

Stage 03: Report to the Authority

National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS) and Grid Code

GSR018/GC0077: Sub-Synchronous Oscillations (SSO)

01	Workgroup Report
02	Industry Consultation
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This proposal seeks to modify the NETS SQSS and the Grid Code to include Sub-Synchronous Oscillations (SSO) related provisions and clarify the associated accountabilities. This includes the SSO phenomenon that need to be considered, the definitions of acceptable and unacceptable SSO conditions and the operating conditions and secured events for which acceptable and unacceptable SSO conditions should be assessed.

This report is submitted to the Authority to assist in its decision in relation to the implementation of the NETS SQSS Modification and the Grid Code Modification proposed.



National Grid recommends:

Implementation of the modifications proposed to the NETS SQSS and the Grid Code



High Impact:

None identified



Medium Impact:

Transmission Licensees
Generators



Low Impact:

Networks Operators

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Any Questions?

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About this Document

This Report outlines the information required to form an understanding of how the issue of Sub-Synchronous Oscillations has been addressed so far by Transmission Licensees, the proposal to modify the Grid Code and the NETS SQSS to clarify the accountabilities in relation to Sub-Synchronous Oscillations, how Transmission System Users might be affected by the proposal, and the feedback received on the proposals through an industry consultation.

This Report is intended to provide the Authority with the information necessary to inform their decision on the implementation of the modifications proposed.

The revisions to the Grid Code and the NETS SQSS proposed by National Grid and sent to the Authority require approval by that body and will, if approved, come into force from such date (or dates) of which Authorised Electricity Operators will be notified by National Grid, in accordance with the Authority's approval.

Document Control

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2.0	30/01/2017	Code Administrator	Report submitted to the Authority

GSR018/GC0077

Report to the Authority

30/01/2017

Version 2.0

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1. Executive Summary

Background

- 1.1 The Grid Code and the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS) do not explicitly specify that Transmission Licensees are required to ensure that no User equipment is subjected to Unacceptable Sub-Synchronous Oscillations. These requirements are though implicit within the Licence Conditions, the principles of the System Instability criteria of the NETS SQSS, and good industry practice.
- 1.2 All Transmission Licensees' investment plans include some reinforcements that may interact with Users' Generating Units at sub-synchronous frequencies. These interactions, if not managed, may result in negatively or poorly damped Sub-Synchronous Oscillations that may cause damage to User's equipment as well as transmission plant. So far, the specifications of these reinforcements have included Sub-Synchronous Oscillation mitigation measures.
- 1.3 Users have requested a clear specification of accountabilities in relation to mitigation of the risks associated with Sub-Synchronous Oscillations. In response to this request, the Grid Code modification GC0077 was consulted on. However, the feedback received highlighted that this modification was not sufficient.
- 1.4 The NETS SQSS Review Panel appointed a Workgroup to propose a modification to the NETS SQSS to address the Users' concerns. Following discussion, the Grid Code Review Panel then requested that the same Workgroup proposed any additional modifications to the Grid Code.
- 1.5 The Workgroup discussed the consequences of operating a system with Unacceptable Sub-Synchronous Oscillations and concluded that the potential damage to plant, loss of revenue, and risks to personnel would dictate that these risks are appropriately mitigated.
- 1.6 The Workgroup compared the high level options that could be implemented to mitigate the risks of Unacceptable Sub-Synchronous Oscillations and concluded the following:
 - 1.6.1 For an investment in a new Transmission Plant and/or User's Plant to be economic, this plant has to be designed in a manner that would not result in Unacceptable Sub-Synchronous Oscillations, prior to or following a Secured Event, under a comprehensive set of background conditions. These background conditions should cover background conditions that would be either encountered on regular basis or last for a period of time long enough to justify the additional investment.
 - 1.6.2 Further to these design conditions, the risk of Unacceptable Sub-Synchronous Oscillations should be mitigated by operational measures including commercial actions in the balancing mechanism.
- 1.7 The Workgroup discussed how to clarify the accountabilities in order to provide Users with assurance that their equipment would not be exposed to unacceptable risks due to Sub-Synchronous Oscillations and that their Access Rights would not be impacted by these risks; while ensuring that Transmission Licensees have the ability to identify the most cost effective mitigation measures.
- 1.8 In order to agree the NETS SQSS requirements on Sub-Synchronous Oscillations, the Workgroup used the requirements for System Instability as a template; discussed the potential issues that may arise from using the same requirements in relation to Sub-Synchronous Oscillations; and agreed the changes required.
- 1.9 The Workgroup discussions were informed by the experience gained by Transmission Licensees through the specification of Series Capacitors and the Western HVDC Link. The modifications proposed took into account the Sub-Synchronous Oscillations mitigation strategy devised under both projects.

The Proposal

1.10 The Workgroup agreed that although the principles of the NETS SQSS criteria apply in relation to Sub-Synchronous Oscillations, the letter of the definition may be almost impossible to be met and hence separate criteria for Sub-Synchronous Oscillations need to be specified.

1.11 The Workgroup proposed to modify the NETS SQSS to:

1.11.1 include a definition for Sub-Synchronous Oscillations and a definition for Unacceptable Sub-Synchronous Oscillations;

1.11.2 specify within Section 2, Section 4, Section 5, Section 7 and Section 9 of the NETS SQSS that following a secured event, there shall be no Unacceptable Sub-Synchronous Oscillations; and

1.11.3 specify within Section 2 and Section 7 of the NETS SQSS that in relation to the power plant under consideration, Sub-Synchronous Oscillations criteria should be met when the Generating Unit is operating at the output level where it is most vulnerable to Sub-Synchronous Oscillations.

No changes have been proposed to the way secured events are defined and applied, to the background conditions specified in Section 4, or to the background conditions for plants other than the plant under consideration specified in Section 2 and Section 7 as these were considered sufficient.

1.12 In addition, the Workgroup proposed to modify the Grid Code to stipulate that:

1.12.1 NGET is required to ensure that no User's plant is subjected to Unacceptable Sub-Synchronous Oscillations in accordance with the relevant Licence Standards; and

1.12.2 where there is a need, NGET may set some site specific requirements related to damping or mitigation of Sub-Synchronous Oscillations on Users.

Transmission Licensees, other than NGET, will need to meet the same requirement as NGET in accordance with the System Operator Transmission Owner Code (STC) Section D Part One.

1.13 In terms of practical implementation of the new Grid Code clauses and the new NETS SQSS criteria, the Workgroup established the following:

1.13.1 All the works required to mitigate the risks of Unacceptable Sub-Synchronous Oscillations will be identified through the Connection Application or Modification Application processes described in CUSC 2.13 and CUSC 6.9.

1.13.2 This will be achieved using the approach outlined in paragraphs 4.105 to 4.111 of this document or any other similar approach.

1.13.3 Where new transmission plant may interact with existing Users' Plant to cause Unacceptable Sub-Synchronous Oscillations, NGET will send the User a Modification Notification to prompt the submission of the Modification Application necessary to identify the impacts on these Users.

1.13.4 All Transmission Reinforcement Works required to mitigate the risks of Unacceptable Sub-Synchronous Oscillations for a new connection will be classified as Enabling Works in accordance with paragraph 13.2.3.4 of the CUSC.

1.13.5 Certain Users may be required to install Sub-Synchronous Oscillations monitoring equipment.

1.13.6 There will be no requirement that Users install Sub-Synchronous Oscillation protection relays.

1.13.7 It is the expectation that new plant will be specified in a manner such that it does not interact with existing plant in a manner that results in Unacceptable Sub-Synchronous Oscillations. If this results in significant incremental cost, or if it is technically infeasible, modifications to the existing plant(s) will be considered in order to minimise the overall cost to the industry.

1.13.8 User Works, site specific requirements, and Transmission Reinforcement Works, and any third party works required to ensure no Unacceptable Sub-Synchronous Oscillations exist will be funded in accordance with the established arrangements and practices.

1.13.9 Any modifications to transmission plant will be charged for in accordance with CUSC.

1.13.10 Where there is a need to restrict the output of any Generator in order to ensure that, following a secured event, all Sub-Synchronous Oscillations are sufficiently damped, e.g. under specific outage combinations that are beyond that which are required by the NETS SQSS to be considered in design timescales, this will be achieved via the Balancing Mechanism and in accordance with the Users' Access Rights.

The Industry Consultation

1.14 The NETS SQSS Review Panel approved the report submitted by the Workgroup. Both the NETS SQSS Review Panel and the Grid Code Review Panel recommended that the report is issued for a combined industry consultation on the changes proposed to the NETS SQSS and the Grid Code.

1.15 An Industry Consultation was published on 11 April 2016 for 20 business days. Five responses were received.

1.16 Four respondents were fully supportive of the change proposed. The comments provided in their responses were either in-line with the proposal or related to issues that are not affected by the proposal and are not the subject of the Grid Code and the NETS SQSS.

1.17 One respondent agreed with the modification proposed to the NETS SQSS and the Grid Code. However the response raised concerns about how these requirements are planned to be met for connections of new Users' Plant. The concerns were discussed by the Grid Code Review Panel and it was clarified why it is reasonable to expect that requirements will be met in the manner proposed.

1.18 Further clarification was added to Section 7 of this report in response to the comments received via the consultation.

Recommendations

1.19 Based on the findings of the Workgroup and the responses received from interested parties, National Grid recommends that:

1.19.1 the NETS SQSS is changed to include the modifications proposed by the Workgroup and detailed in Annex 2 of this report, and that

1.19.2 the Grid Code is changed to include the modifications proposed by the Workgroup and detailed in Annex 3 of this report.

2. Purpose & Scope of Workgroup

- 2.1 A NETS SQSS Modification Proposal was raised at the December 2013 NETS SQSS Review Panel Meeting in relation to the treatment of Sub-Synchronous Oscillations (SSO) within the NETS SQSS.
- 2.2 The NETS SQSS Review Panel recommended the formation of a Sub-Synchronous Oscillations Workgroup. The Workgroup was tasked to report on the following points:
 - 2.2.1 The need to include SSO related provisions within the NETS SQSS;
 - 2.2.2 The SSO phenomena that needs to be considered;
 - 2.2.3 The definition of acceptable or Unacceptable SSO conditions; and
 - 2.2.4 The operating conditions and secured events for which acceptable or Unacceptable SSO conditions should be assessed.
- 2.3 In addition, following discussions at the Grid Code Review Panel and feedback on these discussions to the NETS SQSS Review Panel; the Workgroup was tasked to report on the requirement for changes to the Grid Code arising from the Workgroup's proposals.

Terms of Reference

- 2.4 A copy of the Terms of Reference can be found in Annex 1.

Timescales

- 2.5 It was agreed that this Workgroup would report back to the April 2015 NETS SQSS Review Panel. However, due to the complexity of the issues being considered and the change in Terms of Reference, this was delayed until the October 2015 NETS SQSS Review Panel Meeting.
- 2.6 Verbal updates on the progress of this Workgroup have been provided at the NETS SQSS Review Panel Meetings. The Workgroup Report was approved at the December 2015 NETS SQSS Review Panel meeting. An update was also provided on this issue at the January 2016 GCRP.

3. Why Change?



Timeline

Workgroup Meeting

Dates

- M1 – 21 07 2014
- M2 – 03 10 2014
- M3 – 28 11 2014
- M4 – 24 03 2015
- M5 – 21 07 2015
- M6 – 23 09 2015
- M7 – 05 12 2016

Background

3.1 In order to avoid building new onshore transmission overhead lines, Transmission Licensees in Great Britain have identified a set of reinforcements that aim to:

3.1.1 maximise the capability of existing AC routes via Series Compensation; and

3.1.2 increase the capability of constrained boundaries via the construction of new subsea HVDC Links.

A list of these projects is given in Table 1.

Table 1. Transmission System Reinforcements.

Project	Technology	Transmission Licensee	Need Case	ETYS 2014 EISD*
Harker-Hutton Series Compensation	Thyristor Controlled Series Capacitor (TCSC)	NGET	Increasing the stability limit of the AC interconnection between NGET and SPT	Already in service
Gretna-Harker / Moffat-Harker Series Compensation	Fixed Series Capacitor with Passive SSR Damping Filter	SPT	Increasing the stability limit of the AC interconnection between NGET and SPT	2015
Eccles-Stella West Series Compensation	Fixed Series Capacitor with Passive SSR Damping Filter	SPT	Increasing the stability limit of the AC interconnection between NGET and SPT	2015
Western HVDC Link	CSC HVDC Submarine Cable	NGET / SPT	Primary boundary capability increase	2017
Caithness Moray HVDC Link	VSC HVDC Link (with multi-terminal capability)	SHET	Primary boundary capability increase	2018
Shetland Connection	VSC HVDC Link (to be connected to the Caithness Moray Link)	SHET	Generation connections	2020
Western Isles	VSC HVDC Link	SHET	Generation connections	2020
Orkney	VSC HVDC Link	SHET	Generation connections	2021
Eastern HVDC Link(s)	VSC HVDC Link	NGET / SPT / SHET	Primary boundary capability increase	Post 2024

*EISD: Earliest In Service Date

3.2 Interactions between these new transmission reinforcements and Synchronous Generating Units, Power Park Modules or individual Power Park Units connected to the National Electricity Transmission System (NETS) may result in poorly or even negatively damped power system oscillations at sub-synchronous frequencies. These oscillations impose some risk on User's equipment and may eventually lead to the failure of this equipment.

3.3 The obligation that Transmission Licensees design and operate a Transmission System that does not have Unacceptable SSO conditions is implicit under the NETS SQSS criteria for System Instability and is good industry practice. However, the NETS SQSS does not explicitly refer to SSO and the Grid Code refers to such

oscillations when placing a requirement on HVDC Interconnector Owners to ensure their plant does not cause SSO.

- 3.4 All HVDC Converters and Series Capacitors that have been tendered by Transmission Licensees were specified to ensure that they do not cause any material SSO risks. The specification and detailed design of this equipment required significant liaison between Transmission Licensees and individual Generators who were requested to provide additional data, allow Transmission Licensees and their contractor's access to their plant to fit testing and measurement equipment and, in some cases, fit permanent monitoring equipment on their machines.
- 3.5 This liaison between Transmission Licensees and Generators has taken place on an ad-hoc basis and is not subject to any specific Grid Code or CUSC Clauses other than PC.A.7 of the Grid Code which allows NGET to request additional data. Thereafter, there have been several attempts to clarify the requirements and the responsibilities related to mitigation of SSO risks within the Grid Code and the NETS SQSS.
- 3.6 In August 2013, the Grid Code was modified to include the proposals of "*GC0040: Information Required to Evaluate Sub-Synchronous Resonance*". This modification requires Generators, in relation to their new Synchronous Generating Units, to provide the data required for SSO related studies.
- 3.7 An issue paper, pp13/54, was submitted to the Grid Code Review Panel in August 2013 requesting that the Grid Code ensures that Series Compensation equipment does not cause Sub Synchronous Resonance issues. In response to this paper, a Grid Code Modification Proposal, GC0077, was drafted and sent out for an Industry Consultation in July 2014 and a Modification Proposal was submitted to the NETS SQSS Review Panel to clarify any related requirements that needs to be defined within the NETS SQSS.
- 3.8 "*GC0077: Suppression of Sub-Synchronous Resonance from Series Capacitive Compensation*" proposed a modification to the Grid Code to place an obligation on NGET to ensure that User's Plant and Apparatus are not subject to Unacceptable SSO conditions. It also proposed to stipulate that NGET may specify SSO related requirements in the Bilateral Agreement with the relevant Users. The Industry Consultation on this proposal highlighted some issues that need to be addressed. The Grid Code Review Panel agreed to delay any conclusion on the GC0077 Modification Proposal until the related NETS SQSS proposal had come to a conclusion.
- 3.9 The Modification Proposal submitted to the NETS SQSS Review Panel in April 2014 proposed that an industry Workgroup is set up and tasked to specify how SSO would be better captured within the NETS SQSS. The proposal suggested that the NETS SQSS System Instability criteria was used as a baseline for any SSO related requirements.
- 3.10 The NETS SQSS Review Panel agreed to form the "GSR018: Sub-Synchronous Oscillations" Workgroup to advise on any modification required to the NETS SQSS and, following a request from the Grid Code Review Panel, the Grid Code also.

Issues for Transmission Licensees

- 3.11 Transmission Licensees consider that there is already an obligation on them to develop and operate a Transmission System that is free from any Unacceptable Sub-Synchronous Oscillations. This obligation arises from their licence obligations to develop, maintain and operate the National Electricity Transmission System in a safe and secure manner. It is also linked to the System Instability criteria defined

within the NETS SQSS which, when met, would ensure that the system is secure against the majority, if not all, Unacceptable Sub-Synchronous Oscillations.

3.12 Hence, from the perspective of a Transmission Licensee, any modification to the Grid Code or the NETS SQSS is only required to:

- provide some assurance to industry partners that SSO risks will be mitigated; and
- provide clarity that, although the main accountability lies with Transmission Licensees, a transmission based solution might not always be the most economic and efficient solution. In such cases, NGET should be able to specify some SSO related requirements in the Bilateral Agreement of the relevant Users.

3.13 While achieving the targets specified in Paragraph 3.12, the modification should not:

- trigger unjustifiable investment;
- dictate the use of any specific technology for their projects (e.g. TCSC);
- be too prescriptive; or
- limit the ability to implement, or require a User to implement, the most cost effective Sub-Synchronous Oscillation mitigation measure.

Issues for Transmission System Users

3.14 If the risks of Unacceptable Sub-Synchronous Oscillations were not to be managed, Transmission System Users would be left exposed to a range of consequences. These consequences could include reduction in the lifetime of their plant, significant damage to their Generating Units and/or Power Park Modules and potential health and safety risks to their personnel.

3.15 So far, SSO risks on the Transmission System have been limited to Sub-Synchronous Torsional Interactions (SSTI) between DC Converters and nearby Synchronous Generating Units. This risk has been managed through CC.6.3.16 of the Grid Code which places an obligation on the DC Converter owners.

3.16 As for new projects, SSO risks may arise because of potential interactions between Transmission Plant and User Plant. The accountability of managing this risk is not explicitly defined within the Grid Code.

3.17 Ideally, Users would like to have:

- assurance that their plant will not be subjected to risks due to Unacceptable SSO conditions;
- assurance that their Access Rights will not be negatively affected by SSO;
- clarity on which party is accountable for the mitigation of SSO risks; and
- some understanding of what they might be required to provide in order to allow Transmission Licensees to mitigate SSO risks in the most cost effective way.

4. Workgroup Discussions

- 4.1 The first Workgroup meeting was held on 21 July 2014. The Workgroup met 6 times over the period between 21 July 2014 and 23 September 2015.
- 4.2 The following issues were discussed by the Workgroup:

Sub-Synchronous Oscillations (SSO)

- 4.3 Sub-Synchronous Oscillations (SSO) are power system oscillations at frequencies that are less than the power frequency. They arise from modes of oscillation associated with interactions between certain equipment in the electricity Transmission System such as generator shaft systems; series compensated lines; excitation system controllers; power system stabilisers and controllers of power electronic converters of either high voltage direct current transmission equipment or power park modules.
- 4.4 Sub-Synchronous modes always exist in a power system but, in most cases, the oscillations arising from these modes are of low magnitude and are adequately damped. However, in some instances, poorly or negatively damped SSO could have significant implications on the Transmission System.
- 4.5 Unacceptable SSO are SSO having either negative or insufficient damping such that the magnitude of oscillations will not eventually decay to zero or such that the oscillations persist at high magnitude for an unacceptably long period of time. In such case, the growing oscillations may cause significant damage to, or failure of, generator shaft systems and impose health and safety risks on personnel, significantly reduce the lifetime of generator shafts due to fatigue or result in failure of the electrical components of the generating Unit due to high voltages or currents.
- 4.6 Unacceptable SSO may arise from interactions between Generating Unit(s) and Series Compensation, Generating Unit(s) and the control systems of HVDC Converters or between different control systems and each other. Interactions between Generating Units and Series Capacitors are referred to as Sub-Synchronous Resonance (SSR). These include the induction generator effect, torque interaction and torque amplification. Interactions between Generating Units and the control systems of HVDC Converters are referred to as Sub-Synchronous Torsional Interactions (SSTI). Interactions between control systems are referred to as Sub-Synchronous Control Interactions (SSCI). The Workgroup noted that other interactions of the same nature may exist but that these may not have been reported in literature in sufficient detail.
- 4.7 The term SSO does not cover electromechanical oscillations associated with rotor swings despite the fact that the frequency of these oscillations is less than the synchronous frequency.

Consequences of Unacceptable SSO

- 4.8 The consequences of Sub-Synchronous Oscillations vary according to the type of interaction and the frequency, magnitude and damping of oscillations.
- 4.9 Sub-Synchronous Oscillations at or near to any of the natural frequencies of a generator shaft system will induce oscillatory torques at one or more of the shaft sections. These oscillatory torques, depending on their magnitude and the number of cycles before they are damped, could damage, or at least reduce the life, of the shaft sections.

- 4.10 Sub-Synchronous Oscillations may result in high voltages and currents that may damage the electrical components of Generating Units.
- 4.11 The long term outage of affected plants, following an Unacceptable Sub-Synchronous Oscillations event, could have a significant impact on revenue.
- 4.12 High torques, voltages, or currents arising from Unacceptable Sub-Synchronous Oscillations and the resulting physical damage to the affected plant could endanger personnel operating this plant.

Examples of Unacceptable SSO Incidents

- 4.13 The first incident of Unacceptable Sub-Synchronous Oscillations took place at Mohave power station in 1970 and led to severe damage of the shaft of a Synchronous Generating Unit that was radially connected to the system via a series compensated line. The damaged shaft was replaced and the unit returned back to service.
- 4.14 The same power station suffered a second incident in 1971 causing similar damage. This incident led to the development of the theory of Sub-Synchronous Oscillations. Blocking filters were installed to prevent further incidents taking place.
- 4.15 In 2009, following a fault, a windfarm connected to the ERCOT (Texas) network, and comprising Doubly Fed Induction Generators was left radially connected to the system via a series compensated line. The event caused negatively damped Sub-Synchronous Oscillations to grow rapidly and the resulting high voltages and currents caused extensive damage to the turbines.
- 4.16 A similar event affecting another windfarm was reported in Minnesota in October 2007.

Mitigation of Unacceptable SSO

- 4.17 Due to the potentially severe consequences of Unacceptable Sub-Synchronous Oscillations and the significant impact on the Users and the Transmission System, it is essential to ensure that no Unacceptable Sub-Synchronous Oscillations take place either in normal operation or following any Secured Event on the system as specified in the NETS SQSS.
- 4.18 In general, this could be achieved by
 - 4.18.1 De-Synchronising the Generating Unit(s) that could interact with the relevant Transmission Plant to cause Unacceptable Sub-Synchronous Oscillations when the Transmission Plant is required to be in service;
 - 4.18.2 Taking the Transmission Plant that could interact with Generating Unit(s) to cause Unacceptable Sub-Synchronous Oscillations out of service when these Generating Unit(s) are running; or
 - 4.18.3 Designing the system in accordance with the planning criteria such that Unacceptable Sub-Synchronous Oscillations are economically and efficiently mitigated;
- 4.19 In general, De-Synchronising the affected Generating Unit(s) would be managed via the balancing mechanism. This would result in an power constraint that
 - 4.19.1 could exceed the constraint relief provided by the relevant Transmission Plant;

4.19.2 would have a very high constraint price as there is no market to drive the price down; and

4.19.3 could easily be active for significant periods of time.

For these reasons, it is not considered economic to use this solution to mitigate the risk of Sub-Synchronous Oscillations on regular basis. However, it may be economic to do so for infrequent system conditions.

4.20 Taking the Transmission Plant that could interact with Generating Unit(s) to cause Unacceptable Sub-Synchronous Oscillations out of service is only economic when

4.20.1 the constraint arising from taking the Transmission Plant out of service is very low; or

4.20.2 it is only required to take place over a very limited period of time.

Therefore, it is uneconomic to invest in a reinforcement that causes Unacceptable Sub-Synchronous Oscillations unless the risk is limited to very short periods of time and can be managed operationally.

Table 2: Examples of SSO Mitigation Measures

	Mitigation Measure	Indicative Cost
Transmission Based	Thyristor Controlled Series Capacitor (TCSC)	2x the price of Fixed Series Compensation
	Fixed Series Compensation with Damping Filters	1.5x the price of Fixed Series Compensation
	Damping Control Systems on HVDC Converter Stations	<£250k
	Auto bypass and/or Intertripping Schemes	<£5m
User Based	Blocking Filters	£10m/Generating Unit
	Damping Control Systems (part of the excitation control system)	<2m/Generating Unit
	Windfarm protection	<£250k/Power Park Module

4.21 Examples of potential design solutions that could be implemented to mitigate the risks of Unacceptable Sub-Synchronous Oscillations and their indicative costs are shown in

4.22 Table 2. The technical viability of these solutions varies based on the type of the plant involved.. However, with an outage of a 660MW unit at a modest cost of £50/MWh costing the industry £5.5m/week, the costs listed in

- 4.23 Table 2 would be well below the costs that could reasonably be expected to arise following a single Unacceptable Sub-Synchronous Oscillations event.
- 4.24 Due to the difference in cost of Unacceptable Sub-Synchronous Oscillation mitigation measures and the variability in the level of risk from one plant to another and from one operating point to another, it is not realistic to come up with a generic solution or a generic cost benefit analysis study that would identify an optimal mitigation measure that fits all cases.
- 4.25 Therefore, the view of the workgroup is that,
- 4.25.1 in principle, new Transmission Plant and/or Users' Plant should be equipped with the appropriate measures to mitigate the risks of Unacceptable Sub-Synchronous Oscillations under typical design scenarios. These design scenarios are discussed in paragraphs 4.67 to 4.98; and that,
- 4.25.2 due to the wide range of potential Sub-Synchronous Oscillations interactions, each case should be evaluated carefully in design timescales to identify the most efficient and economical solution.

SSO on the National Electricity Transmission System

HVDC Interconnectors

- 4.26 SSO has been a risk to the National Electricity Transmission System since the first HVDC interconnection between Great Britain and neighbouring countries was established. The risk is generally limited to current source converters operating in DC current control, i.e. rectifier, mode and it materialises when the negative electrical damping introduced by the HVDC Link converter controller at the complementary frequency of one of the natural frequencies of the mechanical shaft system of a nearby Synchronous Generating Unit exceeds the positive mechanical damping at that natural frequency.
- 4.27 The HVDC Converter owner, in line with CC.6.3.16 of the Grid Code, has the enduring responsibility to mitigate any SSO risks that arise from the interactions between the HVDC Link and other plant.
- 4.28 This risk is usually mitigated in design timescales by adequate tuning of the HVDC Converter Controller or by fitting the controller with an SSO damping loop. However, there are a few exceptions where the risk has been managed via intertripping the interconnector for specific combinations of transmission system outage conditions.

The Western HVDC Link

- 4.29 The Western HVDC Link may interact with nearby Synchronous Generating Units in a manner that is similar to HVDC Interconnectors. These risks are mitigated in design timescales by fitting the HVDC Converter Controller with an SSO damping loop backed up by an SSO protection function.
- 4.30 CC.6.3.16 requirements do not cover transmission plant other than OTSDUW HVDC Converters. However, it is implicit that Transmission Licensees are required to mitigate SSO risks in order to ensure that the National Electricity Transmission System is operated in a safe and secure manner.
- 4.31 When the Western HVDC Link was tendered, it was specified that it shall not cause any Unacceptable SSO. SPT and NGET have been liaising with the HVDC Link developers and the relevant Generators in order to ensure that the appropriate SSO mitigation measures are in place.

Series Compensation

- 4.32 A capacitor connected in series with an inductive Transmission System will create an electrical resonance at a sub-synchronous frequency. If this resonance frequency coincides with the complementary frequency of one of the natural frequencies of a nearby Synchronous Generating Unit or if it coincides with a frequency when the overall equivalent system series resistance is very low or negative, Unacceptable SSO might occur.
- 4.33 Similar to the Western HVDC Link, the Series Capacitors are currently only covered by the implicit requirements that Transmission Licensees should ensure that the system is operable in a safe and secure manner and by the NETS SQSS System Instability criteria.
- 4.34 There are several measures that could be used to mitigate SSO risks associated with Series Capacitors. These measures could be transmission based measures, such as the use of Thyristor Controlled Series Compensation (TCSC), fixed capacitors with damping filters or modifications to the Transmission System topology. They could also be Generating Unit based measures such as blocking filters, damping controllers or, to a lesser extent, modifications to the generator shaft system.
- 4.35 When NGET's Series Capacitors were tendered, it was specified that it shall not cause any electrical undamping over the frequency range between 5Hz and 45Hz. When SPT's Series Capacitors were tendered, a maximum undamping characteristic was specified and it was required that the electrical undamping resulting from Series Compensation should be below that maximum value.

SSO Mitigation Strategy: Design Timescales

- 4.36 A minimum electrical damping, or maximum electrical undamping, characteristic was specified for the Series Capacitors at the various locations. This specification was informed by the data and mechanical models provided by the manufacturers of nearby Synchronous Generating Units. For NGET's TCSC solution, the maximum undamping allowed over the relevant frequency range (5Hz to 45Hz) was zero. For SPT's fixed Series Capacitor solution, some undamping was allowed provided that there is a sufficient margin between the electrical undamping and the corresponding mechanical damping.
- 4.37 A set of credible pre-fault operational scenarios where the flows across the Anglo-Scottish boundary are high enough to dictate that the Series Compensation should be in service was identified. These scenarios included Intact System conditions (N) and some pre-fault outage conditions (N'). It also included the credible combinations of Generating Units in and out of service. Combinations of pre-fault outage conditions were not considered as these would restrict the flow across the boundary below the stability limit of the uncompensated system which allows the System Operator to bypass the Series Compensation.
- 4.38 The Series Capacitors were specified such that, at all combinations of Intact System, N-1, N-D, N'-1, N'-D and for all the generation background conditions considered and over the entire frequency range, the electrical damping provided by the Series Capacitor should be higher than the minimum electrical damping characteristic.
- 4.39 There were a few cases when the combination of the pre-fault outage and the fault left a single plant connected to the system via a radial series compensated circuit. These cases, despite having sufficient damping levels, were managed by an auto bypass scheme that would bypass the Series Capacitors.

SSO Mitigation Strategy: Operational Timescales

- 4.40 In operational timescales, it is expected that the Series Capacitors will be bypassed unless the flows across the Anglo-Scottish boundary exceed the stability limit of the uncompensated system.
- 4.41 Once the flows exceed that limit, NGET will switch the Series Capacitors into service and arm the auto bypass scheme necessary to deal with contingences described in paragraph 4.38.
- 4.42 For the comprehensive set of operational scenarios considered in design timescales, the Series Capacitors are not expected to impose any SSO risks to the Transmission System either at pre-fault conditions or at post-fault conditions.
- 4.43 If an operational scenario other than those considered in the design timescales materialise (e.g. due to an enduring fault outage or due to an extensive construction programme), the System Operator will have to re-balance the system to secure it for the next fault taking into account thermal, voltage, and stability constraints. While doing so, it is expected that the flows across the Anglo-Scottish boundary will be reduced to a level below the stability limit of the uncompensated system. In this case, the System Operator will be able to bypass the capacitors to eliminate any SSO risks.
- 4.44 In summary, SSO risks will be mitigated by design, by bypassing the Series Capacitors pre-fault or by bypassing them post-fault. Any actions required from Generators will be instructed via the Balancing Mechanism and in line with the Generator's Access Rights.

SSO Monitoring

- 4.45 A range of metering and monitoring equipment is installed at transmission sites where a need has been identified. This equipment enables Transmission Licensees to assess the state of the system, highlight any risks and identify any actions required to mitigate such risks. This range varies from simple voltage and current measurement equipment to more sophisticated power quality monitors and fault recorders.
- 4.46 Ideally, metering and monitoring equipment would be located at transmission sites. This is to facilitate access to the equipment and data. However, in some cases, some quantities can be measured more accurately if the measurement and monitoring equipment are located at User sites.
- 4.47 In order to ensure that SSO remain within acceptable limits, Transmission Licensees may find it necessary to monitor these oscillations at some critical sites. Due to the nature of the phenomena involved, and in order to achieve the accuracy required, the monitoring equipment may need to be fitted on the shafts of Synchronous Generating Units.
- 4.48 So far, one Transmission Licensee, SPT, has installed SSO monitoring equipment to some of the Synchronous Generating Units connected near the Series Capacitors and the Western HVDC Link. This equipment will allow NGET, SPT, and the User to monitor SSO and ensure that no plant is exposed to Unacceptable SSO risks.
- 4.49 Ongoing monitoring of SSO also provides data that can be used to refine the models used for generators and other plant in SSO studies. This would improve the

confidence in the accuracy of the parameters of machine models which is important when assessing the stability of different Sub-Synchronous modes.

SSO Protection

- 4.50 Protection systems are provided in order to protect the system against risks that could not otherwise be mitigated. They will trip if they identify that one or more quantities on the power system exceeded the capability of the equipment they are trying to protect by a specific discrimination margin for a period of time that is sufficient for the protection system to operate. The discrimination margin should be sufficiently large such that protection systems do not trip unnecessarily when the equipment are operated at their maximum capability. The time required for the protection to operate would usually depend on the type of protection and the magnitude of the overload.
- 4.51 A genuine trip by a protective relay would indicate that some equipment has been operating beyond its capability for some period of time. Hence, Transmission Licensees, when planning their network, and NGET when operating the system, do not use protection as a means of meeting the NETS SQSS criteria or the Grid Code criteria. Instead, the system will be reinforced and operational measures will be taken in operational timescales to ensure that these criteria are met.
- 4.52 Similarly, Transmission Licensees and NGET need to implement an SSO mitigation strategy in both design and operational timescales such that there is no need for SSO protection. Consequently, there is no requirement for SSO protection equipment to be fitted to User's plant.
- 4.53 Where a Generator opts to install SSO protection, it is expected that this will be done at their own risk and that NGET will not be liable for any compensation following the operation of such protection. It is also expected that the Generator will coordinate the protection settings with NGET.

SSO Interactions with Existing Generation Connections

Synchronous Generating Units

- 4.54 Interactions between the mechanical shaft system or the rotor electrical system of Synchronous Generating Units on one side and Series Capacitors or HVDC Link Converter Controllers on the other side may cause Unacceptable SSO to occur. These interactions are assessed using well established methodologies and generic models. Input required from manufacturers is usually limited to the parameters required for these models.
- 4.55 Transmission Licensees, and their contractors, have used the machine parameters provided by manufacturers and, where possible, validated by tests to inform the design of the Series Capacitors and the HVDC Link.
- 4.56 Any work that has been required to be done at existing Users' plant that a) exceeded what the Users are required to do under the CUSC, the Grid Code, or the Bilateral Agreement and b) were attributed to the Series Compensation and/or the Western HVDC link projects, were funded by Transmission Licensees as a part of these projects. Examples of these works are provision of generating unit shaft system data and the tests undertaken by Transmission Licensees contractors to determine the natural frequencies of generating units shaft systems.

4.57 Modifications to existing Users plant that were attributed to the Western HVDC link and/or the Series Compensation projects were limited to the installation of some monitoring equipment at two Users' sites. This equipment has been specified, designed, and installed by Transmission Licensees who will also be responsible for maintaining this equipment.

Power Park Modules

4.58 There is some scope for interactions between Power Park Units from one side and HVDC Links and Series Capacitors on the other side. These interactions, if not taken into consideration while designing and operating the system, might lead to Unacceptable SSO conditions which may damage these Power Park Modules.

4.59 In the case of Power Park Units, Unacceptable SSO could arise from interactions between Series Capacitors or the HVDC Link Converter Controller on one side and the HVDC Converter Controllers of the Power Park Modules on the other side. The models required to assess these interactions are only available to manufacturers.

4.60 The Workgroup discussed the potential mechanisms where the interactions between Power Park Units and series compensated transmission systems could result in Unacceptable SSO. Reference was made to the events involving Doubly Fed Induction Generators (DFIG) that has been reported in literature and analysed by some of the organisations represented within the Workgroup.

4.61 So far there have only been a few cases where Transmission Licensees have identified that some Power Park Units are exposed to potential SSO risks. In these cases, Generators were provided with the network impedance characteristics, as seen from their connection point, and were requested to confirm with manufacturers that these impedance characteristics would not result in Unacceptable SSO.

4.62 If the Generator, having consulted with the manufacturer, were to indicate that there was a risk of Unacceptable SSO, Transmission Licensees would have liaised with the Generator and the manufacturer to identify the measures to mitigate these risks.

New Generation Connections

4.63 The design of the Series Capacitors and the HVDC Links has taken into account potential interactions with the machines that are already connected to the Transmission System. However, it was impractical to take future generation connections into account at this stage due to uncertainties about their parameters.

4.64 Potential SSO risks affecting new plants will be identified by Transmission Licensees once the relevant data has been submitted by the Generators. These risks will be mitigated by either modifying transmission plant, where it is economic and efficient to do so, or by placing some SSO related requirements that the Generator has to meet.

4.65 The SSO related requirements may include installation of filters or modification of the excitation control system to provide additional damping. In extreme cases, modifications to the machine shaft system may be necessary to ensure no adverse interactions take place.

4.66 It is expected that Transmission Licensees, during the different stages of connection design, will liaise with Generators and manufacturers, through Generators, to ensure that SSO risks have been identified and that an effective SSO mitigation measure has been put in place prior to the connection of any new plant. This liaison will be coordinated by NGET and will be formulated through the usual Connection Application or Modification Application processes.

NETS SQSS

- 4.67 The National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS) sets out a coordinated set of criteria and methodologies that Transmission Licensees use in the planning and operation of the National Electricity Transmission System (NETS).
- 4.68 Pursuant to the Standard Licence Condition C17, The System Operator, NGET, is required to operate the NETS in accordance with the operational criteria defined within the NETS SQSS. This is achieved by either managing existing transmission plants or by procuring services from Transmission System Users.
- 4.69 Pursuant to the Standard Licence Conditions C17, D3 and E16, Transmission Licensees are required to plan and develop the NETS in accordance with the planning criteria defined within the NETS SQSS. While doing so, they are required to take into account NGET's obligations under Standard Licence Condition C17. The planning criteria are met via investing in the Transmission System to provide transmission capacity. The operational criteria are met either via investing in the Transmission System to provide additional capacity or via ensuring that enough operational measures are available for NGET to use.
- 4.70 The actual level of investment may differ from the level required to meet the criteria of the NETS SQSS. This difference may be driven by Transmission Licensees based on an economic justification. It may also be driven by a Transmission System User requesting a Design Variation in accordance with the relevant criteria of the NETS SQSS.
- 4.71 The NETS SQSS is applied by the Transmission Licensees when designing and operating the electricity transmission network. Whilst Generators would not typically apply the NETS SQSS, the standards will still have a significant effect on them as it determines the scope of works required to connect them to the electricity transmission network and the terms and conditions of their connection agreements (i.e. restrictions on availability, inter-trips...etc...)
- 4.72 The NETS SQSS is used in design timescales to assess Connection Applications, Modification Applications, changes in conditions at a connection site (i.e. demand) and for ongoing compliance assessments by the Transmission Owners (TO) and System Operator (SO). In addition, the NETS SQSS is also used in operational timescales to assess outage plans (long term to day ahead) and real time system operation.
- 4.73 Occasionally, works required to meet the NETS SQSS criteria affect a Transmission System User other than the User whose application has triggered these works. In these instances, the Affected User will be informed of any potential works via a Modification Notification and will be requested to submit a Modification Application, free of charge, in accordance with the Connection and Use of System Code (CUSC).

Discussions Framework

- 4.74 The Workgroup agreed to use a template for a typical Clause of the NETS SQSS as a basis of the discussion. This typical Clause had the form:

For the background condition X, following the secured event Y, the criterion Z should be met.

On this basis, the Workgroup will need to agree a set of background conditions, a set of secured events and some criteria.

- 4.75 The Workgroup also agreed to start with the assumption that the criteria that Transmission Licensees are required to meet in relation to System Instability is sufficient to ensure that the Transmission System will not be adversely affected by SSO. The Workgroup will then debate the implications of this assumption and propose a change if required.

Secured Events

- 4.76 The NETS SQSS defines a “secured event” as a contingency which would be considered for the purpose of assessing system security and which must not result in the remaining NETS being in breach of the security criteria.
- 4.77 The Workgroup considers that, in respect of the System Instability criteria, the existing set of secured events strikes the right balance between the probability of these events taking place, the cost associated with securing the system against them and the consequences of a contingency that causes System Instability. That is the risks associated with System Instability when not securing the system against these events outweighs the cost saving resulting from not securing the system against them. Also, the costs resulting from securing the system for more-onerous, less-probable contingencies outweighs the risks mitigated by ensuring that the system remains stable following such events.
- 4.78 The Workgroup also considers that the consequences of an event leading to Unacceptable SSO are in the same order of magnitude of an event leading to pole slipping of a synchronous machine.
- 4.79 Hence, the Workgroup recommends that the Transmission System should be planned and operated such that the system should be secured against Unacceptable SSO for the same set of secured events that are considered when securing the system against System Instability.

Background Conditions

- 4.80 Background conditions define the set of operating points of the Transmission System, prior to any secured event taking place, that need to be considered in design timescales. They usually comprise three elements. These are:
- 4.80.1 The output of the power station under consideration, where there is one;
 - 4.80.2 The output of other power stations and demand levels at Grid Supply Points; and
 - 4.80.3 Pre-fault outages.
- 4.81 Background conditions are only required to be defined for the planning criteria defined in Sections 2, 4, and 7 of the NETS SQSS. The operational criteria defined in Sections 5 and 9 are required to be met under prevailing system conditions.
- 4.82 For Generation Connection Capacity Requirements, the background conditions are defined in Paragraphs 2.8 for onshore generation connections and 7.14 for offshore generation connections. For the power station under consideration, 2.8.1 and 7.14.1 specify that the MW output shall be set to its registered capacity. Conditions on the rest of the system, according to 2.8.5 and 7.14.3 are set to those which ought reasonably to be expected to arise in the course of a year of operation. Hence, Transmission Licensees are required to consider all credible scenarios that are likely to occur when the power station under consideration is running at full output.

However, in practice, Transmission Licensees will usually consider additional scenarios when the plant under consideration is running at different levels of output.

4.83 For the Minimum Transmission Capacity Requirements, Section 4 requires Transmission Licensees to consider several scenarios. These are:

4.83.1 a peak demand scenario with an intact Transmission System and generation despatched according to the Security Background defined in Appendix C of the NETS SQSS;

4.83.2 a peak demand scenario with an intact Transmission System and generation despatched according to the Economy Background defined in Appendix E of the NETS SQSS; and

4.83.3 a representative set of scenarios with the background conditions that ought reasonably to be expected to arise in the course of a year of operation as described in Clause 4.7 of the NETS SQSS.

4.84 The Workgroup noted that the background conditions will affect the damping of SSO in the following ways:

4.84.1 The mechanical damping associated with a particular (mechanical) torsional mode increases with turbine load (generator power output). Therefore, the damping margin at low generator load is reduced and the net damping could even become negative (unstable system), depending on the characteristics of the electrical network.

4.84.2 When several machines are in close electrical proximity to each other, unless they share the same torsional modes, they are likely to have a positive contribution to the SSO damping of each other. That means that more onerous SSO may take place during planned outages of some Generating Units.

4.84.3 The potential of Unacceptable SSO increases when there is a credible contingency leaving a machine connected radially to the system through a series compensated overhead line.

4.85 The onerous SSO conditions associated with Transmission System outages and planned Generating Unit outages will be taken account of under Clauses 2.8.5, 4.7, and 7.4.3.

4.86 The onerous SSO conditions associated with the machine under consideration, running at an output level below its rated output is only covered by Transmission Licensees practice to consider such conditions although such operating conditions are not covered by the letter of the NETS SQSS.

4.87 The Workgroup proposes that Clauses 2.8.1 and 7.4.1 be modified to clarify that Transmission Licensees need to study SSO at the loading condition that corresponds to the most onerous SSO risk.

Definitions and Criteria

4.88 The NETS SQSS definition for System Instability does not differentiate between modes arising from rotor swings and those associated with SSO. However, the extent it should be met to the letter is largely dependent on how the definition was originally developed and how compliance against it has been assessed up to date.

4.89 In order to meet the System Instability criteria defined within the NETS SQSS, all electromechanical oscillations need to have sufficient damping such that, the

magnitude of rotor angle and / or speed oscillations, 20 seconds following a disturbance should drop to less than 15% of the peak deviations. In other words, the time constant of the slowest mode should be less than 12 seconds. These values are likely to have been defined using the models that are typically used to study transient stability. These models will have the shaft systems of generating units represented by a single mass and the network modelled by its steady state equations. Compliance against these criteria has always been assessed using the same models. There has been no evidence that suggests that this practice should be revised.

- 4.90 On the other hand, in order to study SSO, the models need to have the shaft systems of generating units modelled as a multi-mass system and the network modelled by its differential equations. These models will show modes of oscillation that would not appear when using the models typically used for transient stability studies with some of these additional modes, i.e. torsional modes, having time constants in excess of the 12 seconds specified within the System Stability definition even without any series compensation or HVDC converters. It is expected that reducing the time constant of these modes to less than 12 seconds is technically challenging and adds very little value to the system.
- 4.91 Based on paragraphs 4.89 and 4.90 the Workgroup concluded that, although the principles of the System Instability criteria apply, the letter of the definition is almost impossible to be met. Consequently, there is a need to have Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations defined explicitly in the NETS SQSS.
- 4.92 The NETS SQSS definition for SSO should be a generic and high level definition such that it covers all well-established phenomena that might result in Unacceptable SSO and it does not restrict Transmission Licensees from investigating any other potential interactions that might arise due to new generation and transmission technologies.
- 4.93 The option to have a definition for Unacceptable SSO that specifies a maximum electrical undamping at the frequencies where Unacceptable SSO might arise is in line with the practice followed by SPT and NGET when the Series Capacitors were specified. This option allows Generators to expect the level of electrical undamping they are going to be exposed to and take that level when specifying their Generating Unit. However, this criterion was based on the Synchronous Generating Units that are already connected to the system and might not be suitable for other types of Synchronous Generating Units or Power Park Modules.
- 4.94 A generic definition that refers to the consequences of Unacceptable SSO that is mechanical failure of Generating Unit shaft systems due to fatigue or electrical failure of Generating Units due to high voltages or currents, with no specific values leaves Transmission Licensees exposed if a Generator procures Generating Units of sub-standard design. However, it has the advantage that it can be made general and independent of generation, HVDC, or Series Compensation technology. It also provides sufficient assurance for Generators that their plant will not fail due to Unacceptable SSO.
- 4.95 The definition for Unacceptable SSO should be such that it is required to be met at frequencies where there is a potential risk. It should also not rule out that positive electrical undamping may coincide with a modal mechanical frequency provided that the overall damping is positive. This is illustrated by point 'a' and point 'b' in Figure 1. However, it should prevent situations where the high positive electrical undamping coincides with a mechanical mode of low mechanical damping as illustrated by point 'c' in Figure 1.

- 4.96 In practice, Generating Units are designed to cope with the high Sub-Synchronous transient torques that may arise following a large disturbance on the system and that, provided that these are positively damped, they will not be of any material risk to the machine. This means that having positive damping is sufficient to ensure that there will be no risk of machine failure due to Unacceptable SSO and that any references to fatigue or damage of equipment is a secondary element of the definition with no actual implications on the design.
- 4.97 The Workgroup discussed the use of the term “insufficient damping” in addition to “negative damping” as this will ensure that there will be a discussion between the User(s) and Transmission Licensees to establish what level of damping is sufficient. It was noted that word “insufficient” is not specific which might undermine Transmissions Licensees’ ability to ensure compliance.
- 4.98 It was agreed to seek feedback from the industry, through the Industry Consultation in order to confirm that compliance against the definition, in its current form, can be demonstrated.

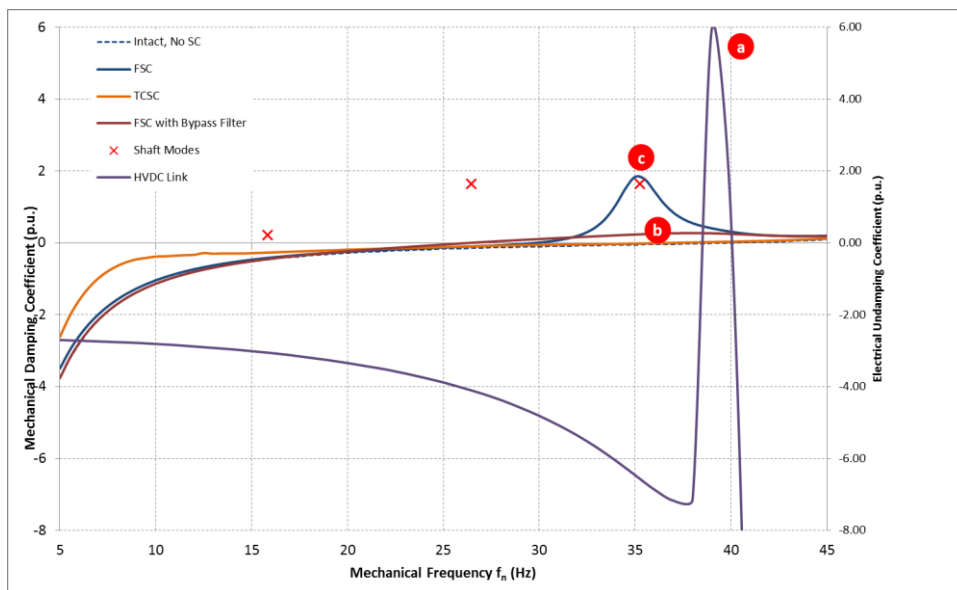


Figure 1: Typical modal electrical undamping characteristics with examples of sufficient damping (point ‘a’ and point ‘b’) and insufficient damping (point ‘c’). This figure is for illustrative purposes only and does not completely reflect the characteristics of any of the projects in progress.

Grid Code

- 4.99 The Grid Code Modification Proposal “GC0077: *Suppression Of Sub-Synchronous Resonance From Series Compensators*” was published for Industry Consultation in July 2014. This proposal aimed to clarify accountabilities related to managing SSO arising from interactions between Users’ plant and transmission plant. Under CC.6.1.9 of this proposal, NGET would be made responsible for ensuring that User’s Plant and Apparatus will not be subject to Unacceptable SSO conditions. Other Transmission Licensees would be required to ensure their Transmission System complies with these requirements in accordance with Section D, Paragraph 2.2.6 of the STC. Where necessary, CC.6.1.10 would require NGET to specify any SSO

related site specific conditions applicable at a User's Connection Site in the Bilateral Agreement between NGET and the User.

- 4.100 The proposed CC.6.1.9 text specifies that NGET shall ensure that Users' Plant and Apparatus will not be subject to unacceptable Sub-Synchronous Oscillation conditions as specified in the relevant Licence Standards. So far, Licence Standards have not referred explicitly to requirements related to SSO. This issue has been addressed via this NETS SQSS Modification Proposal.
- 4.101 This obligation would require NGET to operate the system such that under prevailing system conditions and following any of the secured events defined in Section 5 and Section 9 of the NETS SQSS, the system shall not be subject to Unacceptable SSO. If the pre-fault network configuration has been considered in design timescales, the system will be secure against Unacceptable SSO by virtue of design. If the pre-fault network configuration has not been considered in design timescales, NGET will need to manage generation, via the Balancing Mechanism, in order to allow bypassing the Series Capacitors and / or switching the HVDC Link out of service.
- 4.102 Although events that are more onerous than the secured events defined within the NETS SQSS might take place, the probability of these events is very low to the extent that it is not economic to invest or constrain generation to secure for such events.
- 4.103 Due to the nature of SSO phenomena, there is no single generic solution that would apply for all cases. Requirements Users have to meet in relation to SSO will be assessed on a case by case basis with Transmission Licensees liaising with Users in order to identify the most cost effective solution. This liaison will take place as a part of the Connection Application or Modification Application processes.
- 4.104 In order to allow Transmission Licensees to monitor the performance of their plant, they may choose to require some Users to install monitoring equipment and provide signals to Transmission Licensees.
- 4.105 In general the Grid Code and NETS SQSS criteria are met via investing in transmission capacity or via provision of operational measures. The operational measures include rearrangement of transmission outages, appropriate reselection of Generating Units from those expected to be available, operational intertripping schemes and auto-closure schemes. Operational measures do not include protection relays and hence these will not be used to mitigate SSO risks.
- 4.106 The requirements will equally apply to all Users. However, the complexity and the cost of retrofitting existing plant to meet additional requirements are likely to limit the scope of these requirements.

Practical Application of the Criteria Proposed

- 4.107 The details of the works required to meet the criteria proposed to mitigate SSO risks and the technical requirements that a new User's plant needs to meet will be developed over the lifetime of the User's Construction Agreement from the pre-application stages up to the Completion Date.
- 4.108 At the early stages of application, with no certainty about the connection site, the parameters of any new transmission plant, and the electrical and mechanical parameters of the User's plant, there will be some generic User Works in the Construction Agreement and some generic requirements in the Bilateral Agreement to ensure that the User is aware of the potential requirements.

- 4.109 As the relevant electrical parameters become available, and with certainty about connection site, Transmission Licensees will be able to calculate the impedance characteristics as seen by the Generating Unit and, in case of Synchronous Generating Units, the electrical damping characteristics. These characteristics will be shared with the User who will be required to ensure that their plant is designed such that it will not cause Unacceptable SSO and that it will withstand sub-synchronous torques, voltages, and currents that may arise during transient periods.
- 4.110 As the initial designs of the User's plant, and the mechanical parameters of the shaft system of Synchronous Generating Unit, become available the User will be expected to submit the relevant Grid Code data to NGET and flag any risks that couldn't be mitigated by this initial design. Transmission Licensees will then be able to re-assess the SSO risks, identify potential Transmission Reinforcement Works and/or User Works required to mitigate these risks, and revise the agreements as required. Consequently, the User may need to revise their designs to account for any changes in the requirements.
- 4.111 This is potentially an iterative process with both the User and Transmission Licensees having to modify their designs several times.
- 4.112 Once all the works has been agreed, the electrical damping characteristics and the network impedance characteristics will be updated to take into account the improvement introduced by the Transmission Reinforcement Works referred to in Paragraph 4.110. NGET will then discharge their obligations by
- 4.112.1 providing the User with a transmission system that has damping characteristics or impedance characteristics in line with that that has been advised; and
- 4.112.2 requiring the User to operate their plant such that it does not interact with a transmission system with the updated characteristics in a manner that results in Unacceptable Sub-Synchronous Oscillations.
- 4.113 Generic examples of the site specific requirements related to Sub-Synchronous Oscillations are included in Annex 4.

Relevant Commercial Processes

General

- 4.114 For simplicity, the discussion below uses terminology that is more relevant to Users that are connected directly to the Transmission System. However, the same logic applies for all Generators or, where applicable, for Network Operators on behalf of Generators,
- 4.115 In general, all liaisons between Transmission Licensees and Users will take place through NGET in its capacity as the System Operator.

General Background

- 4.116 Transmission System Users are not required to directly comply with the NETS SQSS. However, they are impacted by its criteria. This impact is identified through the Connection Application or the Modification Application processes defined within the Connection and Use of System Code (CUSC). The effect is reflected in the site specific conditions specified in the Bilateral Agreement between NGET and the User; and Construction Works, User Works, Third Party Works, Completion Date and User Commitment specified in the Construction Agreement between NGET and the User.

- 4.117 Once a Transmission System User submits a Connection Application or a Modification Application, pursuant to 2.13.1 or 6.9.2 of the CUSC, Transmission Licensees will check for compliance against the relevant criteria of the NETS SQSS and identify any transmission reinforcements and Third Party Works required to achieve compliance. Compliance with the NETS SQSS criteria may also trigger some site specific requirements such as Operational Intertripping Schemes, fault clearance times or automatic excitation system control parameters. This information will be reflected in the Construction Agreement and the Bilateral Agreement offered to the User.
- 4.118 From time to time, Transmission Licensees identify that an upgrade to existing transmission plant is necessary to meet the criteria of the NETS SQSS. This upgrade may either be triggered by a specific Connection Application or by a general change of generation and demand backgrounds.
- 4.119 If an upgrade to existing transmission plant is required, Transmission Licensees will identify the Users affected by this upgrade. NGET will then send a Modification Notification to these Users in accordance with 6.9.3.1 of the CUSC and the Users will be invited to submit a Modification Application, free of charge in accordance with 6.9.3.3 of the CUSC, requesting that Transmission Licensees identify the impact on the User's plant and any User Works necessary. The details of any works required to be completed by the User will be specified within the Construction Agreement. Any changes to the site specific requirements will be specified in the Bilateral Agreement.
- 4.120 Once an offer is made to the User, the User will have a chance to discuss and negotiate the contents of this offer with NGET. Where an agreement cannot be reached between NGET and the User, the User is able to refer the issue to the Authority in accordance with Standard Licence Condition C9 of the Transmission Licence.
- 4.121 NGET will provide all advice and assistance reasonably requested by that User to enable that User adequately to assess the implications (including the feasibility) of making a Modification to the User's Equipment in accordance with 6.10.1 of the CUSC.

SSO Interactions

- 4.122 Any works required to comply with the requirements related to SSO that are proposed to be included within the NETS SQSS and / or the Grid Code will be treated in line with the provisions and mechanisms already established under the CUSC.
- 4.123 Works required to manage potential SSO interactions between a new generation connection and an HVDC Interconnector are likely to be identified as Third Party Works within the Construction Agreement of the new generation plant. In this case, the Generator will be expected to liaise with the HVDC Converter Owner, who has the obligation to mitigate the risks of SSO under CC.6.3.16 of the Grid Code, to identify the necessary SSO mitigation measures. The HVDC Converter Owner will have to implement these measures.
- 4.124 The need to assess SSO interactions between new transmission plant and an existing Generating Unit will be identified as a part of the transmission reinforcement project. NGET will issue a Modification Notification to the relevant Users who will need to submit a Modification Application. Transmission Licensees will then, in liaison with the Users, identify the scope of any User Works and any SSO related requirements. User Works will be specified within the Construction Agreement and SSO related requirements will be specified in the Bilateral Agreement.

4.125 The works required to mitigate SSO risks arising from interactions between new User connections and existing transmission plant will be identified through the Connection Application or Modification Application process. As a part of these processes, Transmission Licensees will, in liaison with the relevant User, identify the scope of any User Works and any SSO related requirements. User Works will be specified within the Construction Agreement and SSO related requirements will be specified in the Bilateral Agreement.

4.126 The modification process also allows for any necessary feedback to be provided to Users affected by another party's modification, including where necessary, changes to Bilateral Agreements. This could include the agreement of any mitigation measures should these be determined to be necessary.

Connect and Manage

4.127 Connect and Manage was introduced to allow Generators access to the Transmission System ahead of to the completion of some of the transmission reinforcements that would have otherwise been required to complete ahead of their connection date.

4.128 According to Section 13 of the CUSC and the relevant sections of the STC, following a Connection Application or a Modification Application, in relation to a Generator, Transmission Licensees will identify all the work required to connect this Generator to the National Electricity Transmission System. Thereafter, Transmission Licensees will apply the Connect and Manage Derogation Criteria to classify the works identified into Enabling Works and Wider Transmission Reinforcement Works. The Generator will be allowed access to the Transmission System once all the Enabling Works are completed. Wider Transmission Reinforcement Works completing after the completion date will be covered by a Connect and Manage Derogation.

4.129 The Workgroup discussed the potential interactions between CUSC Section 13, Enabling Works and the NETS SQSS criteria proposed. The potential combinations of these interactions are summarised in Figure 2. There should be no Unacceptable SSO resulting from interactions between existing Transmission Plant and existing User Plant as these would have already been taken care of. Unacceptable SSO resulting from interactions between new Transmission Plant and Users' plant, whether the Users' plant is already connected or due to connect, will be addressed in line with the programme of the relevant transmission project. Where interactions between new Users' plant and existing transmission plant may result in Unacceptable SSO, these interactions will be assessed by Transmission Licensees who will need to identify the works required to meet the NETS SQSS criteria and then classify the works identified into either Enabling Works or Wider Transmission Reinforcement Works.

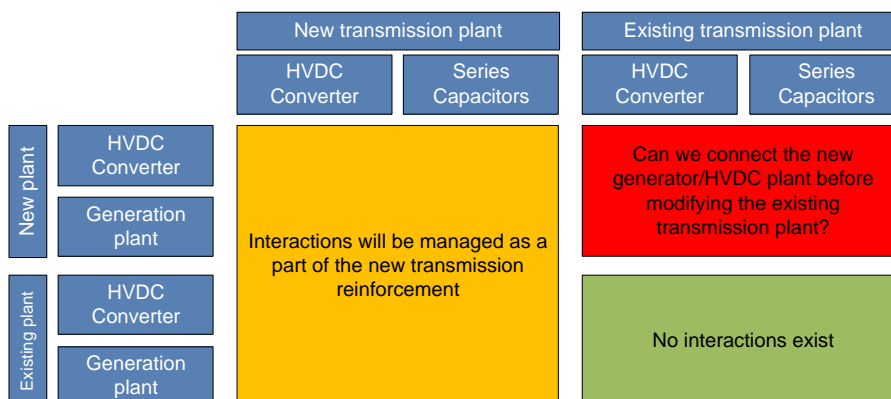


Figure 2: Potential interactions between the proposal and CUSC Section 13.

- 4.130 Transmission reinforcement works required to meet the NETS SQSS Section 2 pre-fault SSO criteria will be automatically classified as Enabling Works in line with Clause 13.2.4.1 of the CUSC, whereas works required to meet the NETS SQSS Section 2 post-fault criteria would need another qualifier if these were to be classified as Enabling Works. This additional qualifier could be that these works are required to enable NGET to operate the NETS in a safe manner (13.2.4.3), comply with the Grid Code criteria (13.2.4.5) or avoid any adverse impacts on other Users (13.2.4.7).
- 4.131 If a User were to connect to the system prior to the completion of all the works required to mitigate Unacceptable SSO, NGET would have to either switch the transmission plant interacting with the User's plant permanently out of service or continuously manage the User's plant interacting with the transmission plant via the Balancing Mechanism. Switching the transmission plant interacting with the User's plant permanently out of service would artificially reduce the transmission capacity available and consequently result in additional transmission constraints. Continuously managing the User's plant interacting with the transmission plant via the Balancing Mechanism would have to be done at the bid price set by the User who would be, due to the nature of SSO, the only User who is able to provide this service. Both options are deemed to be neither economic nor efficient.
- 4.132 In accordance with its Licence Obligations, NGET has to operate the NETS in an economic, efficient, and coordinated manner. While doing so, NGET needs to ensure safety, comply with the additional Grid Code criteria proposed by this Workgroup and avoid adverse impacts on other Users. In order to achieve this, all transmission works required to mitigate Unacceptable SSO have to be classified as Enabling Works in accordance with Clause 13.2.4.3, 13.2.4.5 and 13.2.4.7 of the CUSC.
- 4.133 It is expected that this classification, in the majority of cases, would not result in any delays in connection dates due to the limited scope of the works required to mitigate Unacceptable SSO.

5. Impact & Assessment

Impact on the NETS SQSS

- 5.1 The Workgroup recommends amendments to the following parts of the NETS SQSS:
- 5.1.1 Background conditions for Generation Connection Capacity Requirements in both Section 2 and Section 7.
 - 5.1.2 Pre-fault and Post-fault criteria defined under Section 2, Section 4, Section 5, Section 7, and Section 9.
 - 5.1.3 The terms “Sub-Synchronous Oscillations” and “Unacceptable Sub-Synchronous Oscillations” need to be defined within Section 11.
- 5.2 The text required to give effect to this proposal is contained in Annex 2 of this document.

Impact on the Grid Code

- 5.3 The Workgroup recommends amendments to the following parts of the Grid Code:
- 5.3.1 Connection Conditions CC.6.1: National Electricity Transmission System Performance Characteristics.
- 5.4 The text required to give effect to this proposal is contained in Annex 3 of this document.

Impact on the National Electricity Transmission System (NETS)

- 5.5 The modification proposed formulates requirements that are implicitly defined within the Transmission Licence, the NETS SQSS System Instability criteria and good industry practice. Hence the proposal should have no material impact on the National Electricity Transmission System.

Impact on Transmission Licensees

- 5.6 The modification proposed clarifies the accountabilities related to Sub-Synchronous Oscillations. This clarification ensures that Transmission Licensees will continue to design and operate the Transmission System in a way that does not expose User's equipment to Unacceptable Sub-Synchronous Oscillations.
- 5.7 The modification also allows NGET to place some site specific requirements on the relevant Users in order to facilitate meeting the NETS SQSS and the Grid Code criteria related to Sub-Synchronous Oscillations.

Impact on Transmission System Users

- 5.8 The modification proposed gives Users comfort that their plant will not be subjected to Unacceptable Sub-Synchronous Oscillations.
- 5.9 The modification places an obligation on Users to meet certain site specific requirements related to Sub-Synchronous Oscillations. These requirements will be specified by NGET on a case by case basis and will be discussed with the Users in line with the relevant commercial processes.

Impact on Greenhouse Gas Emissions

5.10 This modification has a neutral impact on greenhouse gas emissions.

Assessment Against NETS SQSS Objectives

5.11 The Workgroup considers that the proposed amendments would better facilitate the NETS SQSS objectives:

- (i) **facilitate the planning, development and maintenance of an efficient, coordinated and economical system of electricity transmission, and the operation of that system in an efficient, economic and coordinated manner;**

The modification proposal clarifies the criteria that Transmission Licensees will need to meet when securing the system against Sub-Synchronous Oscillations. It also clarifies the scenarios that will be considered in both design and operational timescales. This will ensure that no excessive costs are incurred when investing in transmission plant or when operating the system to secure the system against events of significantly low probability.

- (ii) **ensure an appropriate level of security and quality of supply and safe operation of the National Electricity Transmission System;**

The modification proposal stipulates that the system will be secured against Unacceptable Sub-Synchronous Oscillations for the same events that it is secured against for System Instability. This ensures that no User's equipment will be exposed to Sub-Synchronous Oscillation risks for all secured events.

- (iii) **facilitate effective competition in the generation and supply of electricity, and (so far as consistent therewith) facilitating such competition in the distribution of electricity; and**

The proposal reduces the overall risk for Generators and allows them to join/remain active in the generation market. It also mitigates against the risk of excessive constraint payments.

- (iv) **facilitate electricity Transmission Licensees to comply with their obligations under EU law.**

The modification proposal has no impact on this NETS SQSS objective.

Assessment Against Grid Code Objectives

5.12 The Workgroup considers that the proposed amendments would better facilitate the Grid Code objectives:

- (i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;**

The modification proposal clarifies the accountabilities in terms of management of Sub-Synchronous Oscillations on the Transmission System. Whilst doing so, it provides NGET with a tool to enforce, where necessary and where economic to do so, reasonable SSO-related site specific requirements on Transmission System Users. This ensures that the risks are managed using the most coordinated, economic, and efficient means.

- (ii) to facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the National Electricity Transmission System being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity);**

By clarifying that Transmission Licensees will develop and that NGET will operate a Transmission System that is free from Unacceptable Sub-Synchronous Oscillations, under all credible scenarios, Users will have enough assurance to invest in new plant and to continue to operate their existing plant that are connected in close proximity to the series capacitors and/or the HVDC links.

- (iii) subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the National Electricity Transmission System Operator area taken as a whole; and**

The modification proposal clarifies the accountabilities related to management risks of Sub-Synchronous Oscillations. This gives comfort to Transmission System Users that their plant will not be exposed to material risks. While doing so, the modification proposal provides means to ensure that the most appropriate and cost effective countermeasure against Sub-Synchronous Oscillations has been implemented. This is by clarifying that NGET may specify some site specific conditions on some Users to ensure that the Transmission System is not exposed to any Sub-Synchronous Oscillation risks.

- (iv) to efficiently discharge the obligations imposed upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and / or the Agency.**

The modification proposal has no impact on this Grid Code objective.

Impact on Core Industry Documents

5.13 The proposed modification does not impact on any core industry documents.

Impact on Other Industry Documents

5.14 The proposed modification does not impact on any other industry documents.

Implementation

5.15 The Workgroup proposes that, should the proposals be taken forward, the proposed changes be implemented 10 business days after an Authority decision.

6. Workgroup Recommendations

- 6.1 The Workgroup proposed a modification to the NETS SQSS to include:
- 6.1.1 a definition of Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations;
 - 6.1.2 place a requirement on Transmission Licensees to secure the system against Unacceptable Sub-Synchronous Oscillations for the same set of secured events that are used when securing the system against System Instability; and
 - 6.1.3 clarifying that, when securing the system against Unacceptable Sub-Synchronous Oscillations in design timescales, Transmission Licensees have to take into account the most onerous loading condition of the Generating Unit under consideration.
- 6.2 The Workgroup endorsed the Grid Code Modification Proposal GC0077 after having addressed and / or clarified all the points that were raised by the responses to the Industry Consultation. This proposal:
- 6.2.1 places a requirement on NGET to ensure that no User's plant is subject to Unacceptable Sub-Synchronous Oscillations; and
 - 6.2.2 gives NGET a tool to set out site specific requirements for Users.

7. Consultation Responses

Summary of Responses

- 7.1 Five responses, all included in Annex 5, were received.
- 7.2 Four of the responses – SP Energy Networks, ScottishPower Generation, EDF, and SSE Generation – were supportive of the proposal. Some of these responses included comments to seek clarification or highlight some points that may have not been clear in the consultation document. The fifth response – Horizon Nuclear Power – was partially supportive however it raised some concerns.
- 7.3 The feedback received and NGET's response to this feedback has been discussed in both the 18 May 2016 Grid Code Review Panel meeting and the 1 June 2016 NETS SQSS Review Panel meeting. The conclusions of these discussions are summarised below; in each section the points raised in the consultation responses are summarised and the conclusions on these then given.

7.4

SSE Generation:

How is a disagreement between an existing generator and the TO resolved?

Horizon Nuclear Power

The subject of compensation for damage caused to users' plant as a result of another party has not been addressed. In the event that SSO damage can be directly linked to an SSO source which has not been mitigated correctly, the compensation to the affected users must be reasonable.

Also, in cases when the most economic mitigation can be demonstrated to be User Works, it is the affected generator that must pay whereas for Enabling Works this cost is shared.

This is not a consistent charging approach.

- 7.5 The proposal does not set up any new, or change any existing:

- 7.5.1 funding rules/practices;
- 7.5.2 charging methodologies;
- 7.5.3 mechanisms to address any disagreement between Users and Transmission Licensees; or
- 7.5.4 rules around compensation for damage caused to any plant due to failure of any party to meet their obligations under the Licence, the Grid Code, the NETS SQSS, or the Bilateral agreement.

Such arrangements/rules are already in place, were not covered by the scope of the workgroup, and are not the subject of the Grid Code or the NETS SQSS.

7.6 *Horizon Nuclear Power:*
The selection of series compensation/HVDC technologies by other parties should not force developers and designers to make bespoke site specific plant. This will increase costs and technical risks.

7.7 The projects listed in Table 1 bring additional benefits to Transmission System Users. They provide an alternative to new overhead lines that does not have the same visual impact/footprint. They are easier to consent and quicker to build. The capacity they deliver contributes to a reduction in constraints payment which is reflected into BSUoS charge and an accelerated rate of generation connections which may not be achievable if such generation is dependent on new overhead lines.

7.8 It is acknowledged that the projects listed in Table 1 contribute to additional Sub-Synchronous Oscillations risk on the National Electricity Transmission System. However these risks:

7.8.1 do not exceed the risks introduced by HVDC interconnection to external systems;

7.8.2 should not be viewed in isolation from the benefit such projects bring to Transmission System Users; and

7.8.3 will be mitigated by the appropriate specification of Transmission and/or User's Plant.

7.9 *Horizon Nuclear Power:*
It is better for the safety and security of the system to spend the money up front to avoid the problems by the design than spend money on constraint payments.

7.10 Transmission Licensees are required to develop the National Electricity Transmission System in a coordinated, economic, and efficient manner. Equipment will be specified such that no Unacceptable Sub-Synchronous Oscillations take place following a secured event at intact system condition or with a prior single circuit outage as required by the design criteria of the NETS SQSS. Other operational conditions, e.g. with two concurrent independent circuits on a planned outage, are less frequently encountered and, hence, it would not be economic to consider these conditions in design timescales. Under such outage conditions, the System Operator would still be required to operate the system such that, following a secured event, there is no Unacceptable Sub-Synchronous Oscillations. This will be

managed via operational measures such as bypassing any series capacitors and may result in additional constraints payments.

7.11 Horizon Nuclear Power:
Any insufficient damping of SSO will have a negative impact on synchronous generators, and may be of a level that will cause long term loss of plant life which is difficult to quantify and attribute to a particular source.

7.12 The system, including Users' Plant, will be developed and operated such that all Sub-Synchronous Oscillations are sufficiently damped. However, this damping, although sufficient to ensure no damage take place, is not likely to be enough to meet the damping timescales specified by the System Instability criteria.

7.13 Horizon Nuclear Power:
Existing synchronous machine designs do not suffer SSO – this potential risk is entirely the result of actions by TSOs installing series capacitor compensation or others installing HVDC converter stations.
The selection of series compensation/HVDC technologies by other parties should not force developers and designers to make bespoke site specific plant.

7.14 Synchronous Generating Units, similar to series capacitors and HVDC Links, introduce Sub-Synchronous modes to the transmission system. It is the interaction between the modes that could reduce their damping and cause Unacceptable Sub-Synchronous Oscillations to arise. That means that a new Synchronous Generating Unit that interacts with existing Transmission Plant is the source of the Unacceptable Sub-Synchronous Oscillations when viewed in the context of a new connection.

7.15 The same concept applies to Power Park Modules.

7.16 Horizon Nuclear Power:
Only in circumstances where it can be clearly demonstrated that a site specific solution is the most economic and practical way to mitigate SSO can transmission licensees apply additional requirements on the user.
It is highly unlikely that a re-design of the turbine-generator characteristics will be the optimal solution. There are many other design criteria for this plant that are of higher priority..... This will increase costs and technical risks.

ScottishPower Generation

Going forward the simplest solution is to specify requirements on new generation that they must be designed to avoid the frequency bands where negative damping already exists.

SSE Generation

A new generator who is connecting should have ability to negotiate the most economic solution with the TO which may involve work on the TO's assets rather than solely the new generator's assets.

7.17 The expectation is that the User will be able to procure a plant that does not interact with the National Electricity Transmission System in a manner that results in Unacceptable Sub-Synchronous Oscillations. If this result in significant incremental

cost, or if it is technically infeasible, the User will be expected to identify the risks and work together with Transmission Licensees to identify and implement the most cost effective mitigation measure.

7.18 Horizon Nuclear Power:
In cases when the most economic mitigation can be demonstrated to be User Works, it is the affected generator that must pay whereas for Enabling Works this cost is shared. This is not a consistent charging approach.

7.19 The costs associated with any User Works and/or site specific requirements that are required to mitigate the non-compliance introduced to the system due to the connection of a new User's Plant will be covered by the User. This is in line with the existing practice when a new User's Plant results in non-compliance against any of the Grid Code clauses such as CC.6.1.5, CC.6.1.7, or CC.6.3.16.

7.20 On the other hand, Transmission Reinforcement Works required to ensure that all Sub-Synchronous Oscillations are sufficiently damped will be funded by the Transmission Licensees and charged for in accordance with CUSC.

7.21 Horizon Nuclear Power:
Developers and designers should not be forced to make bespoke site specific plant. If site specific requirements on generators are applied, they should not require Users to make costly or technically unproven modifications to their plant

SSE Generation

An existing generator could believe that more monitoring is required to safeguard the generator than the TO believes is necessary – how would this be resolved?

7.22 There is always the possibility that a User requests that Transmission Licensees implement modifications to the National Electricity Transmission System that are over and above the minimum works required to comply with the standards and/or the level that is deemed to be most economic provided that they agree to fund these works.

7.23 Horizon Nuclear Power:
I disagree with the wording below in respect of synchronous plant who are affect by external SSO sources
“The User shall ensure that all Sub-Synchronous Oscillations that may arise from interactions between the User's Generating Unit(s) and the National Electricity Transmission System are sufficiently damped.”
Obligations placed on owners of SSO sources applied via 6.3.16 and 6.1.9 should not be transferred to other parties

7.24 The level of damping associated with a certain Sub-Synchronous mode is dependent on a variety of factors and could be affected by the manner the User operate their plant or the manner the System Operator operate the National Electricity Transmission System. Therefore, once the requirements have been established, the responsibility of ensuring that all Sub-Synchronous Oscillations are sufficiently damped will be shared between the User and the System Operator. The demarcation line between the responsibilities of both parties will be specified in the

Bilateral Agreement. This could be in the form of damping characteristics, impedance characteristics, or any other form as agreed between all parties.

7.25 There also could be some situations where the level of damping that was identified to be “sufficient” at the design stage becomes “insufficient” at a later date. An example for this would be a scenario where the mechanical shaft system of a Synchronous Generating Unit becomes more susceptible to fatigue due to the User operating their plant beyond its capability, the plant is subjected to excessive mechanical stresses, or adequate maintenance schedules not being followed. Under such circumstances, it will be the User’s responsibility to provide the additional damping required.

7.26 For the reasons specified in paragraphs 7.24 and 7.25, it is likely that the Bilateral Agreement will place a requirement on the User to ensure that no Unacceptable Sub-Synchronous Oscillations arise.

ScottishPower Generation:

7.27 *Defining a “specific Generator electrical damping characteristic” for a new generator will probably be location specific and hence Users may be restricted from installing certain generator types at certain location, but it is difficult to see how this can be avoided.*

7.28 The damping characteristics are location specific. There could be situations where a specific Generating Unit or a specific Power Park Module could be connected to one substation without causing any Unacceptable Sub-Synchronous Oscillations. However, the same Generating Unit, or Power Park Module, could require significant User Works, site specific conditions, and/or Transmission Reinforcement Works when connected to another substation. This is similar to any other transmission constraint.

SP Energy Networks

7.29 *Without knowledge of the impedance characteristics of a new or proposed synchronous generator, Transmission Licensees will not be able to provide a generator-specific damping characteristic. However, as TO, SPT would identify any machine considered at risk of SSO and work with the User to achieve an appropriate level of damping and mitigate any SSO risk. Network impedance characteristics are useful when assessing SSO risks and, as TO, we would agree with using this approach where appropriate.*

7.30 Paragraphs 4.107 to 4.113 provide a reasonable approach to identify and agree the works required to ensure that the National Electricity Transmission System is free from Unacceptable Sub-Synchronous Oscillations. However, the approach is not specified in any codes and alternative processes may be followed to achieve the same result.

Recommendation

7.31 Considering the feedback received via the consultation, the subsequent discussions at the Grid Code Review Panel meeting on the 12th of May 2016 and the NETS SQSS Review Panel meeting on the 1st of June 2016, and the position clarified in paragraphs 7.3 to 7.30, it is recommended that the changes proposed in the industry consultation and as detailed in Annex 2 and Annex 3 of this document are implemented.

**National Electricity Transmission System
Security and Quality of Supply Standards
Sub-Synchronous Oscillations (SSO) Workgroup
TERMS OF REFERENCE**

Governance

The Sub-Synchronous Oscillations (SSO) Workgroup was established by the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS) Review Panel at the 02 April 2014 NETS SQSS Review Panel meeting.

The Workgroup shall formally report to the NETS SQSS Review Panel.

Membership

The Workgroup shall comprise a suitable and appropriate cross-section of experience and expertise from across the industry, which shall include:

Name	Role	Representing
Graham Stein	Chair	-
Ryan Place	Chair	Code Administrator
Nick Martin	Technical Secretary	-
Ryan Place	Technical Secretary	Code Administrator
Bieshoy Awad	National Grid SO Representative	National Grid
Andrew Dixon	National Grid SO Representative	National Grid
Danson Joseph	National Grid TO Representative	National Grid
Cornel Brozio	Industry Representative	SPT
David Adam	Industry Representative	SPT
Yash Audichya	Industry Representative	SHE Transmission
Alastair Frew	Industry Representative	Scottish Power
Lorna Short	Industry Representative	RWE
Ankit Patel	Industry Representative	SSE
John Reilly	Industry Representative	EDF
Mayure Daby	Authority Representative	Ofgem

Meeting Administration

The frequency of Workgroup meetings shall be defined as necessary by the Workgroup chair to meet the scope and objectives of the work being undertaken at that time.

National Grid shall provide technical secretary resource to the Workgroup and handle administrative arrangements such as venue, agenda and minutes.

The Workgroup will have a dedicated section on the National Grid website to enable information such as minutes, papers and presentations to be available to a wider audience.

Scope

The Workgroup shall consider and report on the following:

- The need to include SSO related provisions within the NETS SQSS;
- The SSO phenomena that needs to be considered;
- The definition of Acceptable or Unacceptable SSO conditions;
- The operating conditions and secured events for which Acceptable or Unacceptable SSO conditions should be assessed; and
- The requirement for changes to the Grid Code arising from the Workgroup's proposals.

Deliverables

The Workgroup shall provide verbal updates and a Workgroup Report to the NETS SQSS Review Panel which will:

- Detail the findings of the Workgroup;
- Draft, prioritise and recommend changes to the NETS SQSS and any associated documents in order to implement the findings of the Workgroup; and
- Highlight any consequential changes which are or may be required.

Timescales

It is anticipated that this Workgroup shall provide a verbal update to each NETS SQSS Review Panel meeting and present a Workgroup Report to the April 2015 NETS SQSS Review Panel meeting.

The Workgroup will provide a written progress update to the October 2014 NETS SQSS Review Panel meeting including details of the programme of work remaining required to meet its target Workgroup Report date.

If the Workgroup is in existence for more than one year, there is a responsibility for the Workgroup to produce a yearly update report, including but not limited to; current progress, reasons for any delays, next steps and likely conclusion dates.

This section contains the proposed legal text to give effect to the Workgroup proposals. The proposed new text is in red and is based on NETS SQSS Version 2.2, Dated March 5 2012.

Section 2

Generation Connection Capacity Requirements

Background conditions

2.8.1 the active power output of the *power station* shall be set equal to its *registered capacity* or, for the purpose of *Sub-Synchronous Oscillations* studies, that which provides the lowest level of damping for the sub-synchronous mode under consideration;

Pre-fault criteria

2.9 The *transmission capacity* for the connection of a *power station* shall be planned such that, for the background conditions described in paragraph 2.8, prior to any fault there shall not be any of the following:

2.9.1 equipment loadings exceeding the *pre-fault rating*;

2.9.2 voltages outside the pre-fault planning voltage limits or insufficient voltage performance margins; ~~or~~

2.9.3 system instability; or

2.9.4 *Unacceptable Sub-Synchronous Oscillations.*

Post-fault criteria – background condition of no *local system outage*

2.10 The *transmission capacity* for the connection of a *power station* shall also be planned such that for the background conditions described in paragraph 2.8 with no *local system outage* and for the *secured event* of a *fault outage* on the *onshore transmission system* of any of the following:

2.10.1 a single *transmission circuit*, a reactive compensator or other reactive power provider;

2.10.2 a *double circuit overhead line* on the supergrid;

2.10.3 a *double circuit overhead line* where any part of either circuit is in *NGET's transmission system* or *SHETL's transmission system*;

2.10.4 a single *transmission circuit* with the prior outage of another *transmission circuit*;

2.10.5 a section of *busbar* or mesh corner; or

2.10.6 a single *transmission circuit* with the prior outage of a *generating unit*, a reactive compensator or other reactive power provider;

there shall not be any of the following:

2.10.7 a *loss of supply capacity* except as permitted by the demand connection criteria detailed in Section 3;

2.10.8 unacceptable overloading of any primary transmission equipment;

2.10.9 unacceptable voltage conditions or insufficient voltage performance margins; ~~or~~

2.10.10 System Instability; or

2.10.11 *Unacceptable Sub-Synchronous Oscillations.*

Section 4

Minimum Transmission Capacity Requirements

At ACS peak demand with an intact system

4.5 The minimum *transmission capacity* of the *MITS* shall be planned such that, for the background conditions described in paragraph 4.4, prior to any fault there shall not be:

4.5.1 equipment loadings exceeding the *pre-fault rating*;

4.5.2 voltages outside the pre-fault planning voltage limits or insufficient voltage performance margins; ~~or~~

4.5.3 system instability; ~~or~~

4.5.4 *Unacceptable Sub-Synchronous Oscillations.*

4.6 The minimum *transmission capacity* of the *MITS* shall also be planned such that for the conditions described in paragraph 4.4 and for the *secured event* of a *fault outage* of any of the following:

4.6.1 a single *transmission circuit*, a reactive compensator or other reactive power provider;

4.6.2 a *double circuit overhead line* on the supergrid;

4.6.3 a *double circuit overhead line* where any part of either circuit is in *NGET's transmission system* or *SHETL's transmission system*;

4.6.4 a section of *busbar* or mesh corner; or

4.6.5 provided both the *fault outage* and prior outage involve plant in *NGET's transmission system*, any single *transmission circuit* with the prior outage of another *transmission circuit*, or a *generating unit*, reactive compensator or other reactive power provider,

there shall not be any of the following:

4.6.6 *loss of supply capacity* (except as permitted by the demand connection criteria detailed in Section 3 and Section 8);

4.6.7 unacceptable overloading of any primary transmission equipment;

4.6.8 unacceptable voltage conditions or insufficient voltage performance margins; ~~or~~

4.6.9 system instability; ~~or~~

4.6.10 *Unacceptable Sub-Synchronous Oscillations.*

Under conditions in the course of a year of operation

4.8 The minimum *transmission capacity* of the *MITS* shall be planned such that, for the background conditions described in paragraph 4.7, prior to any fault there shall not be:

4.8.1 equipment loadings exceeding the *pre-fault rating*;

4.8.2 voltages outside the pre-fault planning voltage limits or insufficient voltage performance margins; ~~or~~

4.8.3 system instability; or

4.8.4 *Unacceptable Sub-Synchronous Oscillations.*

Section 5

Normal Operational Criteria

5.1 The onshore transmission system shall be operated under prevailing system conditions so that for the secured event of a fault outage on the onshore transmission system of any of the following:

5.1.1 a single *transmission circuit*, a reactive compensator or other reactive power provider; or

5.1.2 the most onerous *loss of power infeed*; or

5.1.3 where the system is designed to be secure against a *fault outage* of a section of *busbar* or mesh corner under *planned outage* conditions, a section of *busbar* or mesh corner,

there shall not be any of the following:

5.1.4 a *loss of supply capacity* except as specified in Table 5.1;

5.1.5 unacceptable frequency conditions;

5.1.6 unacceptable overloading of any primary transmission equipment;

5.1.7 unacceptable voltage conditions; or

5.1.8 system instability; or

5.1.9 *Unacceptable Sub-Synchronous Oscillations.*

5.3 The *onshore transmission system* shall be operated under prevailing system conditions so that for the *secured event* on the *onshore transmission system* of a *fault outage* of:

5.3.1 a double circuit overhead line; or

5.3.2 a section of *busbar* or mesh corner,

there shall not be any of the following:

5.3.3 a *loss of supply capacity* greater than 1500 MW;

5.3.4 unacceptable frequency conditions; or

5.3.5 *unacceptable voltage conditions* affecting one or more *Grid Supply Points* for which the total *group demand* is greater than 1500 MW; or

5.3.6 system instability of one or more Generating Units connected to the supergrid;
or

5.3.7 *Unacceptable Sub-Synchronous Oscillations.*

Conditional Further Operational Criteria

- 5.5 If:
- 5.5.1 there are *adverse conditions* such that the likelihood of a *double circuit overhead line* fault is significantly higher than normal; or
- 5.5.2 there is no significant economic justification for failing to secure the *onshore transmission system* to this criterion and the probability of *loss of supply capacity* is not increased by following this criterion,
- the onshore transmission system shall be operated under prevailing system conditions so that for the secured event of
- 5.5.3 a fault outage on the supergrid of a double circuit overhead line there shall not be:
- 5.5.4 where possible and there is no significant economic penalty, any *loss of supply capacity* greater than 300 MW;
- 5.5.5 unacceptable overloading of any primary transmission equipment;
- 5.5.6 unacceptable voltage conditions; ~~or~~
- 5.5.7 system instability; ~~or~~
- 5.5.8 *Unacceptable Sub-Synchronous Oscillations.*

Section 7

Generation Connection Capacity Requirements

Background conditions

- 7.14.1 the active power output of the *offshore power station* shall be set to deliver active power at the offshore *grid entry point* equal to its registered capacity ~~or~~, *for the purpose of Sub-Synchronous Oscillations studies, that which provides the lowest level of damping for the sub-synchronous mode under consideration;*

Pre-Fault Criteria – background conditions of no *local system outage*

- 7.15 The *transmission capacity* of the *offshore transmission circuits* for the connection of one or more *offshore power stations* shall be planned such that, for the background conditions described in paragraph 7.14, with *no local system outage* and prior to any fault, there shall not be any of the following:
- 7.15.1 Equipment loadings exceeding the *pre-fault rating*;
- 7.15.2 Voltages outside the *pre-fault planning voltage limits* or *insufficient voltage performance margins*; ~~or~~
- 7.15.3 *system instability*; ~~or~~

7.15.4 *Unacceptable Sub-Synchronous Oscillations.*

Post-Fault Criteria – background conditions of no *local system outage*

7.16 The *transmission capacity* of the *offshore transmission circuits* for the connection of one or more *offshore power stations* shall also be planned such that for the background conditions described in paragraph 7.14 with *no local system outage* and for the *secured event* on the *offshore transmission system* of any of the following:

7.16.1 In the case of an *offshore power park module* connection with an *OffGEP capacity* of 90MW or more, with the *OffGEP capacity* reduced by 50%, a *fault outage* or *planned outage* of a single AC *offshore transmission circuit* on the *offshore platform*;

7.16.2 In the case of an *offshore power park module* connection with an *OffGEP capacity* of 120MW or more, with the *OffGEP capacity* reduced to 50%, a *fault outage* or a *planned outage* of a single AC *offshore transmission circuit* at the onshore transformation facilities

And in all cases other than specified in 7.16.1 and 7.16.2 above:

7.16.3 a *fault outage* or a *planned outage* of a single *offshore transmission circuit*;

And in all cases:

7.16.4 a *fault outage* or a *planned outage* of a single reactive compensator or other reactive provider;

7.16.5 a *fault outage* of a single *offshore transmission circuit* during a *planned outage* of another *offshore transmission circuit*;

7.16.6 a *fault outage* or a *planned outage* of a single section of *busbar* or mesh corner;

There shall not be any of the following:

7.16.7 a *loss of supply capacity* except as permitted by the demand connection criteria detailed in Section 8;

7.16.8 *Unacceptable overloading* of any *primary transmission equipment*;

7.16.9 *Unacceptable voltage conditions* or *insufficient voltage performance margins*; ~~or~~

7.16.10 system instability; ~~or~~

7.16.11 *Unacceptable Sub-Synchronous Oscillations.*

Section 9

Normal Operational Criteria

9.1 An offshore transmission system shall be operated under prevailing system conditions so that for the secured event on the offshore transmission system of a fault outage of any of the following:

9.1.1 a single *transmission circuit*, a reactive compensator or other reactive power provider; or

9.1.2 the most onerous *loss of power infeed*; or

9.1.3 a section of busbar or mesh corner, or

9.1.4 a double circuit overhead line

there shall not be any of the following:

9.1.5 a *loss of supply capacity* except as specified in Table 9.1;

9.1.6 unacceptable frequency conditions;

9.1.7 unacceptable overloading of any primary transmission equipment;

9.1.8 unacceptable voltage conditions; ~~or~~

9.1.9 *system instability*; or

9.1.10 *Unacceptable Sub-Synchronous Oscillations*.

Section 11 Terms and Definitions

Sub-Synchronous Oscillations

Power system oscillations at frequencies that are less than the power frequency. They arise from modes of oscillation associated with interactions between certain elements on the system such as generator rotor circuits, generator shaft systems, series compensated lines, excitation system controllers, power system stabilisers, converter controllers of power park modules and converter controllers of DC interconnectors and links.

Unacceptable Sub-Synchronous Oscillations

Unacceptable Sub-Synchronous Oscillations are Sub-Synchronous Oscillations with the relevant modes of oscillation having negative or insufficient net damping. Unacceptable Sub-Synchronous Oscillations may have a significant effect on generating units including a significant reduction in the lifetime of the machine shaft system due to fatigue or the failure of some of its electrical components due to high voltages and / or currents.

This section contains the proposed legal text to give effect to the Workgroup proposals. The proposed new text is in red and is based on Grid Code Issue 5, Revision 13, and Dated 22 January 2015.

Grid Code Connection Conditions

Sub-Synchronous Resonance and Sub-Synchronous Torsional Interaction

CC.6.1.9 **NGET** shall ensure that **Users' Plant and Apparatus** will not be subject to unacceptable Sub-Synchronous Oscillation conditions as specified in the relevant **Licence Standards**.

CC.6.1.10 **NGET** shall ensure where necessary, and in consultation with **Transmission Licensees** where required, that any relevant site specific conditions applicable at a **User's Connection Site**, including a description of the Sub-Synchronous Oscillation conditions considered in the application of the relevant **License Standards**, are set out in the **User's Bilateral Agreement**.

This section contains a generic example of the site specific requirements for both Synchronous Generating Units and Power Park Modules. The two versions provided reflect the position prior to and after the agreement of the works required to mitigate Sub-Synchronous Oscillation risks.

Synchronous Generating Units

The text below is to be used at the early stages of a connection application prior to the agreement of the Works required to ensure that all Sub-Synchronous Oscillations are sufficiently damped,

Sub-Synchronous Resonance

The Company may specify to the User a set of characteristics depicting the electrical damping the User's Generating Unit(s) are expected to experience over the sub-synchronous frequency range. The User shall inform The Company of any Sub-Synchronous Oscillations that it believes to be insufficiently damped ("Unacceptable Sub-Synchronous Oscillations").

Where a risk of Unacceptable Sub-Synchronous Oscillations has been identified, the User and The Company shall agree the site specific requirements and the works, including any Transmission Reinforcement Works and/or User Works, required to ensure that all Sub-Synchronous Oscillations are sufficiently damped. Neither the User nor The Company shall unreasonably withhold their agreement to these works.

The Company shall provide the User with an updated set of electrical damping characteristics reflecting the effect of the agreed Transmission Reinforcement Works. The Company reserves the rights to review the designs and request the models of any measures the User implements in order to prevent Unacceptable Sub-Synchronous Oscillations.

Where necessary, The Company may also require that the User installs Sub-Synchronous Oscillations monitoring equipment.

There is no requirement on the User to install any Sub-Synchronous Oscillations protection.

The text below is to replace the previous text following the agreement of the works required to ensure that all Sub-Synchronous Oscillations are sufficiently damped,

Sub-Synchronous Resonance

The characteristics¹ depicting the electrical damping the User's Generating Unit(s) are expected to experience over the sub-synchronous frequency range are included in Schedule X to this Appendix F5. The User² shall ensure that all Sub-Synchronous Oscillations that may arise from interactions between the User's Generating Unit(s) and the National Electricity Transmission System are sufficiently damped.

The User's Generating Unit(s) shall meet the following requirements:

- Requirement 1 as previously agreed with the User
- Requirement 2 as previously agreed with the User
- ...etc.

The User shall install the following equipment:

- Equipment 1 as previously agreed with the User
- Equipment 2 as previously agreed with the User
- ...etc.

The User shall provide The Company with the designs and the models of the systems used to meet the above requirements and of the equipment listed above.

There is no requirement on the User to install any Sub-Synchronous Oscillations protection.

¹ These characteristic represent the Transmission System after the completion of all Transmission Reinforcement Works that are planned to increase the electrical damping at the relevant frequencies as previously agreed between the User and The Company.

² This intends to cover Transmission Licensees against a scenario when a User does not highlight SSO risks during the design or when User's equipment suffer some damage that could have been avoided by adequate maintenance of this equipment.

Power Park Modules

The text below is to be used at the early stages of a connection application prior to the agreement of the Works required to ensure that all Sub-Synchronous Oscillations are sufficiently damped,

Sub-Synchronous Resonance

The Company may specify to the User a set of characteristics depicting the network resistance and reactance as seen by the User's Power Park Module(s) over the sub-synchronous frequency range. The User shall inform The Company of any Sub-Synchronous Oscillations that it believes to be insufficiently damped ("Unacceptable Sub-Synchronous Oscillations").

Where a risk of Unacceptable Sub-Synchronous Oscillations has been identified, the User and The Company shall agree the site specific requirements and the works, including any Transmission Reinforcement Works and/or User Works, required to ensure that all Sub-Synchronous Oscillations are sufficiently damped. Neither the User nor The Company shall unreasonably withhold their agreement to these works.

The Company shall provide the User with an updated set of network resistance and reactance characteristics reflecting the effect of the agreed Transmission Reinforcement Works. The Company reserves the rights to review the designs and request the models of any measures the User implements in order to prevent Unacceptable Sub-Synchronous Oscillations.

Where necessary, The Company may also require that the User installs Sub-Synchronous Oscillations monitoring equipment.

There is no requirement on the User to install any Sub-Synchronous Oscillations protection.

The text below is to replace the previous text following the agreement of the works required to ensure that all Sub-Synchronous Oscillations are sufficiently damped,

Sub-Synchronous Resonance

The characteristics³ depicting the network resistance and reactance as seen by the User's Power Park Module(s) over the sub-synchronous frequency range are included in Schedule X to this Appendix F5. The User⁴ shall ensure that all Sub-Synchronous Oscillations that may arise from interactions between the User's Power Park Module(s) and the National Electricity Transmission System are sufficiently damped.

The User's Power Park Module(s) shall meet the following requirements:

- Requirement 1 as previously agreed with the User
- Requirement 2 as previously agreed with the User
- ...etc.

The User shall install the following equipment:

- Equipment 1 as previously agreed with the User
- Equipment 2 as previously agreed with the User
- ...etc.

The User shall provide The Company with the designs and the models of the systems used to meet the above requirements and of the equipment listed above.

There is no requirement on the User to install any Sub-Synchronous Oscillations protection.

³ These characteristic represent the Transmission System after the completion of all Transmission Reinforcement Works that are planned to increase the electrical damping at the relevant frequencies as previously agreed between the User and The Company.

⁴ This intends to cover Transmission Licensees against a scenario when a User does not highlight SSO risks during the design or when User's equipment suffer some damage that could have been avoided by adequate maintenance of this equipment.

SP Energy Networks

Industry parties are invited to respond to this consultation expressing their views and supplying the rationale for those views, particularly in respect of any specific questions detailed below.

Please send your responses by 09 May 2016 to box.SQSS@nationalgrid.com. Please note that any responses received after the deadline or sent to a different email address may not receive due consideration.

These responses will be included in the Report to the Authority which is drafted by National Grid and submitted to the Authority for a decision.

Respondent:	Graeme Vincent (graeme.vincent@spenergynetworks.co.uk)
Company Name:	SP Energy Networks
Does the modification proposed provide Transmission System Users with enough assurance that their Plant is not going to be subjected to unacceptable risks due to Sub-Synchronous Oscillations? If not, please clarify why.	Yes, having been actively involved in the working group process we believe that the proposed modification provides Users with the appropriate degree of reassurance.
Does the modification proposed strike the right balance between operational risks and the cost of constraints required to mitigate this risk? If not, please provide evidence.	Yes, we believe that the right balance has been struck.
Does the modification proposed strike the right balance between capital investment and operational expenditure? If not, please provide evidence.	Yes, we believe so.
The Workgroup concluded that although the System Instability criteria stipulated within the NETS SQSS apply in principle to Sub-Synchronous Oscillations, the letter of the definition is not necessarily applicable as it is	We agree that, in the context of SSO, the System Instability criteria would have been very difficult and probably costly to meet. No, we do not consider this constitutes any operational risk to the Transmission System and/or User's Plant.

<p>almost impossible to be met. Does this constitute any operational risk to the Transmission System and/or User's Plant? If yes, please specify these risks.</p>	
<p>Do you agree that the definitions for Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations should be generic such that it covers all well-established phenomena that might result in Unacceptable SSO; does not restrict Transmission Licensees from investigating any other potential interactions that might arise due to new generation and transmission technologies; and applies equally to all types of generation and transmission plant? If not, please clarify your rationale.</p>	<p>Yes we are in agreement that the definition should be suitably generic to allow for the Transmission Licensees to investigate any future interactions which might arise from the introduction of new technology onto the Transmission system.</p>
<p>Do the definitions proposed for both Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations meet the criteria mentioned above? If not, please clarify why.</p>	<p>We believe the wording to be consistent with the criteria mentioned above.</p>
<p>Do you agree to the choice of word "Insufficient damping" within the definition of Unacceptable Sub-Synchronous Oscillations rather than specifying a numerical value (e.g. zero)? If not, please advise what level of damping is deemed to be sufficient taking into account the potential differences between different types of plants and between units of the same type but of different rating.</p>	<p>We agree with the choice of the word 'insufficient' as this allows a level to be specified taking into account the particular characteristics of the network under consideration and the different plant involved.</p>
<p>The modification proposal places the responsibility of mitigating the risks of Unacceptable Sub-Synchronous Oscillations arising</p>	<p>We agree with this approach particularly when considering that a site-specific requirement could provide the most cost-effective overall solution.</p>

<p>because of transmission plant on Transmission Licensees. However, it allows them to partially or fully fulfil this obligation via reasonably specifying some site specific requirements on Transmission System Users. Do you agree to this approach? If no, please clarify your concerns.</p>	
<p>In order to comply with the generic definition of Unacceptable Sub-Synchronous Oscillations, it is expected that, where necessary, Transmission Licensees will specify to a Generator an electrical damping characteristic, in case of Synchronous Generating Units, or a network impedance characteristic, in case of Power Park Modules, and require that the Generator design their plant such that it does not result in Unacceptable Sub-Synchronous Oscillations. Do you agree to that approach? If no, please propose alternatives.</p>	<p>Without knowledge of the impedance characteristics of a new or proposed synchronous generator, Transmission Licensees will not be able to provide a generator-specific damping characteristic. However, as TO, SPT would identify any machine considered at risk of SSO and work with the User to achieve an appropriate level of damping and mitigate any SSO risk. Network impedance characteristics are useful when assessing SSO risks and, as TO, we would agree with using this approach where appropriate.</p>
<p>Do you agree to the general outline proposed for the process of defining and/or agreeing the damping characteristics or the network impedance characteristics? Please highlight any risks that might arise from this approach.</p>	<p>Yes – we agree with the general process outlined in the document.</p>
<p>Do you agree to the generic wording proposed for the Bilateral Agreement set out in Annex 4 of this Consultation Document? Please clarify any concerns.</p>	<p>Yes we agree.</p>
<p>Do the modifications proposed protect Transmission Access rights for all Transmission System Users? If not, please specify why.</p>	<p>Yes.</p>

<p>Is there any evidence that Users will be inappropriately or adversely affected by the changes proposed? If so please provide details.</p>	<p>We are currently not aware of any evidence which would suggest that Users would be adversely affected by the proposals.</p>
<p>Do you believe that GC0077 better facilitates the appropriate Grid Code objectives?</p>	<p><i>For reference the applicable Grid Code objectives are:</i></p> <p><i>(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;</i></p> <p><i>(ii) to facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity);</i></p> <p><i>(iii) subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole; and</i></p> <p><i>(iv) to efficiently discharge the obligations imposed upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and/or the Agency.</i></p>
<p>Do you believe that GSR018 better facilitates the appropriate NETS SQSS objectives?</p>	<p><i>For reference the applicable NETS SQSS objectives are:</i></p> <p><i>(i) facilitate the planning, development and maintenance of an efficient, coordinated and economical system of electricity transmission, and the operation of that system in an efficient, economic and coordinated manner;</i></p> <p><i>(ii) ensure an appropriate level of security and quality of supply and safe operation of the National Electricity Transmission System;</i></p>

	<p><i>(iii) facilitate effective competition in the generation and supply of electricity, and (so far as consistent therewith) facilitating such competition in the distribution of electricity; and</i></p> <p><i>(iv) facilitate electricity Transmission Licensees to comply with their obligations under EU law.</i></p>
Do you generally support the modifications proposed by the workgroup? If not, please clarify your concerns.	Having been actively involved in the workgroup and its deliberations we are supportive of the modifications proposals being put forward by the workgroup.
Are there any further technical considerations that need to be taken into account?	
Please provide any other comments you feel are relevant to the proposed changes.	No additional comments

EDF Energy

Industry parties are invited to respond to this consultation expressing their views and supplying the rationale for those views, particularly in respect of any specific questions detailed below.

Please send your responses by 09 May 2016 to box.SQSS@nationalgrid.com. Please note that any responses received after the deadline or sent to a different email address may not receive due consideration.

These responses will be included in the Report to the Authority which is drafted by National Grid and submitted to the Authority for a decision.

Respondent:	John Reilly John.Reilly@EDF-Energy.com 09 May 2016
Company Name:	EDF Energy
Does the modification proposed provide Transmission System Users with enough assurance that their Plant is not going to be subjected to unacceptable risks due to Sub-Synchronous Oscillations? If not, please clarify why.	Yes. Noting that the NETS SQSS should be modified to: - include a definition for Sub-Synchronous Oscillations and a definition for Unacceptable Sub-Synchronous Oscillations; - specify within Section 2, Section 4 and Section 7 of the NETS SQSS that following a secured event, there shall be no Unacceptable Sub-Synchronous Oscillations; and - specify within Section 2 and Section 7 of the NETS SQSS that in relation to the power plant under consideration, Sub-Synchronous Oscillations criteria should be met when the Generating Unit is operating at the output level where it is most vulnerable to Sub-Synchronous Oscillations.
Does the modification proposed strike the right balance between operational risks and the cost of constraints required to mitigate this risk? If not, please provide evidence.	Yes
Does the modification proposed strike the right balance between capital investment and operational expenditure? If not, please provide evidence.	Yes
The Workgroup concluded that although the System Instability criteria stipulated within the NETS	No

<p>SQSS apply in principle to Sub-Synchronous Oscillations, the letter of the definition is not necessarily applicable as it is almost impossible to be met. Does this constitute any operational risk to the Transmission System and/or User's Plant? If yes, please specify these risks.</p>	
<p>Do you agree that the definitions for Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations should be generic such that it covers all well-established phenomena that might result in Unacceptable SSO; does not restrict Transmission Licensees from investigating any other potential interactions that might arise due to new generation and transmission technologies; and applies equally to all types of generation and transmission plant? If not, please clarify your rationale.</p>	<p>Yes</p>
<p>Do the definitions proposed for both Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations meet the criteria mentioned above? If not, please clarify why.</p>	<p>Yes</p>
<p>Do you agree to the choice of word "Insufficient damping" within the definition of Unacceptable Sub-Synchronous Oscillations rather than specifying a numerical value (e.g. zero)? If not, please advise what level of damping is deemed to be sufficient taking into account the potential differences between different types of plants and between units of the same type but of different rating.</p>	<p>Yes</p>

<p>The modification proposal places the responsibility of mitigating the risks of Unacceptable Sub-Synchronous Oscillations arising because of transmission plant on Transmission Licensees. However, it allows them to partially or fully fulfil this obligation via reasonably specifying some site specific requirements on Transmission System Users. Do you agree to this approach? If no, please clarify your concerns.</p>	<p>Yes.</p> <p>It is noted that in 4.31 that one Transmission Licensee, SPT, has installed SSO monitoring equipment to some of the Synchronous Generating Units connected near the Series Capacitors and the Western HVDC Link. This equipment will allow NGET, SPT, and the User to monitor SSO and ensure that no plant is exposed to Unacceptable SSO risks. This was at the Transmission Licensee's cost.</p> <p>However it is important to confirm that there are no requirements on the User to install any Sub-Synchronous Oscillations protection.</p>
<p>In order to comply with the generic definition of Unacceptable Sub-Synchronous Oscillations, it is expected that, where necessary, Transmission Licensees will specify to a Generator an electrical damping characteristic, in case of Synchronous Generating Units, or a network impedance characteristic, in case of Power Park Modules, and require that the Generator design their plant such that it does not result in Unacceptable Sub-Synchronous Oscillations. Do you agree to that approach? If no, please propose alternatives.</p>	<p>Yes</p>
<p>Do you agree to the general outline proposed for the process of defining and/or agreeing the damping characteristics or the network impedance characteristics? Please highlight any risks that might arise from this approach.</p>	<p>Yes</p>
<p>Do you agree to the generic wording proposed for the Bilateral Agreement set out in Annex 4 of this Consultation Document? Please clarify any concerns.</p>	<p>Yes</p>

<p>Do the modifications proposed protect Transmission Access rights for all Transmission System Users? If not, please specify why.</p>	<p>Yes</p>
<p>Is there any evidence that Users will be inappropriately or adversely affected by the changes proposed? If so please provide details.</p>	<p>No</p>
<p>Do you believe that GC0077 better facilitates the appropriate Grid Code objectives?</p>	<p><i>For reference the applicable Grid Code objectives are:</i></p> <p><i>(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;</i></p> <p><i>(ii) to facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity);</i></p> <p><i>(iii) subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole; and</i></p> <p><i>(iv) to efficiently discharge the obligations imposed upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and/or the Agency.</i></p>
<p>Do you believe that GSR018 better facilitates the appropriate NETS SQSS objectives?</p>	<p><i>For reference the applicable NETS SQSS objectives are:</i></p> <p><i>(i) facilitate the planning, development and maintenance of an efficient, coordinated and economical system of electricity transmission, and the operation of that system in an efficient, economic and coordinated manner;</i></p>

	<p>Yes</p> <p><i>(ii) ensure an appropriate level of security and quality of supply and safe operation of the National Electricity Transmission System;</i></p> <p>Yes</p> <p><i>(iii) facilitate effective competition in the generation and supply of electricity, and (so far as consistent therewith) facilitating such competition in the distribution of electricity; and</i></p> <p>Yes</p> <p><i>(iv) facilitate electricity Transmission Licensees to comply with their obligations under EU law.</i></p> <p>Yes</p>
<p>Do you generally support the modifications proposed by the workgroup? If not, please clarify your concerns.</p>	<p>Yes</p>
<p>Are there any further technical considerations that need to be taken into account?</p>	<p>No</p>
<p>Please provide any other comments you feel are relevant to the proposed changes.</p>	<p>None</p>

SSE Generation

Industry parties are invited to respond to this consultation expressing their views and supplying the rationale for those views, particularly in respect of any specific questions detailed below.

Please send your responses by 09 May 2016 to box.SQSS@nationalgrid.com. Please note that any responses received after the deadline or sent to a different email address may not receive due consideration.

These responses will be included in the Report to the Authority which is drafted by National Grid and submitted to the Authority for a decision.

Respondent:	<i>Damian Jackman</i> SSE Generation, 01412247107 Damian.jackman@sse.com
Company Name:	SSE
Does the modification proposed provide Transmission System Users with enough assurance that their Plant is not going to be subjected to unacceptable risks due to Sub-Synchronous Oscillations? If not, please clarify why.	Yes
Does the modification proposed strike the right balance between operational risks and the cost of constraints required to mitigate this risk? If not, please provide evidence.	Yes
Does the modification proposed strike the right balance between capital investment and operational expenditure? If not, please provide evidence.	Yes
The Workgroup concluded that although the System Instability criteria stipulated within the NETS SQSS apply in principle to Sub-Synchronous Oscillations, the letter of the definition is not necessarily applicable as it is almost impossible to be met. Does this constitute any	

<p>operational risk to the Transmission System and/or User's Plant? If yes, please specify these risks.</p>	
<p>Do you agree that the definitions for Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations should be generic such that it covers all well-established phenomena that might result in Unacceptable SSO; does not restrict Transmission Licensees from investigating any other potential interactions that might arise due to new generation and transmission technologies; and applies equally to all types of generation and transmission plant? If not, please clarify your rationale.</p>	<p>Yes</p>
<p>Do the definitions proposed for both Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations meet the criteria mentioned above? If not, please clarify why.</p>	<p>Yes</p>
<p>Do you agree to the choice of word "Insufficient damping" within the definition of Unacceptable Sub-Synchronous Oscillations rather than specifying a numerical value (e.g. zero)? If not, please advise what level of damping is deemed to be sufficient taking into account the potential differences between different types of plants and between units of the same type but of different rating.</p>	<p>Yes</p>
<p>The modification proposal places the responsibility of mitigating the risks of Unacceptable Sub-Synchronous Oscillations arising because of transmission plant on Transmission Licensees.</p>	<p>How is it agreed what level of monitoring is required and how is a disagreement between an existing generator and the TO resolved? i.e. an existing generator could believe that more</p>

<p>However, it allows them to partially or fully fulfil this obligation via reasonably specifying some site specific requirements on Transmission System Users. Do you agree to this approach? If no, please clarify your concerns.</p>	<p>monitoring is required to safeguard the generator than the TO believes is necessary – how would this be resolved?</p>
<p>In order to comply with the generic definition of Unacceptable Sub-Synchronous Oscillations, it is expected that, where necessary, Transmission Licensees will specify to a Generator an electrical damping characteristic, in case of Synchronous Generating Units, or a network impedance characteristic, in case of Power Park Modules, and require that the Generator design their plant such that it does not result in Unacceptable Sub-Synchronous Oscillations. Do you agree to that approach? If no, please propose alternatives.</p>	<p>Yes – however a new generator who is connecting should have ability to negotiate the most economic solution with the TO which may involve work on the TO's assets rather than solely the new generator's assets.</p>
<p>Do you agree to the general outline proposed for the process of defining and/or agreeing the damping characteristics or the network impedance characteristics? Please highlight any risks that might arise from this approach.</p>	<p>yes</p>
<p>Do you agree to the generic wording proposed for the Bilateral Agreement set out in Annex 4 of this Consultation Document? Please clarify any concerns.</p>	<p>yes</p>
<p>Do the modifications proposed protect Transmission Access rights for all Transmission System Users? If not, please specify why.</p>	
<p>Is there any evidence that Users will be inappropriately or</p>	<p>no</p>

<p>adversely affected by the changes proposed? If so please provide details.</p>	
<p>Do you believe that GC0077 better facilitates the appropriate Grid Code objectives?</p>	<p>Yes</p> <p><i>For reference the applicable Grid Code objectives are:</i></p> <p><i>(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;</i></p> <p><i>(ii) to facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity);</i></p> <p><i>(iii) subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole; and</i></p> <p><i>(iv) to efficiently discharge the obligations imposed upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and/or the Agency.</i></p>
<p>Do you believe that GSR018 better facilitates the appropriate NETS SQSS objectives?</p>	<p>Yes</p> <p><i>For reference the applicable NETS SQSS objectives are:</i></p> <p><i>(i) facilitate the planning, development and maintenance of an efficient, coordinated and economical system of electricity transmission, and the operation of that system in an efficient, economic and coordinated manner;</i></p>

	<p><i>(ii) ensure an appropriate level of security and quality of supply and safe operation of the National Electricity Transmission System;</i></p> <p><i>(iii) facilitate effective competition in the generation and supply of electricity, and (so far as consistent therewith) facilitating such competition in the distribution of electricity; and</i></p> <p><i>(iv) facilitate electricity Transmission Licensees to comply with their obligations under EU law.</i></p>
Do you generally support the modifications proposed by the workgroup? If not, please clarify your concerns.	yes
Are there any further technical considerations that need to be taken into account?	No
Please provide any other comments you feel are relevant to the proposed changes.	-

ScottishPower Generation

Industry parties are invited to respond to this consultation expressing their views and supplying the rationale for those views, particularly in respect of any specific questions detailed below.

Please send your responses by 09 May 2016 to box.SQSS@nationalgrid.com. Please note that any responses received after the deadline or sent to a different email address may not receive due consideration.

These responses will be included in the Report to the Authority which is drafted by National Grid and submitted to the Authority for a decision.

Respondent:	Alastair Frew
Company Name:	ScottishPower Generation
Does the modification proposed provide Transmission System Users with enough assurance that their Plant is not going to be subjected to unacceptable risks due to Sub-Synchronous Oscillations? If not, please clarify why.	Yes, the requirement that no user's equipment shall cause damage to another user's equipment related to SSO is definitive, although users may wish a safety margin this is very difficult to define as a level of "undamage".
Does the modification proposed strike the right balance between operational risks and the cost of constraints required to mitigate this risk? If not, please provide evidence.	Yes
Does the modification proposed strike the right balance between capital investment and operational expenditure? If not, please provide evidence.	Yes
The Workgroup concluded that although the System Instability criteria stipulated within the NETS SQSS apply in principle to Sub-Synchronous Oscillations, the letter of the definition is not necessarily applicable as it is almost impossible to be met. Does this constitute any operational risk to the Transmission System and/or	No

<p>User's Plant? If yes, please specify these risks.</p>	
<p>Do you agree that the definitions for Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations should be generic such that it covers all well-established phenomena that might result in Unacceptable SSO; does not restrict Transmission Licensees from investigating any other potential interactions that might arise due to new generation and transmission technologies; and applies equally to all types of generation and transmission plant? If not, please clarify your rationale.</p>	<p>Yes</p>
<p>Do the definitions proposed for both Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations meet the criteria mentioned above? If not, please clarify why.</p>	<p>Yes</p>
<p>Do you agree to the choice of word "Insufficient damping" within the definition of Unacceptable Sub-Synchronous Oscillations rather than specifying a numerical value (e.g. zero)? If not, please advise what level of damping is deemed to be sufficient taking into account the potential differences between different types of plants and between units of the same type but of different rating.</p>	<p>Yes, as it is impossible to get damping values of zero or greater for all frequencies less than 50Hz as soon as series capacitors are added to the transmission network.</p>
<p>The modification proposal places the responsibility of mitigating the risks of Unacceptable Sub-Synchronous Oscillations arising because of transmission plant on Transmission Licensees. However, it allows them to partially or fully fulfil this</p>	<p>Yes provided the costs of implementing site specific requirements by a user are met by the Transmission Licensees as it is their obligation.</p>

<p>obligation via reasonably specifying some site specific requirements on Transmission System Users. Do you agree to this approach? If no, please clarify your concerns.</p>	
<p>In order to comply with the generic definition of Unacceptable Sub-Synchronous Oscillations, it is expected that, where necessary, Transmission Licensees will specify to a Generator an electrical damping characteristic, in case of Synchronous Generating Units, or a network impedance characteristic, in case of Power Park Modules, and require that the Generator design their plant such that it does not result in Unacceptable Sub-Synchronous Oscillations. Do you agree to that approach? If no, please propose alternatives.</p>	<p>Yes, as previously stated it is impossible to have damping values of above zero for all frequencies, hence negative damping must exist at some frequencies. As system modifications take place the system will be tuned on the basis of existing generation with the negative damping frequencies being set not to cause issues with these generators, hence going forward the simplest solution is to specify requirements on new generation that they must be designed to avoid the frequency bands where negative damping already exists.</p>
<p>Do you agree to the general outline proposed for the process of defining and/or agreeing the damping characteristics or the network impedance characteristics? Please highlight any risks that might arise from this approach.</p>	<p>Yes</p>
<p>Do you agree to the generic wording proposed for the Bilateral Agreement set out in Annex 4 of this Consultation Document? Please clarify any concerns.</p>	<p>Yes</p>
<p>Do the modifications proposed protect Transmission Access rights for all Transmission System Users? If not, please specify why.</p>	<p>In principle yes, however defining a "specific Generator electrical damping characteristic" for a new generator will probably be location specific and hence Users may be restricted from installing certain generator types at certain location, but it is difficult to see how this can be avoided.</p>
<p>Is there any evidence that Users will be inappropriately or</p>	<p>No</p>

adversely affected by the changes proposed? If so please provide details.	
Do you believe that GC0077 better facilitates the appropriate Grid Code objectives?	Yes
Do you believe that GSR018 better facilitates the appropriate NETS SQSS objectives?	Yes
Do you generally support the modifications proposed by the workgroup? If not, please clarify your concerns.	Yes
Are there any further technical considerations that need to be taken into account?	No
Please provide any other comments you feel are relevant to the proposed changes.	No

Horizon Nuclear Power

Industry parties are invited to respond to this consultation expressing their views and supplying the rationale for those views, particularly in respect of any specific questions detailed below.

Please send your responses by 09 May 2016 to box.SQSS@nationalgrid.com. Please note that any responses received after the deadline or sent to a different email address may not receive due consideration.

These responses will be included in the Report to the Authority which is drafted by National Grid and submitted to the Authority for a decision.

Respondent:	<i>Philip Jenner</i> <i>Philip.jenner@horizonnuclearpower.com</i>
Company Name:	<i>Horizon</i>
Does the modification proposed provide Transmission System Users with enough assurance that their Plant is not going to be subjected to unacceptable risks due to Sub-Synchronous Oscillations? If not, please clarify why.	yes
Does the modification proposed strike the right balance between operational risks and the cost of constraints required to mitigate this risk? If not, please provide evidence.	Although the costs of potential constraints have not been quantified, it does appear that the right balanced has been achieved.
Does the modification proposed strike the right balance between capital investment and operational expenditure? If not, please provide evidence.	The proposal has not quantified the potential capital or operational expenditure. It is implied that the most efficient solution to mitigate SSO will be adopted – provided this is demonstrated by a cost benefit analysis that is shared with affected parties the right balance is expected. It is better for the safety and security of the system to spend the money up front to avoid the problems by the design than spend money on constraint payments

<p>The Workgroup concluded that although the System Instability criteria stipulated within the NETS SQSS apply in principle to Sub-Synchronous Oscillations, the letter of the definition is not necessarily applicable as it is almost impossible to be met. Does this constitute any operational risk to the Transmission System and/or User’s Plant? If yes, please specify these risks.</p>	<p>Clearly any insufficient damping of SSO will have a negative impact on synchronous generators, and may be of a level that will cause long term loss of plant life which is difficult to quantify and attribute to a particular source.</p> <p>Monitoring of at-risk plant appears to be the most effect way of mitigating this, but any monitoring has to go hand-in-hand with an agreed plan on what actions to take if unacceptable levels are observed</p>
<p>Do you agree that the definitions for Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations should be generic such that it covers all well-established phenomena that might result in Unacceptable SSO; does not restrict Transmission Licensees from investigating any other potential interactions that might arise due to new generation and transmission technologies; and applies equally to all types of generation and transmission plant? If not, please clarify your rationale.</p>	<p>Yes</p>
<p>Do the definitions proposed for both Sub-Synchronous Oscillations and Unacceptable Sub-Synchronous Oscillations meet the criteria mentioned above? If not, please clarify why.</p>	<p>Yes</p>
<p>Do you agree to the choice of word “Insufficient damping” within the definition of Unacceptable Sub-Synchronous Oscillations rather than specifying a numerical value (e.g. zero)? If not, please advise what level of damping is deemed to be sufficient taking into account the potential differences between</p>	<p>Yes</p>

<p>different types of plants and between units of the same type but of different rating.</p>	
<p>The modification proposal places the responsibility of mitigating the risks of Unacceptable Sub-Synchronous Oscillations arising because of transmission plant on Transmission Licensees. However, it allows them to partially or fully fulfil this obligation via reasonably specifying some site specific requirements on Transmission System Users. Do you agree to this approach? If no, please clarify your concerns.</p>	<p>In the majority of cases, no.</p> <p>Only in circumstances where it can be clearly demonstrated that a site specific solution is the most economic and practical way to mitigate SSO can transmission licensees apply additional requirements on the user. However, the obligation to mitigate SSO should remain with transmission licensees (i.e the licensee must still ensure the mitigation is acceptable)</p> <p>If site specific requirements on generators are applied, they should not require Users to make costly or technically unproven modifications to their plant. i.e. installing monitoring or alarms is OK, making custom modifications to plant is not.</p>
<p>In order to comply with the generic definition of Unacceptable Sub-Synchronous Oscillations, it is expected that, where necessary, Transmission Licensees will specify to a Generator an electrical damping characteristic, in case of Synchronous Generating Units, or a network impedance characteristic, in case of Power Park Modules, and require that the Generator design their plant such that it does not result in Unacceptable Sub-Synchronous Oscillations. Do you agree to that approach? If no, please propose alternatives.</p>	<p>No. It is highly unlikely that a re-design of the turbine-generator characteristics will be the optimal solution. There are many other design criteria for this plant that are of higher priority and the selection of series compensation/HVDC technologies by other parties should not force developers and designers to make bespoke site specific plant. This will increase costs and technical risks.</p> <p>The generator is responsible to identify if there is a risk of SSO, but changing the design is not the default (or likely) solution. Mitigation measures external to the power plant may represent better value, and potentially give the System Operator more flexibility in future. A CBA is required to demonstrate what the best solution is.</p> <p>HNP is not aware of technical solutions that will easily add a known amount of damping to torsional modes of vibration to a turbine generator. Hence there is a large technical and cost risk.</p> <p>It would be helpful if National Grid can identify</p>

	credible technical solutions before we could agree such words that might place an obligation on generators to do something.
Do you agree to the general outline proposed for the process of defining and/or agreeing the damping characteristics or the network impedance characteristics? Please highlight any risks that might arise from this approach.	Yes
Do you agree to the generic wording proposed for the Bilateral Agreement set out in Annex 4 of this Consultation Document? Please clarify any concerns.	<p>I disagree with the wording below in respect of synchronous plant who are affect by external SSO sources</p> <p><i>“The User₂ shall ensure that all Sub-Synchronous Oscillations that may arise from interactions between the User’s Generating Unit(s) and the National Electricity Transmission System are sufficiently damped.”</i></p> <p>Obligations placed on owners of SSO sources applied via 6.3.16 and 6.1.9 should not be transferred to other parties.</p> <p>It is in the affected parties’ interest to monitor and ensure SSO does not exist, but they shall not be obligated to ensure SSO does not arise – for certain mitigation designs they will not even have the ability to control the level of SSO so are not even in a position to meet this requirement.</p> <p>It should be recognised that existing synchronous machine designs do not suffer SSO – this potential risk is entirely the result of actions by TSOs installing series capacitor compensation or others installing HVDC converter stations.</p>
Do the modifications proposed protect Transmission Access rights for all Transmission System Users? If not, please specify why.	yes
Is there any evidence that Users will be inappropriately or adversely affected by the changes proposed? If so please provide	<p>The subject of compensation for damage caused to users’ plant as a result of another party has not been addressed.</p> <p>In the event that SSO damage can be directly</p>

<p>details.</p>	<p>linked to an SSO source which has not been mitigated correctly, the compensation to the affected users must be reasonable.</p> <p>Also, in cases when the most economic mitigation can be demonstrated to be User Works, it is the affected generator that must pay whereas for Enabling Works this cost is shared. This is not a consistent charging approach.</p>
<p>Do you believe that GC0077 better facilitates the appropriate Grid Code objectives?</p>	<p><i>For reference the applicable Grid Code objectives are:</i></p> <p><i>(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;</i></p> <p>Yes</p> <p><i>(ii) to facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity);</i></p> <p>No, as user works are charged differently to enabling works. Adversely affected users may also be subject to greater technical risks without sufficient compensation measures in place.</p> <p><i>(iii) subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole; and</i></p> <p>Yes</p> <p><i>(iv) to efficiently discharge the obligations imposed</i></p>

	<p><i>upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and/or the Agency.</i></p> <p>No, the transmission licensee's should not be able to pass their obligations on to users.</p>
<p>Do you believe that GSR018 better facilitates the appropriate NETS SQSS objectives?</p>	<p><i>For reference the applicable NETS SQSS objectives are:</i></p> <p><i>(i) facilitate the planning, development and maintenance of an efficient, coordinated and economical system of electricity transmission, and the operation of that system in an efficient, economic and coordinated manner;</i></p> <p>Yes</p> <p><i>(ii) ensure an appropriate level of security and quality of supply and safe operation of the National Electricity Transmission System;</i></p> <p>Yes</p> <p><i>(iii) facilitate effective competition in the generation and supply of electricity, and (so far as consistent therewith) facilitating such competition in the distribution of electricity; and</i></p> <p>No, as user works are charged differently to enabling works. Adversely affected users may also be subject to greater technical risks without sufficient compensation measures in place.</p> <p><i>(iv) facilitate electricity Transmission Licensees to comply with their obligations under EU law.</i></p> <p>No, the transmission licensee's should not be able to pass their obligations on to users.</p>
<p>Do you generally support the modifications proposed by the workgroup? If not, please clarify</p>	<p>The proposed wording on p45 of the consultation report requires modifying.</p> <p>The handling of user works and enabling works</p>

your concerns.	costs needs to be consistent and fair Transmission licensees should not be able to transfer to others their obligations as written in the grid code and SQSS.
Are there any further technical considerations that need to be taken into account?	No
Please provide any other comments you feel are relevant to the proposed changes.	