Report to the Grid Code Review Panel

Grid Code Short Circuit Ratio requirement in respect of Very Large Synchronous Generating Units

1 Executive Summary

1.1 The issue of Short Circuit Ratio (SCR) was first raised at the Grid Code Review Panel in May 2008, the principle issue being that the current Grid Code specifies a minimum value of 0.5. With the advent of new Generation technologies approaching single machine sizes of up to 2000MVA, concern was expressed that such a value would be difficult to achieve.

1.2 This paper seeks to address this concern based on discussions held with manufacturers and a qualitative assessment by National Grid of the potential impacts on the Transmission System. The paper concludes with a proposal to change the Grid Code SCR for Synchronous Generators from 0.5 to 0.4 in instances where the MVA rating is 1600MVA or greater.

2 Introduction

2.1 National Grid has a duty to review the requirements of the Grid Code at all times and be responsive to changes in technology which may impact on Users. At the May 2008 Grid Code Review Panel, the issue of new generation technologies including nuclear and supercritical coal was discussed.

2.2 With regard to new nuclear, single synchronous generating unit sizes of up to 1800MW have been proposed and for supercritical coal, respective values of up to 1000MW have been suggested.

2.3 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.

2.4 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 some 2000MVA, supplying synchronous generators 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 2000MVA generator 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”

3. Scope

3.1 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.

3.2 It is beyond the scope of this 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.

4 Background – Short Circuit Ratio

4.1 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".

4.2 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.

4.3 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.

5.0 Manufacturer Capabilities

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

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

i) Their ability to manufacture a 2000MVA machine with a 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

5.3 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].

5.4 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.

5.5 For those manufacturers who currently supply machines 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.

5.6 Of those manufacturers questioned, a number do not supply machines 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.

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

5.8 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.

6.0 **Conclusions**

6.1 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.

6.2 Based on the work completed to date, and discussions held, it is concluded that manufacturers can produce a machine of up to 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.

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

7.0 **Options**

7.1 As a result of the above research, the following options have been considered.

(i) Leave CC.6.3.2 (a) of the Grid Code unchanged, and require all synchronous generators (irrespective of size) to be designed with a short circuit ratio of not less than 0.5.

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

7.2 Item (i) is considered not to be appropriate as there is evidence to suggest that manufacturers will have difficulty in supplying large machines to this requirement. Option (ii) provides a relaxation for larger generators in excess of 1600MVA whilst maintaining the current requirements for smaller machines for which there is not considered to be a manufacturing issue. National Grid considers Option (ii) as the most appropriate way forward.

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

8.0 Recommendations

8.1 The GCRP is invited to agree to an industry consultation on reducing the Grid Code Short Circuit Ratio requirement to 0.4 for synchronous generators of 1600MVA or greater.

9.0 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.

Appendix A - Proposed Grid Code Changes

CC.6.3.2 The short circuit ratio of **Synchronous Generating Units** less than 1600MVA shall be not less than 0.5 and the short circuit ratio of **Synchronous Generating Units** of 1600MVA or above shall be not less than 0.4.