9 **Power Factor** at all **Active Power** output levels in excess of **Rated MW**. Further, the **User** shall comply with the provisions of and any instructions given pursuant to BC1.8 and the relevant **Bilateral Agreement**: or

(ii) Have a **CEC** in excess of **Rated MW** (or the **CEC** of the **CCGT Units** **module** exceeds the sum of **Rated MW** of the **Generating** comprising the **CCGT module**) and a **Completion Date** before 1st May 2009, alternative provisions relating to **Reactive Power** capability may be specified in the **Bilateral Agreement** and where this is the case such provisions must be complied with.

The short circuit ratio of **Onshore Synchronous Generating Units** with an **Apparent Power** rating of less than 1600MVA shall be not less than 0.5. The short circuit ratio of **Onshore Synchronous Generating Units** with a rated **Apparent Power** of 1600MVA or above shall be not less than 0.4.

(b) Subject to paragraph (c) below, all **Onshore Non- Synchronous Generating Units, Onshore DC Converters** and **Onshore Power Park Modules** must be capable of maintaining zero transfer of **Reactive Power** at the **Onshore Grid Entry Point** (or **User System Entry Point** if **Embedded**) at all **Active Power** output levels under steady state voltage conditions. For **Onshore Non-Synchronous Generating Units** and **Onshore Power Park Modules** the steady state tolerance on **Reactive Power** transfer to and from the **National Electricity Transmission System** expressed in MVAr shall be no greater than 5% of the **Rated MW**. For **Onshore DC Converters** the steady state tolerance on **Reactive Power** transfer to and from the **National Electricity Transmission System** shall be specified in the **Bilateral Agreement.**

APPENDIX B: CONSULTATION PAPER G/09

nationalgrid

GRID CODE

CONSULTATION DOCUMENT

Grid Code short circuit ratio requirement in respect of very Large Synchronous Generating Units

The purpose of this document is to consult on the above Grid Code Modification Proposal with authorised electricity operators liable to be materially affected by the proposed changes

Consultation Ref	G/09
Issue	V1.0
Date of Issue	12th November 2009
Responses required by	**10th December 2009**
Prepared by	National Grid

DOCUMENT LOCATION

National Grid website:

http://www.nationalgrid.com/uk/Electricity/Codes/gridcode/gridcodedocs/

DISTRIBUTION

Name	Organisation
AEO's	Various
GCRP Members/Alternates	Various
Interested Parties	Various
National Grid Industry Information Website	

A. Introduction

1. National Grid Electricity Transmission plc ("National Grid"), in accordance with its obligations under paragraph 2 of Condition 7 of the Transmission Licence, believes that the time has come to review, in consultation with authorised electricity operators liable to be materially affected thereby, the Grid Code and its implementation in certain respects.

2. This review is concerned with Short Circuit Ratio (SCR). The proposed changes to the Grid Code were discussed at the Grid Code Review Panel meeting held on the 17 September 2009 at National Grid House and Panel members agreed that having taken account of comments received at the Panel meeting National Grid should issue a Consultation Paper.

3. Following receipt of comments from those authorised electricity operators which it has consulted by this Paper, National Grid intends, in accordance with paragraph 2 of Condition 7 of the Transmission Licence, to send to the Authority :-

   (a) a report on the outcome of its review, including this consultation process;

   (b) the proposed revisions to the Grid Code which National Grid (having regard to the outcome of such review) reasonably thinks fit for the achievement of the objectives of the Grid Code referred to in sub-paragraph (b) of paragraph 1 of Condition 7 of the Transmission Licence; and

   (c) any written representations or objections from authorised electricity operators (including any proposals by such operators for revisions to the Grid Code not accepted by National Grid in the course of the review) arising during the consultation process and subsequently maintained.

4. The report will also be made publicly available on National Grid's website.

5. The revisions to the Grid Code proposed by National Grid and sent to the Authority then require approval by that body and will, if approved, come into force on such date (or dates) of which you will be notified by National Grid, in accordance with the Authority's approval.

B. Description of the proposed amendments and their effects

6 Background

6.1 At the May 2008 Grid Code Review Panel, the issue of new generation technologies including nuclear and supercritical coal was discussed. With regard to new nuclear, single synchronous generating unit sizes with a Rated MW output of up to 1800MW have been proposed and for supercritical coal, values of up to 1000MW have been suggested.

6.2 The Grid Code places minimum requirements on the capabilities of synchronous generating units. One such parameter is the SCR which under section CC.6.3.2 of the Grid Code is required to be not less than 0.5.

6.3 The largest synchronous generator currently connected to the National Electricity Transmission System is in the order of 660 MW (776MVA). With the introduction of new generation technologies where individual machine size increases to a rated Apparent Power of 2000MVA, supplying a synchronous generator with an SCR of 0.5 or above becomes more challenging. Not least, the higher the SCR, the larger the machine size, which for a generator with a rated Apparent Power of 2000MVA causes significant manufacturing and transport issues. From Reference [1] "Increasing a generator SCR from 0.4 to 0.5 results in an increase in the total volume of about 5 to 10% depending on the type of the generator"

7. Scope

7.1 This paper only considers the Grid Code SCR requirement in respect of very large Synchronous Generating Units and the threshold at which a relaxation (if any) should be applied. This review has been undertaken in response to the concerns raised in respect of these units.

7.2 It is beyond the scope of this Consultation Paper to undertake a complete and thorough review of the SCR requirement irrespective of Generating Unit size. Although SCR was considered as part of the Reactive Power Working Group [2] published in January 2001, a complete reassessment would be required to cater for the significant differences in Generation and Transmission System background currently envisaged compared to that at the time of the original study.

8. Introduction – Short Circuit Ratio

8.1 The SCR of a synchronous generator is defined in IEC34-4 as "The ratio of the field current for rated armature voltage on open–circuit to the field current for rated armature current on sustained symmetrical short circuit, both with the machine running at rated speed".

8.2 A generator with a higher SCR requires a larger field winding which in most cases requires an increase in the size of the machine. It is for this reason that very large generators may struggle to achieve an SCR of 0.5 or greater.

8.3 The implications of reducing the SCR of a synchronous generator are further clarified in [1] but in summary the SCR has a direct impact on the machine's stability performance. This is likely to result in more onerous excitation system requirements, for example higher ceiling voltages and /or faster rise times. In addition, it also affects the machine's reactive capability in the underexcited mode of operation (ie leading capability). It should also be noted that CC.6.3.15 of the Grid Code places obligations on Generating Units to remain transiently stable for a range of Transmission System faults which may require additional measures or enhanced excitation systems to be employed.

9.0 Manufacturer Capabilities

9.1 Having discussed the impact of short circuit ratio on machine design, it is important to establish if the manufacturers of generating plant with Apparent Power ratings of up to 2000MVA can design, build and supply a machine with a SCR of 0.5 or greater.

9.2 With this in mind, National Grid contacted five major turbo Generator manufactures to establish:-

i) Their ability to manufacture a machine with a rated Apparent Power of 2000 MVA and SCR of 0.5 or greater.
ii) The limit in terms of size, at which a 0.5 SCR can no longer be achieved
iii) The type of excitation system available.
iv) Limitations on reactive capability

9.3 Of the five manufactures contacted, some provided a full response, some provided limited information, some provided no information, and in some cases the data was obtained via alternative sources [3].

9.4 Due to confidentiality issues National Grid is unable to publish the responses received, however general trends can be presented which are believed to be sufficient to draw some conclusions from this work.

9.5 For those manufacturers who currently supply machines with a rated Apparent Power of 2000MVA, the SCR ranges between 0.41 – 0.46. The limitation on SCR is determined largely by transport, but other issues such as country of origin and manufacturing capability play an important factor. Based on the Generator Saturated Reactance values shown in Figure 16 of [3], the SCR at best of the 2000MW Turbogenerator described is 0.43.

9.6 Of those manufacturers questioned, a number do not supply machines with a rated Apparent Power of 2000MVA, but the majority of them advised that the maximum limit at which an SCR of 0.5 could be achieved would be in the order of 1600 MVA.

9.7 With regard to reactive capability, it would appear a reactive range of 0.95 lead to 0.85 lag at the Generator Unit terminals on a rated Apparent Power of 2000MVA is achievable, although the cooling water temperature would need to be limited.

9.8 With regard to excitation, some manufacturers promote rotating systems whilst others use static. Each type is limited on excitation ceiling voltage to about 2 p.u. It would appear from the research carried out that both systems can be employed although it is envisaged that a manufacturer supplying a static system would be reluctant/unable to use a rotating system and vice versa due to changes of an authorised design. Both systems can incorporate a power system stabiliser.

10.0 Conclusions

10.1 The work undertaken has enabled an assessment of the size limits to which manufacturers are capable of supplying a machine which would be compliant with the SCR requirements of the Grid Code.

10.2 Based on the work completed to date, and discussions held, it is concluded that manufacturers can produce a machine of up to a rated Apparent Power of 1600MVA with a short circuit ratio of 0.5. It is clear from the evidence available that manufacturing and supplying a machine with an SCR in excess of this value would become increasingly difficult.

10.3 Connecting large machines with lower SCR capabilities may require excitation systems with higher performance than currently used on such machines.

10.4 If a wider review of SCR is to be undertaken, this can be added to the Grid Code Review Panel Issues list.

11.0 **References**

[1] Specifying a Turbogenerator's Electrical Parameters guided by Standards and Grid Codes – C-E Stephan and Z Baba 2001 – Ref 0-7803-7091-0/01/$10©2001 IEEE.

[2] Grid Code Reactive Power Sub-Group – Report to the Grid Code Review Panel. Available at:- http://www.nationalgrid.com/NR/rdonlyres/D9A1B2C1-20BB-4D1C-8F29-39DFA51081C6/3165/reactwgrep.pdf

[3] Type Testing a 2000MW Turbogenerator K Sedlazeck, C Richter, S. Strack, Siemens Energy, Mulheim, Germany, S Lindholm, J Pipkin, F Fu, B Humphries, L. Montgomery, Siemens Energy Orlando, FL, USA – IEEE paper reference 978-1-4244-4252-2/09/$25.00 © 2009 IEEE.

12. COMMENTS

12.1 National Grid would be grateful to receive your comments on, or any suggestions you may have in relation to, these proposed amendments to the Grid Code. Comments would be welcomed and should be sent to National Grid by close of business on **10th December 2009**. The comments will be reviewed and responded to and National Grid will then prepare its report to the Authority.

12.2 Unless otherwise marked as confidential any responses containing objections to the proposals which are maintained will be published on our website in the copy of the Report to the Authority referred to in paragraphs 3 and 4.

12.3. Your formal responses may be:-

Posted to: Tom Ireland
Electricity Codes
Commercial Frameworks
National Grid Electricity Transmission plc
National Grid House
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

Emailed to: thomas.ireland@uk.ngrid.com

Appendix A – Description of the Proposed Grid Code Changes

A.1 Amend CC.6.3.2 (a) of the Grid Code requiring synchronous generators with an Apparent Power rating of less than 1600MVA to be designed with a short circuit ratio of not less than 0.5, and for synchronous generators with an Apparent Power rating of, or in excess of, 1600MVA to be designed with a short circuit ratio of not less than 0.4.

A.2 The proposed changes to CC.6.3.2 of the Grid Code in relation to Short Circuit Ratio are shown in Appendix B.

A.3 It is not proposed to change CC.6.3.2(e) of the Grid Code in respect of Offshore Synchronous Generators. At the present time it is unlikely that a single Synchronous Generator with a rated Apparent Power of 1600MVA would connect to an Offshore Transmission System.

Appendix B

CC.6.3.2 (a) When supplying **Rated MW** all **Onshore Synchronous Generating Units** must be capable of continuous operation at any point between the limits 0.85 **Power Factor** lagging and 0.95 **Power Factor** leading at the **Onshore Synchronous Generating Unit** terminals. At **Active Power** output levels other than **Rated MW**, all **Onshore Synchronous Generating Units** must be capable of continuous operation at any point between the **Reactive Power** capability limits identified on the **Generator Performance Chart**.

In addition to the above paragraph, where **Onshore Synchronous Generating Unit(s)**:

(i) have a **CEC** which has been increased above **Rated MW** (or the **CEC** of the **CCGT module** has increased above the sum of the **Rated MW** of the **Generating Units** compromising the **CCGT module**), and such increase takes effect after 1st May 2009, the minimum lagging **Reactive Power** capability at the terminals of the **Onshore Synchronous Generating Unit(s)** must be 0.9 **Power Factor** at all **Active Power** output levels in excess of **Rated MW**. Further, the **User** shall comply with the provisions of and any instructions given pursuant to BC1.8 and the relevant **Bilateral Agreement**: or

(ii) Have a **CEC** in excess of **Rated MW** (or the **CEC** of the **CCGT module** exceeds the sum of **Rated MW** of the **Generating Units** comprising the **CCGT module**) and a **Completion Date** before 1st May 2009, alternative provisions relating to **Reactive Power** capability may be specified in the **Bilateral Agreement** and where this is the case such provisions must be complied with.

The short circuit ratio of **Onshore Synchronous Generating Units** with an **Apparent Power** rating less than 1600MVA shall be not less than 0.5. The short circuit ratio of **Onshore Synchronous Generating Units** with an **Apparent Power** rating of 1600MVA or above shall be not less than 0.4.

(b) Subject to paragraph (c) below, all **Onshore Non-Synchronous Generating Units, Onshore DC Converters** and **Onshore Power Park Modules** must be capable of maintaining zero transfer of **Reactive Power** at the **Onshore Grid Entry Point** (or **User System Entry Point** if **Embedded**) at all **Active Power** output levels under steady state voltage conditions. For **Onshore Non-Synchronous Generating Units** and **Onshore Power Park Modules** the steady state tolerance on **Reactive Power** transfer to and from the **National Electricity Transmission System** expressed in MVAr shall be no greater than 5% of the **Rated MW**. For **Onshore DC Converters** the steady state tolerance on

Reactive Power transfer to and from the **National Electricity Transmission System** shall be specified in the **Bilateral Agreement.**

APPENDIX C: CONSULTATION RESPONSES TO THE PROPOSED CHANGE

The following Appendix contains copies of all representations received from Authorised Electricity Operators through the consultation period.

Original Responses to G/09 Consultation

No.	Company	File Number
1	E.On	G/09-CR-01
2	EDF	G/09-CR-02
3	RWE	G/09-CR-03

National Grid Replies to Consultation Responses

No.	Company	File Number
1	E.On	G/09-CRR-01
2	EDF	G/09-CRR-02
3	RWE	G/09-CRR-03

Reference	G/09-CR-01
Company	E.On

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Tom Ireland
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NGET
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Wednesday 9th December 2009

Dear Tom,

Response to Grid Code Consultation G/09 – Short Circuit Ratio requirement in respect of very Large Synchronous Generating Units

Thank you for the opportunity to respond to the above consultation. This response is on behalf of E.ON UK and E.ON Energy Trading.

We support the proposed change as a pragmatic response to the changing nature of generating units. We agree that it is unnecessary to apply the proposed wording offshore at the present time, given the planned sizes of offshore generating units.

If you have any queries, please do not hesitate to contact me on the above number.

Yours sincerely

Claire Maxim
Trading Arrangements

Reference	G/09-CR-02
Company	EDF

To: thomas.ireland@uk.ngrid.com

10 December 2009

Dear Tom,

EDF Energy response to Grid Code Consultation paper G/09: Grid Code short circuit ratio requirement in respect of very Large Synchronous Generating Units

Key Points

- **EDF Energy fully supports the proposal by NG to amend the Grid Code to require large synchronous generating units rated above 1600MVA to have a short circuit ratio (SCR) of greater than 0.4.**
- **EDF Energy would support adding SCR to the Grid Code Review Panel issues list for subsequent further review.**

The largest single synchronous generator currently connected to the GB Transmission System is rated 660 MW (776MVA). Proposed new generation technologies, in particular the EPR design nuclear power plant, introduces a generating unit with a rating up to 2000MVA. Designing a large synchronous generating unit with an SCR of >0.5 as required by the Grid Code becomes more challenging at this rating, not least because this causes significant manufacturing and transport issues.

Based on responses that NG received from manufacturers, NG has proposed that the SCR may be >0.4 for synchronous generating units of ratings greater than 1600MVA. It is probable therefore that generating units of less than 1600MVA could be manufactured to have a SCR >0.5 by, for example, over sizing the machine frame size compared to the nameplate rating. However this approach has implications for efficiency, cost, civil work impact and dynamic of the shaft (turbine + generator). It may be more appropriate for a lower threshold to be investigated in a further review and this could be based on generating unit ratings greater than 1000MVA. The rationale for this lower limit is that it represents the rating above which 4 pole rotors are likely to be specified. Thus designing such large generating units for >0.4 SCR rather than >0.5 SCR can result in more efficient machines (less losses) which would give additional carbon benefit.

If you have any queries regarding this response, please contact me on 01452 653492.

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Yours sincerely,

John Morris
Senior Trading Consultant
Corporate Policy & Regulation

Reference	G/09-CR-03
Company	RWE

RWE Supply & Trading

RWE
The energy to lead

Mr Tom Ireland
Electricity Codes Regulatory Frameworks
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Name John Norbury
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10th December 2009

Dear Tom

Grid Code short circuit ratio requirement in respect of very Large Synchronous Generating Units (G/09)

Thank you for the invitation to provide comments on the above Grid Code consultation dated 12th November 2009. The following response is provided on behalf of the RWE group of companies, including RWE Npower plc, RWE Supply & Trading GmbH and RWE Innogy GmbH.

Whilst we acknowledge the reasons put forward for reducing the SCR requirement for onshore generating units rated at 1600MVA and above, such treatment may be considered discriminatory in relation to generating units rated below 1600MVA. Despite the note given in paragraph 7.2 that such consideration would be beyond the scope of this consultation, no reasons appear to have been advanced why it would not be acceptable to similarly reduce the SCR for all generating units . An alternative and less discriminatory approach to that proposed might be to reduce the SCR for all generating units with a completion date after a specified date.

We note that one of the reasons given in Reference Item 2 for reducing the SCR from 0.5 to 0.4 for all generating plant was the need to align the Grid Code with international standards. Reference paper Item 1 also recognises the need to harmonise Grid Code requirements and international standards. It would therefore seem appropriate to consider this proposal and its application to all generating units within the context of aligning the Grid Code with international standards.

Paragraph 10.3 (conclusions) of the Consultation Paper states: "Connecting large machines with lower SCR capabilities may require excitation systems with higher performance than currently used on such machines." We note that Reference Item 1 concludes that there is no clear advantage to Critical Clearance Times of generating units having field excitation ceiling voltages greater than 2 p.u. and also identifies issue with manufacturers in meeting this requirement. It would therefore be helpful if National Grid would clarify the changes likely to be imposed on generating units, particularly obligations related to excitation performance, should this proposed Grid Code change be made.

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HR B 14327

Without prejudice to the above comments, we suggest the following changes to the proposed text of CC.6.3.2, final paragraph:

2nd line - insert "of" after "rating" and before "less".

Given that "an Apparent Power rating" is a term which is both undefined and not currently used in the Grid Code, we suggest it is substituted with "a Rated MVA"

I trust that you will find the above comments helpful. If you wish to discuss any matters further please do not hesitate to contact me.

Yours sincerely

By e-mail

John Norbury
Network Connections Manager

Reference	G/09-CRR-01
Company	E.On

nationalgrid

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01 April 2010

Dear Claire

G/09 Short Circuit Ratio

Thank you for your comments on December 9th to our consultation on proposals to modify the Grid Code provisions relating to Short Circuit Ratio of very Large Synchronous Generating Units (Consultation G/09).

We note your support of the proposed modifications.

If you have any queries please contact me at thomas.ireland@uk.ngrid.com

Yours sincerely

Tom Ireland

Commercial Analyst
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18 May 2010

Dear John,

G/09 Short Circuit Ratio

Thank you for your supportive comments in relation to the Grid Code Short Circuit Ratio provisions in respect of very Large Synchronous Generating Units.

We acknowledge that the scope of this Consultation was limited in respect of very Large Synchronous Generating Units but will at least prevent delays and higher costs to forthcoming projects which wish to utilise such technology in the near future.

Notwithstanding this, we acknowledge that a lower threshold could be investigated in the future and we would be happy to place this on the Grid Code Review Panel list for subsequent further review. As a final point, it should be noted that any such review would need to have a clearly defined scope in addition to considering the impact on overall Transmission System integrity under a rapidly changing generation background.

If you have any queries please contact me at thomas.ireland@uk.ngrid.com

Yours sincerely

Tom Ireland

Commercial Analyst
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18 May 2010

Dear John,

G/09 Short Circuit Ratio

Thank you for your response on December 10th to our consultation on proposals to modify the Grid Code requirements relating to Short Circuit Ratio for very Large Synchronous Generators (Consultation G/09).

We acknowledge that the scope of this consultation was limited in respect of very Large Synchronous Generating Units but will at least prevent delays and higher costs to forthcoming projects which wish to utilise such technology in the near future. With regard to the issue of discrimination for plant less than 1600MVA and your suggested proposal to reduce the Short Circuit Ratio for all Generating Units after a specified date, we acknowledge that a lower threshold could be investigated in the future and we would be happy to place this on the Grid Code Review Panel issues list for subsequent review. In addition, it should be noted that any such review would need to have a clearly defined scope in addition to considering the impact on overall Transmission System integrity under a rapidly changing generation background.

We note your comments with regard to Reference 1 of the Consultation document relating to Short Circuit Ratio and Critical Clearance Times which states:

> "We note that Reference Item 1 concludes that there is no clear advantage to Critical Clearance Times of generating units having field excitation ceiling voltages greater than 2 p.u and also identifies issue with manufacturers in meeting this requirement. It would therefore be helpful if National Grid would clarify the changes likely to be imposed on generating units, particularly obligations related to excitation performance, should this proposed Grid Code change be made."

With regard to the first statement, the conclusion drawn from the paper has to be put in context, as the study in question only considered a 500MVA machine connected to an infinite busbar, with no account of varying system strength, generation background or a range of machine sizes and parameters. System stability will be influenced by a range of factors including, but not limited to inertia, system strength, ceiling voltage, short circuit ratio, winding arrangements and frame size. The conclusions of this paper are of interest but must be put in the context of the publication and studies conducted. It is therefore dangerous to draw the

same conclusions on a GB wide and individual machine basis without conducting a full and thorough analysis. With regard to the second point you have raised and in light of the above comments, any such requirements on excitation performance would need to be conducted on a site specific basis and within the framework of the Grid Code which was last debated at length under the G/06 consultation.

We note your comments with regard to the legal text and are happy with the comment in relation to the inclusion of the word "of" after "rating" and before "less".

We note your suggestion of using the term "Rated MVA" but would like to confirm this is not a defined term. We would therefore recommend the term "Apparent Power" rating (as Apparent Power is a defined term or amending the final sentence to read "The short circuit ratio of Onshore Synchronous Generating Units with a rated Apparent Power of 1600MVA or above shall be not less than 0.4".

With regard to your second comment, the term "Apparent Power" is a defined term (although accept "Apparent Power rating" is undefined), but we also note that your suggestion of Rated MVA is also undefined and therefore we suggest the original suggestion of Apparent Power rating is retained.

If you have any queries please contact me at thomas.ireland@uk.ngrid.com

Yours sincerely

Tom Ireland

Commercial Analyst
Electricity Codes
National Grid