



## **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**

|                        |                           |
|------------------------|---------------------------|
| Consultation Paper Ref | G/09                      |
| Issue                  | 1.0                       |
| Date of Issue          | 19 <sup>th</sup> May 2010 |
| Prepared by            | National Grid             |

## DISTRIBUTION

| Name                                       | Organisation |
|--|--------------|
| Authority                                  | Ofgem        |
| Grid Code Review Panel Members             | Various      |
| National Grid Industry Information Website |              |

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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). The intention of the proposals is to test and lower the Short Circuit Ratio (SCR) obligations for future very Large Synchronous Generating Units greater than 1600MVA. This is to better match the characteristics of generation available on the market whilst ensuring that generator stability characteristics are not detrimentally affected. The proposals were discussed at the GCRP meeting on 17<sup>th</sup> September 2009 and the Panel agreed that they should be taken to industry consultation.
- 0.2 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.
- 0.3 The final proposal is to lower the minimum SCR obligation in the Grid Code from 0.5 to 0.4 for generation greater than 1600MVA.
- 0.4 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 Requirement in respect to very Large Synchronous Generating Units that are intended to allow the use of very large machines in the future that are available on the global market but have a Short Circuit Ratio between 0.4 and 0.5. 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 17<sup>th</sup> 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 10<sup>th</sup> 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 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 a 2001 IEEE paper<sup>1</sup> "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 The Consultation paper 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 review has been undertaken in response to the concerns raised in respect of these units.
- 7.2 It is beyond the scope of this modification 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<sup>2</sup> 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 (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

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<sup>1</sup> 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<sup>©</sup>2001 IEEE.

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

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employed.

## 9. 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
  - 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<sup>3</sup>.
- 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 (footnote 3, figure 16), 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. Conclusions

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<sup>3</sup> 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.

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- 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. The proposed Grid Code changes are to:
- 11.1 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.
12. Impact on the National Electricity Transmission System
- 12.1 The proposed changes will not have any adverse impact on the National Electricity Transmission System because it has been shown that lowering the minimum Short Circuit Ratio for very Large Synchronous Generators does not detrimentally affect their stability characteristics.
13. Impact on Grid Code Users
- 13.1 The proposed changes will allow Grid Code Users to connect to the NETS with very Large Synchronous Generating Units with a SCR between 0.4 and 0.5 allowing a greater range of the generator market to be available.
14. Assessment against Grid Code Objectives
- 14.1 The proposed changes outlined in G/09 Report to the Authority will better facilitate and maintain Grid Code Objectives:
- 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*
- Firstly, Objective (ii) is better achieved by the proposals as Users wishing to connect very Large Generators (>1600MVA) will be able to procure the plant from a wider range of suppliers and will not have to invest in enhanced excitation systems. The proposals do not detrimentally affect unit stability and therefore security of the National Electricity Transmission System and therefore maintains Objective (iii).
15. Impact of Core Industry Documents
- 15.1 Grid Code Report to the Authority G/09 has no impact on Core Industry Documents.
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16. Impact on other Industry Documents

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

17. Environmental Impact Assessment

17.1 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.

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## C. CONSULTATION RESPONSES

14. 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.
  15. 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.
  16. 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.
  17. 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.
  18. 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”.
  19. 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.
  20. 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.
  21. 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 as neither were defined terms neither should be used. 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.
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**D. LEGAL TEXT AND RECOMMENDATIONS**

22. Connection Conditions

22.1 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 CC6.3.2

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## 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** comprising the **CCGT module**), and such increase takes effect after 1<sup>st</sup> 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 1<sup>st</sup> 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 MVA<sub>r</sub> 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**.
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## **APPENDIX B: CONSULTATION PAPER G/09**



### **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                | 12 <sup>th</sup> November 2009       |
| <b>Responses required by</b> | <b>10<sup>th</sup> December 2009</b> |
| 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.

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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.

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- 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<sup>©</sup>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 **10<sup>th</sup> 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](mailto: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.

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**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** comprising the **CCGT module**), and such increase takes effect after 1<sup>st</sup> 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 1<sup>st</sup> 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 MVA 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**.

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## **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**

| <b>No.</b> | <b>Company</b> | <b>File Number</b> |
|------------|----------------|--------------------|
| 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**

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

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|                  |            |
|------------------|------------|
| <b>Reference</b> | G/09-CR-01 |
| <b>Company</b>   | E.On       |



Tom Ireland  
Commercial Frameworks  
NGET  
National Grid House  
Warwick Technology Park  
Gallows Hill  
Warwick  
CV34 6DA

**E.ON UK plc**  
Westwood Way  
Westwood Business Park  
Coventry  
CV4 8LG  
eon-uk.com

Claire Maxim  
T +44 (0)2476 183226  
M +44 (0)7595 125089

claire.maxim@eon-uk.com

—  
Wednesday 9<sup>th</sup> 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

E.ON UK plc  
Registered in  
England and Wales  
No 2366970  
Registered Office:  
Westwood Way  
Westwood Business Park  
Coventry CV4 8LG

|                  |            |
|------------------|------------|
| <b>Reference</b> | G/09-CR-02 |
| <b>Company</b>   | EDF        |

To: [thomas.ireland@uk.ngrid.com](mailto: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.



|   |  |  |  |
|---|--|--|--|
|    | <b>EDF Energy</b><br>40 Grosvenor Place<br>London SW1X 7EN | Tel +44 (0) 20 7752 2200<br>Fax +44 (0) 20 7752 2128 | <a href="http://edfenergy.com">edfenergy.com</a> |
| <small>EDF Energy plc. Registered in England and Wales. Registered No. 2368652. Registered Office: 40 Grosvenor Place, Victoria, London, SW1X 7EN</small> |  |  |  |

Yours sincerely,



**John Morris**  
Senior Trading Consultant  
Corporate Policy & Regulation



|                  |            |
|------------------|------------|
| <b>Reference</b> | G/09-CR-03 |
| <b>Company</b>   | RWE        |

RWE Supply & Trading



Mr Tom Ireland  
Electricity Codes Regulatory Frameworks  
National Grid Electricity Transmission plc  
National Grid House  
Warwick Technology Park  
Gallows Hill  
Warwick  
CV34 6DA

Name John Norbury  
Phone +44 (0)1793 892667  
Mobile +44 (0)7795 354382  
E-Mail john.norbury@RWE.com

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 12<sup>th</sup> 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.

RWE Supply & Trading GmbH  
Swindon Branch

Windmill Hill Business Park  
Whitehill Way  
Swindon SN5 6PB  
United Kingdom

T +44(0)1793/87 77 77  
F +44(0)1793/89 25 25  
I www.rwe.com

Registered No. BR 7373

VAT Registration No.  
GB 524 921 354

Advisory Board:  
Dr. Ulrich Jobs (Chairman)

Board of Directors:  
Stefan Judisch (CEO)  
Dr. Bernhard Günther  
Dr. Peter Kreuzberg  
Richard Lewis  
Alan Robinson

Head Office:  
Essen, Germany  
Registered at:  
Local District Court, Essen  
Registered No.  
HR B 14 327

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

2<sup>nd</sup> 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

|                  |             |
|------------------|-------------|
| <b>Reference</b> | G/09-CRR-01 |
| <b>Company</b>   | E.On        |



National Grid House  
Warwick Technology Park  
Gallows Hill, Warwick  
CV34 6DA

Mrs Claire Maxim  
Trading Arrangements  
E.ON UK  
Westwood Way  
Westwood Business Park  
Coventry  
CV4 8LG

Tom Ireland  
Commercial Analyst

Thomas.ireland@uk.ngrid.com  
Direct tel +44 (0)1926 656152  
Direct fax +44 (0)1926 656521

[www.nationalgrid.com](http://www.nationalgrid.com)

01 April 2010

Dear Claire

**G/09 Short Circuit Ratio**

Thank you for your comments on December 9<sup>th</sup> 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](mailto:thomas.ireland@uk.ngrid.com)

Yours sincerely

Tom Ireland

Commercial Analyst  
Electricity Codes  
National Grid

|                  |             |
|------------------|-------------|
| <b>Reference</b> | G/09-CRR-02 |
| <b>Company</b>   | EDF         |



National Grid House  
Warwick Technology Park  
Gallows Hill, Warwick  
CV34 6DA

John Morris  
Senior Trading Consultant  
Corporate Policy & Regulation  
EDF Energy

John.morris@edf-energy.com

Tom Ireland  
Commercial Analyst

Thomas.ireland@uk.ngrid.com  
Direct tel +44 (0)1926 656152  
Direct fax +44 (0)1926 656521

[www.nationalgrid.com](http://www.nationalgrid.com)

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](mailto:thomas.ireland@uk.ngrid.com)

Yours sincerely

Tom Ireland

Commercial Analyst  
Electricity Codes  
National Grid

National Grid is a trading name for:  
National Grid Electricity Transmission plc  
Registered Office: 1-3 Strand, London WC2N 5EH  
Registered in England and Wales, No 2366977

National Grid is a trading name for:  
National Grid Gas plc  
Registered Office: 1-3 Strand, London WC2N 5EH  
Registered in England and Wales, No 2006000

|                  |             |
|------------------|-------------|
| <b>Reference</b> | G/09-CRR-03 |
| <b>Company</b>   | RWE         |



National Grid House  
Warwick Technology Park  
Gallows Hill, Warwick  
CV34 6DA

Mr John Norbury  
Network Connections Manager  
RWE Supply and Trading

John.norbury@rwe.com

Tom Ireland  
Commercial Analyst

Thomas.ireland@uk.ngrid.com  
Direct tel +44 (0)1926 656152  
Direct fax +44 (0)1926 656521

www.nationalgrid.com

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

National Grid is a trading name for  
National Grid Electricity Transmission plc  
Registered Office: 1-3 Strand, London WC2N 5EH  
Registered in England and Wales, No 2366977

National Grid is a trading name for  
National Grid Gas plc  
Registered Office: 1-3 Strand, London WC2N 5EH  
Registered in England and Wales, No 2006000

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](mailto:thomas.ireland@uk.ngrid.com)

Yours sincerely

Tom Ireland

Commercial Analyst  
Electricity Codes  
National Grid

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