GC0076 Grid Code Limits On Rapid Voltage Changes

What stage is this document at?

01	Working Group Report
02	Industry Consultation
03	Report to the Authority

This document describes revised proposals to modify the Grid Code limits on the Rapid Voltage Changes which can occur because of planned Transmission system and Transmission User operations

This document is open for Industry Consultation. Any interested party is able to make a response in line with the guidance set out in Section 6 of this document.

Published on: **17 February 2015**
Length of Consultation: **20 Working Days**
Responses by: **17 March 2015**

National Grid recommends:
Implementation of changes to the Connection Conditions to allow for cheaper connections to the transmission networks

High Impact:
None identified

Medium Impact:
Transmission Licensees
Network Operators
Offshore and Onshore Generators

Low Impact:
None identified

Contents

Any Questions?

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About this document

This Industry Consultation outlines the information required for interested parties to form an understanding of a defect within the Grid Code. It contains proposals first consulted upon in April 2014 which have been revised in response to comments received. The consultation seeks the views of interested parties in relation to the issues raised by this document.

Parties are requested to respond by **17 March 2015** to grid.code@nationalgrid.com

Document Control

Version	Date	Author	Change Reference
0.1	4 January 2015	National Grid	Draft Consultation for Panel Review
1.0	17 February 2015	National Grid	Consultation

1 Executive Summary

1.1 This consultation document describes proposals to modify Grid Code limits on Rapid Voltage Changes.

1.2 The issue paper "GC0076 Grid Code Limits On Rapid Voltage Changes" (pp11/24) was submitted to the Grid Code Review Panel on 19 May 2011[1]. National Grid submitted a revised proposal to the Panel on 15 January 2014. The Panel asked for the proposal to progress to Industry Consultation for 20 business days subject to incorporation of comments from Panel members.

1.3 An Industry Consultation was published on 02 April 2014 for 20 business days[2]. Seven responses were received. A majority were supportive of the proposed changes but some concerns and suggestions for improvements were raised. This consultation contains revised proposals which seek to address the concerns raised in consultation responses.

1.4 The Grid Code sets out criteria relating to "Voltage Fluctuations" at a Point of Common Coupling within CC.6.1.7. This clause includes references to step changes, voltage excursions and a cross reference to Engineering Recommendation P28 for the Transmission System in Scotland.

1.5 CC.6.1.7 (a) states that "large voltage excursions other than steps" may be allowed, up to a level of 3%. The limit applies regardless of the impact of an "excursion", either in duration, frequency or repetitiveness of the occurrence.

1.6 Voltage changes of greater than 3% have been observed coincident with the energisation of transmission Users' transformers. These voltage changes, which are associated with transformer energisation, are short-lived and occur infrequently. A number of developers have indicated that they have not yet found a way to meet the existing limits in future projects.

1.7 This document recommends revisions to the Grid Code to give due account to short lived, infrequent and non-repetitive voltage changes. This change would remove the need for disproportionate additional investment in equipment and changes to connection designs whilst maintaining current standards of safety, security and quality of supply to customers.

1.8 The Grid Code requirements are specified at a Point of Common Coupling. As several users can be connected at one site there is potential for voltage changes to become frequent or repetitive. Consequently the revisions specify that, for new connections, User switching may be restricted at a site where this would contribute to unacceptable voltage performance at the site.

National Grid Recommendation

1.9 National Grid supports the implementation of GC0076 as it better facilitates the Applicable Grid Code Objectives.

1.10 This is achieved by setting clear limits on the magnitude and duration of Rapid Voltage Changes. The new limits allow for larger short duration voltage changes to occur than is currently permitted meaning that new connection designs can be simpler and cheaper. The interests of other network users are protected because the limits are clearly time bound such that the largest voltage changes have to be demonstrated to be limited in duration and frequency of occurrence as well as magnitude.

[1] The proposals were developed and subsequently refined by Dr Forooz Ghassemi of National Grid, initially in paper PP 11/51 which can be found on the GC0076 page under the "Issue Proforma" tab. The direct link is: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=27869

[2] The April 2014 consultation can be found on the GC0076 page under the "Industry Consultation" tab. The direct link is: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=32478

2 Why Change?

Grid Code, SQSS and Engineering Recommendation Context

2.1 The voltage change criteria applicable to the National Electricity Transmission System (NETS) are set out in a number of documents.

2.2 The SQSS sets out step change limits applicable to operational switching and to secured events (ie faults) which the NETS needs to be designed and operated within. A 3% limit applies to operational switching, with 6% and 12% limits applied to secured events. The SQSS also includes a cross reference to Engineering Recommendation P28.

2.3 The SQSS definitions also state that the voltage step limits apply at the "end of the transient time phase", where the transient time phase is "typically 0 to 5 seconds after an initiating event". The transient time phase is also described as the time within which "transient decay and recovery occurs".

2.4 The Grid Code specifies criteria on "Voltage Fluctuations" to be applied "at a Point of Common Coupling with a fluctuating Load" in CC.6.1.7. These criteria apply to changes in voltage following a number of possible patterns including dips, ramps and steps. The current text is:

> "CC.6.1.7 Voltage fluctuations at a **Point of Common Coupling** with a fluctuating **Load** directly connected to the **Onshore Transmission System** shall not exceed:
>
> (a) In England and Wales, 1% of the voltage level for step changes which may occur repetitively. Any large voltage excursions other than step changes may be allowed up to a level of 3% provided that this does not constitute a risk to the **National Electricity Transmission System** or, in **NGET's** view, to the **System** of any **User**. In Scotland, the limits for voltage level step changes are as set out in **Engineering Recommendation** P28."

2.5 Note that the Voltage Fluctuation criteria within CC.6.1.7 (b) includes Flicker, but it is not considered necessary to review this as the treatment of flicker is well defined in IEC documentation and the Grid Code is consistent with this.

2.6 The Grid Code also sets out requirements on Transmission Users to ride through faults, including events (voltage dips) where voltage goes to zero for up to 140ms, or for longer in some circumstances. Again, these requirements have not been reviewed for the purposes of this consultation.

Impact of Voltage Changes

2.7 Voltage changes of limited magnitude, duration and frequency affect power quality but do not have a direct impact on the safety and security of a network. Their impact can be observed on perceived levels of electric lighting for example.

2.8 Beyond a certain point, voltage changes can impact adversely on the operation of network customers' equipment (eg motors, computing equipment), including generating station auxiliaries. Some industrial processes are known to use low voltage relays to protect the equipment concerned. There is therefore a continuing need to manage voltage

changes, including the impact of any limits on users creating voltage changes and the impact on users affected by voltage changes.

Impact of the Current Grid Code Criteria

2.9 CC.6.1.7 imposes an absolute ceiling of 3% on the magnitude of voltage fluctuations at a Point of Common Coupling in England and Wales. For sites in Scotland there is a cross reference to P28 for voltage steps, to which P28 imposes a limit of 3%. The requirement as currently expressed is equally applicable to events which occur frequently (eg a number of times per day) or occur once or twice a year, and events which are short lived or events which have a semi-permanent effect.

2.10 Additional equipment can be needed in order to make sure that the 3% limit can be met under all circumstances. Mitigation measures can include Point on Wave controlled switching equipment, additional switchgear and reconfiguration and/or re-design of the Transmission network up to and including the construction of additional circuits. For some design choices, in certain locations, it is not possible to stay within the 3% limit.

2.11 Where the voltage change of concern is short lived (in the case of transformer energisation this is likely to be less than 1 second), and is caused by re-energisation after maintenance, this can mean that additional equipment is needed to deal with an effect which occurs for a few seconds over the lifetime of the plant concerned. In cases where no Transmission Users are adversely affected, the case for such investment is weak.

3 Solution

Proposed Solution

3.1 The proposals in this document are based on a review of international experience, equipment specifications and academic research. The numbered references quoted in the text below within square brackets are listed in Annex 3. The proposals also incorporate changes arising from feedback to the GC0076 consultation in April 2014 which are explained further in Section 4 of this document.

Definitions

3.2 EN 50160 [1] defines a supply voltage 'dip' as a sudden reduction of the supply voltage to a value of between 90% and 10% of the declared voltage (ie greater than 10%), followed by a voltage recovery after a short period of time. Conventionally the duration of a voltage dip is between 10 ms and 1 minute.

3.3 The depth of a voltage dip is defined as the difference between the minimum root mean square (rms) voltage during the voltage dip and the declared voltage. Voltage changes which do not reduce the supply voltage to less than 90% of the declared voltage are not considered to be dips.

3.4 EN 50160 defines a Rapid Voltage Change (RVC) as a voltage variation of less than 10%. IEC 61000-2-1 [2] states that; 'Voltage fluctuations can be described as a cyclical variation of the voltage envelope or a series of random voltage changes the magnitude of which does not normally exceed the range of operational voltage changes mentioned in IEC 38 (up to ± 10 %).'

Characterisation and Quantification of a Rapid Voltage Change

3.5 A Rapid Voltage Change is defined [3] as a change in the rms value of a voltage signal that moves from a steady state value to a maximum change and then gradually varies and settles at a new level determined by $V_{steadystate}$. It is characterised by a maximum depth, ΔV_{max}, duration (T) and new steady state value (see Figure 1).

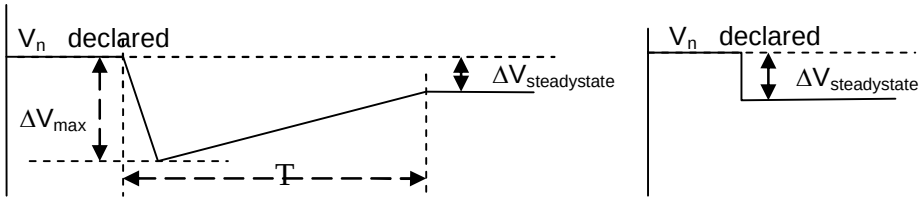

Figure 1: RVC Characterisation

3.6 In order for the event to be classified as a RVC, ΔV_{max} should be less than ±10%. Voltage changes with larger depth are generally classified as voltage dips as above.

3.7 References [4] and [5] have provided significant contribution in the analysis of RVCs. SINTEF and Norwegian Water Resources and Energy Directorate have published the results of their investigations in Reference [4].

3.8 This work included a survey for visibility of light when supply voltage changes. Ninety six people of different age groups (students to pensioners) took part.

3.9 The results of the survey suggested:

- Even a 2% instantaneous voltage change is visible for the majority of the population (67%). For 5% instantaneous voltage change 100% of the population noticed the change in light levels;

- There was a marked difference between the light perceptions of population when RVCs caused by motor start were considered. For the maximum voltage change of 5% and time to stationary voltage of 0.5seconds, 68% of population noticed the light change; and

- Most people will notice a change in light when the rate of change of rms voltage averaged over one second is greater than 0.5% ($dV/dt \geq 0.5\%$).

3.10 We understand that these findings were used in the development of limits for RVCs in the Norwegian Grid Code which were set at ±10%. Exactly the same limits have been used in the Swedish Grid Code. It should be noted however that RVCs due to inrush current from transformers appear to be excluded from these criteria, along with faults, fault restoration and actions taken to improve quality of supply as a whole.

Review and Assessment

3.11 The main objective of this review is to ensure that proposals are developed in the full knowledge of whether the effect of Rapid Voltage Changes is an immunity and compatibility issue (which causes damage or disruption) or an issue of nuisance to customers. An extensive literature survey was carried out and a large number of references were collected to determine:

- The impact of voltage variations other than voltage dips on domestic and industrial equipment;
- The relationship between equipment immunity levels and voltage variations; and
- Human eye perception sensitivity level to voltage variations.

Immunity of Electrical Equipment

3.12 Reference [6] sets out the test procedure for equipment connected to a low voltage (up to 1kV) network, which includes domestic appliances. Class 1 products are tested on a case by case basis. Class 2 products are tested for defined voltage changes up to 70% of the nominal voltage for 25 cycles (0.5 seconds) and Class 3 products are tested up to 70% for 250 cycles (5 seconds).

3.13 Reference [7] requires that all products with currents less than 16A per phase are tested for voltage changes. For Class 1, no test is required. For Class 2, the change in voltage ΔV to be considered is ±8% of V_n for equipment intended for connection to public networks or other lightly disturbed networks. For Class 3, the test voltage is ΔV=±12% of V_n for equipment connected to heavily disturbed networks (i.e. industrial networks). The test duration for class 3 is relatively long at 5 seconds.

3.14 CIGRE working group C4.110 published their report [8] in 2010 after investigating a wide range of equipment and industrial processes. All equipment and processes examined withstood voltage changes of up to 10%. A large number of processes were examined in a separate exercise looking at Process Immunity Time (PIT) [9] and shown to withstand voltage changes of 20% for at least 3 seconds.

3.15 ERA Technology surveyed voltage dip immunity in industrial and commercial power distribution systems in 1999 [10]. The report concludes that the immunity levels of all equipment surveyed were higher than 10% voltage

change. It appeared that the most sensitive equipment type was variable speed drives which could though ride through a voltage change of 100% for about 60 to 70 ms.

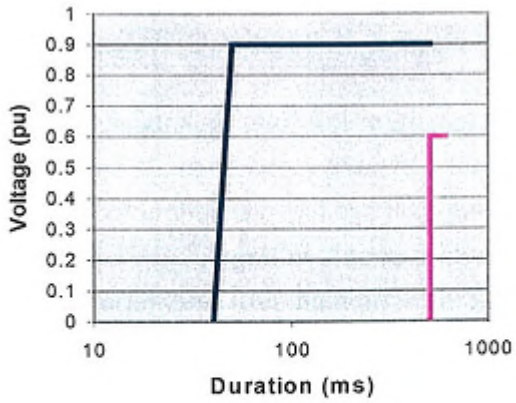

Figure 2: Sample measured maximum and minimum sensitivities of a variable speed drive

(Figure sourced from ERA Technology Ltd's "How to Improve Voltage Dip Immunity in Industrial and Commercial Power Distribution Systems" publication at www.era.co.uk)

3.16 Reference [11] shows that all commercially available variable speed drives tested did not trip for three phase voltage changes of motor start type of up to 72%.

3.17 Reference [12] studied the susceptibility of Personal Computers (PCs), high pressure sodium (HPS) lamps, fluorescent lamps and industrial ac contactors for to voltage dips of variable depth, angle and duration. The paper illustrates a generic curve that shows that all equipment maintains correct operation for a 20% voltage dip lasting for 1 second. Reference [13] examined PCs, gas discharge lamps and industrial contactors. It states that all contactors tested tolerated 70% of voltage with dip duration effect. HPS lamps were found to be the most sensitive to a no voltage (100% dip) which can be tolerated for only 0.5 to 1 cycle but they could ride through a voltage dip of 20% (voltage of 80%). More rigid lamp standards allow 90% of the nominal voltage for continuous operation.

3.18 Electric synchronous and asynchronous motors are more tolerant to voltage changes than other equipment because of their inertia. They can ride through voltages of 70% of nominal for longer than 1 second [14].

3.19 In conclusion, no evidence was found amongst the literature surveyed that a voltage change of 10% over a limited period affects equipment and industrial processes supplied by the public network. Thus, setting a limit for RVCs is not an equipment immunity problem but rather an issue of visibility and annoyance to customers.

Relationship of Rapid Voltage Changes to Flicker

3.20 Repetitive changes in voltage, such as those generated by arc furnaces for example, are captured by the standards relating to Flicker. The Rapid Voltage Changes described above are different in nature in that they are not repetitive and need to be treated as discrete events.

3.21 However, if a number of Rapid Voltage Changes occur in relatively quick succession, they could potentially have a similar effect on visual disturbance.

3.22 By applying the Flicker level calculation method to the Rapid Voltage Change characteristic described above it is possible to derive a limit on the

number of occurrences per day which would ensure there was no impact on flicker levels. Such a limit provides assurance that visual disturbance levels would not exceed those to which network users are currently exposed.

3.23 For RVCs up to 12%, the equivalent limit is approximately 7 per day based on the 95th percentile of P_{st} and P_{lt} over one week [3]. In order to provide an additional assurance, the proposal set out in this consultation sets a maximum limit of 4 per day on the largest category of Rapid Voltage Change. This limit is based on the number of changes experienced by customers at a site, and may therefore require lower limits to be applied to connectees at sites where more than one may cause significant changes. As there are no current system operational issues with RVCs, the proposal allows for application of these lower limits to new connections only.

Relationship between EHV and LV networks during Rapid Voltage Changes

3.24 The majority of network customers are connected to Low Voltage networks. Therefore, in developing the Rapid Voltage Change criteria to be applied to the Transmission System within the Grid Code, it is essential to consider how a rapid voltage change will propagate to the point of connection for most customers.

3.25 The relationship between voltage levels can be expressed in terms of transfer coefficients. The actual transfer coefficient at any particular point of common coupling will depend on the network topology, loads, embedded generators and transformer winding arrangements (which can have the effect of redistributing unbalanced voltage changes across the phases giving them a smaller magnitude). IEC 61000-3-7 gives guidance on the transfer coefficient which should be assumed between EHV and LV networks and advises that a coefficient of 1.0 should be applied for repetitive voltage changes.

3.26 Reference [15] explores the relationship between voltages at EHV and LV and provides evidence by analysis and measurement that a coefficient of less than 1.0 can be assumed, driven in part by the voltage dependency of electricity demand (demand reduces as voltage falls), as does Reference [8], the CIGRE Working Group C4.110 report, "Voltage dip immunity of equipment and installations"

Proposal

3.27 The total number of Rapid Voltage Changes (ΔV) from all connectees should not exceed the following limits specified in Table 1 at the point of common coupling with the stated frequency of occurrence.

Category	Maximum number of occurrences	$\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$
1	No Limit	$\%\Delta V_{max} \leq 1\%$ & $\%\Delta V_{steadystate} \leq 1\%$
2	no more than 4 per hour	$\%\Delta V_{max} \leq 3\%$ & $\%\Delta V_{steadystate} \leq 3\%$

Category	Maximum number of occurrences	$\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$
3	no more than 4 per day for Commissioning, Maintenance and Fault Restoration	For decreases in voltage: $\%\Delta V_{max} \leq 12\%$* & $\%\Delta V_{steadystate} \leq 3\%$ For increases in voltage: $\%\Delta V_{max} \leq 5\%$ & $\%\Delta V_{steadystate} \leq 3\%$ (see Figure 3)

* 12% is permissible for up to 80ms as highlighted in the shaded area in Figure 3

Where: $\%\Delta V_{steadystate} = 100 \times \Delta V_{steadystate} / V_0$

and $\%\Delta V_{max} = 100 \times \Delta V_{max} / V_0$

Table 1: Limits for Rapid Voltage Changes

3.28 For new connections, it is proposed that Bilateral Agreements may include clauses that will allow the System Operator to restrict switching activity where this will lead to operation at the site outside of the limits in Table 1.

Categories 1 and 2 Rapid Voltage Change

3.29 The proposed limits fall within the criteria currently specified within the current Grid Code requirements.

Category 3 Rapid Voltage Change

3.30 For this category of Rapid Voltage Changes, operations are restricted to those required for commissioning, planned maintenance and fault restoration which are infrequent in nature. The cost benefit case for applying tighter limits is weak in these situations as the cost of mitigation would be spread across a limited number of short occurrences.

3.31 The proposed time dependent characteristic is shown in Figure 2.

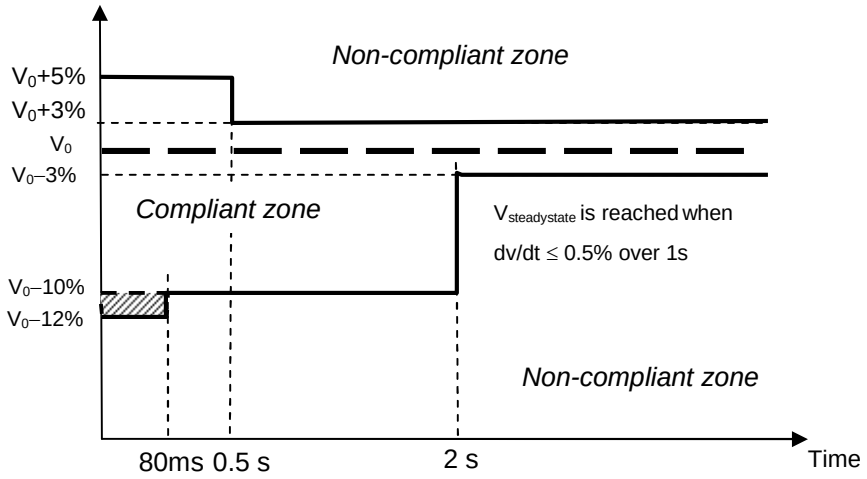

Figure 3: Limits for Category 3 Rapid Voltage Changes

3.32 Note also that:

1) V_0 is the initial steady state system voltage;

2) All voltages are the root mean squared (rms) of the voltage measured over one cycle and refreshed every half a cycle as per IEC 61000-4-30 [16];

3) A steady state voltage is said to have been reached when dv/dt ≤ 0.5%, with reference to the rms of voltage averaged over 1 second;

4) The shaded area is proposed as it is in accordance with the 12% voltage change stipulated in NETS SQSS. The duration of the maximum allowable depth (V_0 - 12%) has been specified in coordination with fast acting voltage controllers;

5) The voltage changes specified are the absolute maximums allowed, applied to phase to ground or phase to phase voltages whichever are the highest by %. Thus in order to determine maximum voltage changes, assessments should consider propagation of voltage changes to other voltage levels through three phase transformers with different winding arrangements.

Applicability of New Grid Code Provisions

3.33 As explained in section 2 of this document, CC.6.1.7 expresses similar criteria in different ways to be applied to networks in England and Wales and to networks in Scotland. In order to ensure Transmission Users are treated equitably it is desirable to remove these regional differences in any new proposals.

3.34 No changes are proposed to the arrangements for connection to offshore transmission networks which are site-specific reflecting the nature of current offshore network designs.

3.35 The proposed solution is consistent with the NETS SQSS provisions for voltage changes treated as steps. The NETS SQSS limits apply at the "end of the transient time phase" and the transient time phase is "typically 0 to 5 seconds after an initiating event". Therefore no consequential changes to the SQSS have been identified in this consultation.

4 Previous Consultation Responses

4.1 National Grid has previously consulted Authorised Electricity Operators (AEOs) on this issue. This consultation opened on 2 April 2014 and closed on 2 May 2014. Seven responses were received during the consultation period. National Grid would like to thank all of the respondents for their comments.

4.2 The table below provides an overview of the 7 responses received. Copies of the responses are included in Annex 2.

Ref	Company	Supportive	Comments
GC0076-CR-01	Electricity North West	Yes	• Do not think it is appropriate to write limits into the bilateral agreement • Changes proposed protect the interests of users
GC0076-CR-02	Northern Powergrid	Yes	• Proposal minimised the requirement to install equipment to unnecessarily limit voltage changes • Should not be an adverse effect on users
GC0076-CR-03	RES Ltd	Yes	• Welcomes the intent of the proposals but questions some of the detail • The proposed changes should apply to all parties equally
GC0076-CR-04	RWE Supply and Trading GmbH	Mixed	• Welcomes new limits • Concerned about restrictive bilateral arrangements • Clarification required in categorisation • Questions derivation of limits
GC0076-CR-05	Scottish Power Renewables	No	• Requirements are too restrictive • Inconsistency with P28 Categorisation unclear
GC0076-CR-06	Scottish Power Generation	Yes	• Proposed table CC.6.1.7 needs to be clarified
GC0076-CR-07	Western Power Distribution	No	• Some customers with processes sensitive to voltage dips will be affected • Proposed frequency of occurrence is too high • Proposal should be aligned with Distribution Code (10% maximum, once per year)

National Grid Comments on Responses

4.3 National Grid representatives' comments on the seven responses received are summarised below. In a number of cases, comments and suggestions have been incorporated in changes to the original legal text proposals with new text provided in Annex 2. The changes are described below.

4.4 A number of the responses questioned the need for the text "Bilateral Agreements may include provision for NGET to reasonably limit the number of voltage changes in category 2 or 3". One response suggested that additional text should be included, which is similar to current provisions, to limit the circumstances in which a restriction could be imposed to those which represented a genuine risk to other Users.

4.5 National Grid's view is that there will be a need to be able to manage the impact of Rapid Voltage Changes under the criteria proposed at some sites. This would be expected to occur at sites with multiple users, where network strength is relatively low, and there is a risk of disruption to a network user or users.

4.6 National Grid's view is therefore that this provision should be retained with the addition to the proposed legal text of the suggested words "and where voltage changes would constitute a risk to the National Electricity Transmission System or, in NGET's view the System of any User".

4.7 One consultation response asked whether the proposals could be considered discriminatory as they imposed limits on Users but not on transmission companies. National Grid does not believe the proposals are discriminatory as they apply equally to transmission companies as they do to Users.

4.8 A number of the respondents said that the categorisation and description proposed in table CC6.1.7 was unclear and suggestions were provided for improvements to the table.

4.9 Another response stated that the proposals were restrictive and highly inconsistent with current provisions in Engineering Recommendation P28 which the Grid Code applies to connections in Scotland. Subsequent discussion revealed that the majority of the concerns arose because the respondent interpreted the table in a way which did not reflect the intent of the proposals and that these could be addressed by improvements to the table.

4.10 One of the concerns raised was over the limit of 2 per hour on the number of occurrences of "Category 2" voltage changes. This is inconsistent with ER P28 which effectively allows 4 occurrences per hour. The proposed new legal text has been amended to 4 occurrences per hour to be consistent with ER P28.

4.11 Suggested changes and improvements to table CC6.1.7 have been included in the revised proposals. Table 2 below is the version presented in the first consultation document. Table 3 is the amended version included in the legal text in Annex 1 of this document. One response highlighted that times were missing from the x-axis of the Figure CC.6.1.7 which has been corrected in the proposed text.

Category	Maximum number of occurrences (n)	$\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$
1	No Limit	$\%\Delta V_{max} \leq 1\%$ & $\%\Delta V_{steadystate} \leq 1\%$
2	For $n \leq 2$ per hour & $n > 4$ per day	$\%\Delta V_{max} \leq 3\%$ & $\%\Delta V_{steadystate} \leq 3\%$
3	Commissioning, Maintenance and Fault Restoration up to $n \leq 4$ per day	$\%\Delta V_{max} \leq 12\%$ & $\%\Delta V_{steadystate} \leq 3\%$ (see Figure CC6.1.7)

Table 2: Table CC6.1.7 from April 2014 Consultation

Category	Maximum number of occurrences	$\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$
1	No Limit	$\%\Delta V_{max} \leq 1\%$ & $\%\Delta V_{steadystate} \leq 1\%$
2	no more than 4 per hour	$\%\Delta V_{max} \leq 3\%$ & $\%\Delta V_{steadystate} \leq 3\%$
3	no more than 4 per day for Commissioning, Maintenance and Fault Restoration	For decreases in voltage: $\%\Delta V_{max} \leq 12\%$* & $\%\Delta V_{steadystate} \leq 3\%$ For increases in voltage: $\%\Delta V_{max} \leq 5\%$ & $\%\Delta V_{steadystate} \leq 3\%$ (see Figure CC6.1.7)

* 12% is permissible for up to 80ms as highlighted in the shaded area in Figure CC6.1.7

Table 3: Proposed new table CC6.1.7

4.12 One of the responses raised significant concerns that the proposals would adversely affect network users with processes sensitive to voltage dips, that the proposals allow for too many rapid voltage changes to occur and that a change of 12% was too large. The respondent also provided examples of customer complaints in follow up discussions.

4.13 In developing the proposals in this document, National Grid has used the information available to it to establish limits which do not present unacceptable risks to other network users. There are key features in the proposal which help achieve this:

- The circumstances in which Category 3 voltage changes (the largest ones) are acceptable are restricted to Commissioning, Maintenance and Fault Restoration;
- Voltage changes up to 12% are restricted in duration to 80ms which is shorter than the times generally used in voltage based protection and the time required to affect electrical equipment; and
- Where there is a demonstrable risk to a network user, the number of voltage changes can be limited.

4.14 At this time, National Grid's view is that the proposed changes result in a very small increase in the risk of infrequent events adversely affecting sensitive network users which is outweighed by the benefits of the change in clarifying the need for additional investment. The benefits are that the proposed requirements are clearer than the current provisions, and that they allow for cheaper and simpler connections to the transmission networks. In the absence of a change, it is likely that specialist solutions will have to be deployed in order to comply with the 3% voltage change limit set by the current provisions. Where system strength is low, it will become difficult to achieve compliance when energising standard sizes or designs of transformers leading to more operational restrictions and potential derogations.

4.15 Finally, a number of the responses suggested that more research and

analysis would help inform the development of proposals. National Grid's view is that further research could be valuable but that there is a need to move away from the current unsustainable provisions. Further research can be factored in to future reviews of voltage change requirements as system conditions develop. It should be noted that work to review Engineering Recommendation P28 has commenced and that this may inform further changes to the Grid Code at an appropriate time.

4.16 As described above, National Grid's view is that the Grid Code should be changed to implement new provisions for Rapid Voltage Changes. The draft legal text required to implement the change is given in Annex 1 to this consultation. National Grid believes that this further consultation is required due to the number of small changes made to the proposed legal text compared to the previous version and to provide another opportunity to seek views on the potential risks of the proposed changes.

5 Impact & Assessment

Impact on the Grid Code

5.1 GC0076 requires amendments to the Connection Conditions, CC.6.1.7 paragraph (a)

Impact on National Electricity Transmission System (NETS)

5.2 The proposal will allow larger Rapid Voltage Changes to occur up to defined limits and will lift a potential restriction on the use of transformers of a standard size and design.

Impact on Grid Code Users

5.3 The proposal will allow Users to use standard transformers and connection arrangements. The impact on electricity end consumers will be limited such that there will be no material change to observed power quality.

Impact on Greenhouse Gas emissions

5.4 None

Assessment against Grid Code Objectives

5.5 National Grid considers that GC0076 Grid Code Limits on Rapid Voltage Changes 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

by facilitating standard connection arrangements and equipment choices leading to cheaper connections

(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 facilitating standard connection arrangements and equipment choices leading to cheaper connections

(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

by setting clear limits on the magnitude and duration of Rapid Voltage Changes

(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 proposed change is consistent with international standards and practice but is not directly impacted by any of the current drafts of the European Commission's codes or regulations

Impact on core industry documents

5.6 The proposed modification does not impact on any core industry documents

Impact on other industry documents

5.7 The proposed modification does not impact on any other industry documents

Implementation

5.8 National Grid proposes GC0076 should be implemented 10 business days after an Authority decision.

6 Responding to this Consultation

6.1 Views are invited upon the proposals outlined in this consultation, which should be received by 17 March 2015.

6.2 Your formal responses may be emailed to grid.code@nationalgrid.com.

6.3 The proposals set out in this consultation are intended to better meet the Grid Code Objectives. To achieve this, they are intended to facilitate efficient and economic connection arrangements whilst ensuring there is no impact on the safety and security of the transmission system, and no discernible impact on the visual disturbance to electricity consumers.

6.4 Responses are invited to the following questions:

(i) Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?

(ii) Can you provide any example(s) of disruption caused by Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposals presented in this consultation?

(iii) Do you believe that GC0076 better facilitates the appropriate Grid Code objectives as described in Section 5 of this document?

(iv) Please provide any other comments you feel are relevant to the proposed change.

6.5 If you wish to submit a confidential response please note the following:

(i) Information provided in response to this consultation will be published on National Grid's website unless the response is clearly marked "Private and Confidential", in which case we will contact you to establish the extent of the confidentiality. A response marked "Private and Confidential" will be disclosed to the Authority in full but, unless agreed otherwise, will not be shared with the Grid Code Review Panel or the industry and may therefore not influence the debate to the same extent as a non-confidential response.

(ii) Please note an automatic confidentiality disclaimer generated by your IT System will not in itself mean that your response is treated as if it had been marked "Private and Confidential".

Annex 1 - Proposed Legal Text

This section contains the proposed and amended legal text to give effect to the proposals. The proposed new text is in red and is based on Grid Code Issue 5 Revision 0.

Connection Code

"CC.6.1.7 Voltage ~~fluctuations~~ changes at a **Point of Common Coupling** ~~with a fluctuating **Load** directly connected to~~ on the **Onshore Transmission System** shall not exceed:

(a) ~~In England and Wales, 1% of the voltage level for step changes which may occur repetitively. Any large voltage excursions other than step changes may be allowed up to a level of 3% provided that this does not constitute a risk to the **National Electricity Transmission System** or, in **NGET's** view, to the **System** of any **User**. In Scotland, the limits for voltage level step changes are as set out in **Engineering Recommendation** P28~~. The limits specified in Table CC.6.1.7 with the stated frequency of occurrence, where:

(i) $\%\Delta V_{steadystate} = 100 \times \frac{\Delta V_{steadystate}}{V_0}$

and

$\%\Delta V_{max} = 100 \times \frac{\Delta V_{max}}{V_0}$;

(ii) V_0 is the initial steady state system voltage;

(iii) $V_{steadystate}$ is the system voltage reached when the rate of change of system voltage over time is less than or equal to 0.5% over 1 second;

(iii) ΔV_{max} is the absolute value of the maximum change in the system voltage relative to the initial steady state system voltage of V_0;

(iv) All voltages are the rms of the voltage measured over one cycle refreshed every half a cycle as per IEC 61000-4-30;

(v) The voltage changes specified are the absolute maximum allowed, applied to phase to ground or phase to phase voltages whichever is the highest change;

(vi) Voltage changes in category 3 do not exceed the limits depicted in the time dependant characteristic shown in Figure CC.6.1.7; and

(vii) Voltage changes in category 3 only occur infrequently, typically not planned more than once per year on average over the lifetime of a connection, and in circumstances

notified to **NGET,** such as for example commissioning in accordance with a commissioning programme, implementation of a planned outage notified in accordance with **OC2** or an **Operation** or **Event** notified in accordance with **OC7**.

For connections with a **Completion Date** after 1st September 2015 and where voltage changes would constitute a risk to the **National Electricity Transmission System** or, in **NGET**'s view the **System** of any **User**, **Bilateral Agreements** may include provision for **NGET** to reasonably limit the number of voltage changes in category 2 or 3 to a lower level than specified in Table CC.6.1.7 to ensure that the total number of changes at the **Point of Common Coupling** across multiple **Users** remains within the limits of Table CC.6.1.7.

Category	Maximum number of occurrences	$\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$
1	No Limit	$\%\Delta V_{max} \leq 1\%$ & $\%\Delta V_{steadystate} \leq 1\%$
2	no more than 4 per hour	$\%\Delta V_{max} \leq 3\%$ & $\%\Delta V_{steadystate} \leq 3\%$
3	no more than 4 per day for Commissioning, Maintenance and Fault Restoration	For decreases in voltage: $\%\Delta V_{max} \leq 12\%$* & $\%\Delta V_{steadystate} \leq 3\%$ For increases in voltage: $\%\Delta V_{max} \leq 5\%$ & $\%\Delta V_{steadystate} \leq 3\%$ (see Figure CC6.1.7)

* 12% is permissible for up to 80ms as highlighted in the shaded area in Figure CC6.1.7

Table CC.6.1.7 - Limits for Rapid Voltage Changes

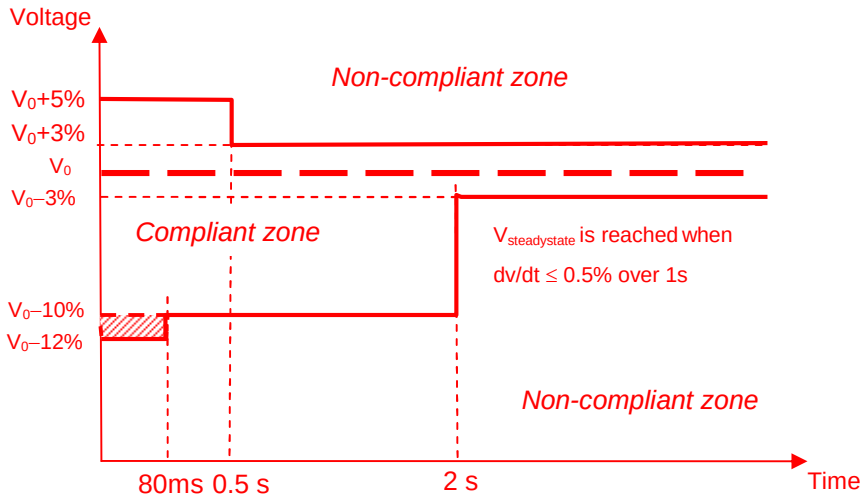

Figure CC6.1.7 -
Time and magnitude limits for a Category 3 Rapid Voltage Change

Annex 2 - Consultation Responses

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **02 May 2014** to Grid.Code@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:	*Mike Kay,mkay@iee.org*
Company Name:	*Electricity North West*
Do the proposed changes facilitate efficient connection arrangements for large electrical components (eg transformers)? If not, why do they fail to do so?	*Yes in general. We are not convinced of the necessity of the text putting limits into bilateral agreements. We suggest the following text instead:* ~~For connections with a **Completion Date** after 1 September 2014, **Bilateral Agreements** may include provision for~~ **NGET** will generally look for its agreement to customer switching to reasonably limit the number of voltage changes in category 2 or 3 to a lower level than specified in Table CC.6.1.7 to ensure that the total number of changes at the **Point of Common Coupling** across multiple **Users** remains within the limits of Table CC.6.1.7.
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	*Yes*
Should the proposed changes cover the whole of the onshore Transmission System, or should different criteria be applied to the networks in Scotland (P28 for example) or to different voltage levels.	*There would need to be a clear cost benefit for applying different standards in different zones. The general assumption is that SQSS applies across GB giving all GB customers the same service.*
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen	*Not that we are aware of.*

at lower voltages?	
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	*None*
Do the criteria applicable to Voltage Changes in Category 3 strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	*Yes*
Are there other adverse consequences of the proposed change?	*None foreseen, subject to making the alterations to the draft legal text above.*
Do you believe that GC0076 better facilitates the appropriate Grid Code objectives?	*For reference the applicable Grid Code objectives are:* *(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity; Yes* *(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); Yes* *(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; andYes* *(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. Yes
Please provide any other comments you feel are relevant to the proposed change.	*We believe that normal system operating criteria and management should be used to achieve the desired limit on significant switching effects day by day. We do not think it appropriate to write limits into the bilateral agreement.*

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **02 May 2014** to Grid.Code@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:	Alan Creighton
Company Name:	Northern Powergrid
Do the proposed changes facilitate efficient connection arrangements for large electrical components (eg transformers)? If not, why do they fail to do so?	The proposals should facilitate the connection of larger electrical plant by minimising the requirement to install equipment to unnecessarily limit voltage changes.
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	The proposed changes in effect clarify and codify present connection arrangements for some sites where no effects have been observed; hence these proposals shouldn't have an adverse impact on users. The proposal is to limit the number, frequency and magnitude of changes at connection points; this will limit the impact on consumers. However there will be an additional requirement to manage Category 2 and 3 events. The proposal is to include in new Bilateral Connection Agreements the possibility that NGET may impose limits on switching activity however it is unclear how any such limits might be imposed on new connected customers in practice.
Should the proposed changes cover the whole of the onshore Transmission System, or should different criteria be applied to the networks in Scotland (P28 for example) or to different voltage levels.	We are aware that there are particular concerns in Scotland due to the 132kV system being classed as a transmission system and the large volume of embedded generation schemes. The Scottish transmission / distribution companies are best placed to respond to this question.
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen	Not specifically, although as mentioned in our response to the second question, policing the requirements of the table in CC 6.1.7 could be challenging in the future and require the collection of voltage change data.

at lower voltages?	
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	Not that we are aware of.
Do the criteria applicable to Voltage Changes in Category 3 strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	We support the proposal to define Category 3 voltage changes as those occurring infrequently and can see that it should normally be possible to plan activities so that not more than 4 such voltage step changes occur in one day. We would not expect post fault switching of DNO systems (at new GSPs) to restore supplies / restore security to customers to be subject to the 'number of occurrences' limits in the table.
Are there other adverse consequences of the proposed change?	Not that we are aware of.
Do you believe that GC0076 better facilitates the appropriate Grid Code objectives?	*For reference the applicable Grid Code objectives are:* *(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;* Yes –the proposals aim to avoid unnecessary expenditure to manage low impact voltage change events *(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);* Yes –the proposals aim to avoid unnecessary expenditure on new generation connections. *(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*

	Yes – by clarifying the design and operational requirements in relation to voltage changes *(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 proposals are largely neutral in this area.
Please provide any other comments you feel are relevant to the proposed change.	*Please see the comments below.*

1 Reference in Table CC.6.1.7 to 'maximum' and 'up to' mean that the table is confusing to understand; the suggested changes to Column 2 in the table below make the table clearer.

Category	**Number of occurrences (n)**	**%DVmax & %DVsteadystate**
1	No Limit	%DVmax _ 1% & %DVsteadystate _ 1%
2	No more than 3 per hour, and No more than 4 per day	%DVmax _ 3% & %DVsteadystate _ 3%
3	For Commissioning, Maintenance and Fault Restoration No more than 4 per day	%DVmax _ 12% & %DVsteadystate _ 3% (see Figure 2)

2 There is a need to include the note from Section 3.32 (4) of the Consultation document to explain the shaded area ie:

The shaded area is proposed as it is in accordance with the 12% voltage change stipulated in NETS SQSS. The duration of the maximum allowable depth (V0 - 12%) has been specified in coordination with fast acting voltage controllers.

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **02 May 2014** to Grid.Code@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:	*Joe Duddy* *joe.duddy@res-ltd.com*
Company Name:	*RES Ltd.*
Do the proposed changes facilitate efficient connection arrangements for large electrical components (eg transformers)? If not, why do they fail to do so?	*Yes. Subject to satisfactory resolution of ambiguities, errors, omissions and proposed amendments described in this consultation response, the proposed changes provide improved criteria by which connections can be planned and assessed.* *RES welcomes the intent of the proposals but queries some of the details.*
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	*No. The proposed changes put requirements onto users' connections to protect other users from nuisance. However the proposed changes do not apply to Onshore Transmission Licensees assets and operations which may also cause nuisance to users. Therefore the proposals would not protect users from rapid voltage change nuisance from all sources i.e. both from other users' operations and from Onshore Transmission Licensees' operations.* *By discriminating in this fashion National Grid* • *would be allowing itself the leeway to cause nuisance to users,* • *would be holding users to a higher (and more expensive to mitigate) standard than it would apply to itself*
Should the proposed changes cover the whole of the onshore Transmission System, or should different criteria be applied to the	*The proposed changes should apply to all parties equally in any given region i.e. they should apply equally to Onshore Transmission Licensees and to users.*

networks in Scotland (P28 for example) or to different voltage levels.	*RES welcomes the clarity that this consultation has brought to the consideration of customer nuisance caused by voltage fluctuations and recommends that the principles of this proposal are applied to a revision of P28. In this way the benefits of a consistent approach can be brought to all parts of the Transmission System and the Distribution System.*
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen at lower voltages?	*There seems to have been no study of actual transfer coefficients in the GB Transmission System to support the P_{st} and P_{lt} limits specified in the existing CC.6.1.7(b), IEC6100-3-7 table 2 and P28 table 1 which are all based on assumed transfer coefficients of 1.* *I assume that transfer coefficient values of 1 were used when calculating the limits proposed in Table CC.6.1.7. How is this justified?* *Some guidance on actual transfer coefficients which apply in common situations and some flexibility in the proposals based on actual transfer coefficients would be useful and may further help avoid investment in unnecessary mitigation measures.*
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	*No comment.*
Do the criteria applicable to Voltage Changes in Category 3 strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	*No evidence is presented in the consultation document to help readers understand the balance which is proposed.* *Section 3.23 says RVCs of 12% could be accepted up to 7 times per day but then a limit of 4 times per day is proposed without any discussion of the reasons for this reduction other than for "additional assurance".*
Are there other adverse consequences of the proposed change?	*No comment.*
Do you believe that GC0076 better	*Yes. Subject to satisfactory resolution of the ambiguities, errors, omissions and proposed*

facilitates the appropriate Grid Code objectives?	*amendments described in this consultation response.*
Please provide any other comments you feel are relevant to the proposed change.	*The proposed text for CC.6.1.7(a) does not include a definition of* ΔV_{max}
	Proposed CC.6.1.7(a)(iii) is incorrectly defined and its units should include a "per time period" element e.g. "$V_{steadystate}$ is the system voltage reached when the rate of change of system voltage over time is less than or equal to 0.5%/s when averaged [or measured] over 1 second;"
	Section 3.23 says "As there are no current system operational issues with RVCs, the proposal allows for application of these lower limits to new connections only." *This does not follow logically. National Grid has provided no clear reason why the proposed lower limits should not apply to existing connections. Therefore it is pleasing to note that the proposed changes to CC.6.1.7(a) do not discriminate between new and existing users (except with respect to NGET's ability to insert terms in Bilateral Agreements after 1st September regarding Points of Common Coupling with multiple user connections 2014, which seems reasonable).*
	In proposed Figure CC6.1.7: • *the reason for a proposed* V_0*+5% for 0.5s compliant zone is not discussed in the consultation document. What is National Grid's reasoning for this?* • *the relevance of the statement "*$V_{steadystate}$ *when dv/dt <=0.5% over 1s" to the diagram is not clear.* • *The relationship of the unnamed vertical axis with* $\%\Delta V_{steadystate}$ *and* $\%\Delta V_{max}$ *is not clear* • *I assume that the unnamed horizontal axis represents time between voltage disturbances*

	• *The time parameters which were proposed in consultation document figure 2 have been omitted from Figure CC6.1.7* • *Table CC.6.1.7 category 3 says $\%\Delta V_{max}$ up to 12% may be acceptable but Figure CC6.1.7 only allows negative rapid voltage changes of this magnitude (while allowing positive and negative rapid voltage changes of 3%). What is the reason for this?*

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **02 May 2014** to Grid.Code@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 Norbury Network Connections Manager RWE Supply & Trading GmbH Windmill Hill Business Park Whitehill Way Swindon SN5 6PB T +44 (0)1793 89 2667 M +44 (0)7795 354 382 john.norbury@rwe.com
Company Name:	RWE Group of GB companies, including RWE Npower plc, RWE Innogy UK Limited and RWE Supply & Trading GmbH.
Do the proposed changes facilitate efficient connection arrangements for large electrical components (e.g. transformers)? If not, why do they fail to do so?	We welcome the higher limits for specific actions, such as transformer energisation. We are concerned that that multiple Users may be subject to more onerous and unnecessary conditions than currently exist, since it is implicitly assumed that multiple Users would be undertaking similar activities at the same time. We do not consider such an assumption to be realistic and, in any event, do not consider it appropriate to include the proposed requirements within a bilateral agreement and would prefer any such restriction to be applied via operational processes. Without prejudice to the above, we would suggest that the proposed text be amended as follows: "For connections with a **Completion Date** after 1st September 2014 and where voltage changes would constitute a risk to the National Electricity Transmission System or, in NGET's view, to the System of any User, **Bilateral Agreements** may include provision for **NGET** to reasonably limit the number of voltage changes in category 2 or 3 to a lower level than specified in Table CC.6.1.7 to

	ensure that the total number of changes at the **Point of Common Coupling** across multiple **Users** remains within the limits of Table CC.6.1.7."
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	We believe the proposal to relax the current CC6.1.7 requirements would benefit any affected User. However we do not believe that the imposition of a strict limit on the number of daily occurrences as given in CC.6.1.7 (b) is appropriate or necessary to protect Users and, in certain circumstances, could impede the normal commissioning and operation of transmission connected plant. We do not believe that Users would deliberately seek to perform actions leading to rapid voltage changes more frequently than necessary, irrespective of any Grid Code requirements. We therefore believe it wholly appropriate that operational liaison should provide sufficient safeguard against multiple occurrences of rapid voltage change that might interfere with the efficient operation of the network.
Should the proposed changes cover the whole of the onshore Transmission System, or should different criteria be applied to the networks in Scotland (P28 for example) or to different voltage levels.	We would prefer consistent treatment to be applied across GB.
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen at lower voltages?	It is our understanding that the proposed switching limits have been derived from data relating to LV networks. However, it is not clear from the consultation that the relationship between LV networks and the transmission network has been adequately explored to the extent that the proposed switching limits can be justified.
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	During plant commissioning, transformers may be required to be energised in excess of the proposed limit of four times daily, particularly if more than one transformer and/or User is involved.
Do the criteria applicable to Voltage Changes in Category 3 strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	In addition to the above comments regarding the proposed limits, the proposed application to multiple Users is likely to be unnecessarily onerous.

Are there other adverse consequences of the proposed change?	The requirement to notify and agree commissioning activities via the OC7.5.4 (IET) process up to 4 weeks in advance together with the proposed limitation of maximum number of events could, in certain circumstances, frustrate the User's commissioning activities.
Do you believe that GC0076 better facilitates the appropriate Grid Code objectives?	*For reference the applicable Grid Code objectives are:* *(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;* *(ii) to facilitate competition in the generation and supply of electricity (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);* *(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* *(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.* We agree with the general assertions given in the consultation that the proposal would facilitate standard connection arrangements and equipment choices, set limits on the magnitude and duration of rapid Voltage Changes, and achieve consistency with international standards and practice. However, we do not consider that the consultation adequately justifies either the need or magnitude of the occurrence limits proposed.
Please provide any other comments you feel are relevant to the proposed change.	Please clarify Category 2 – as drafted we assume that 3 or 4 voltage dips within a one hour period would be permitted.

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **02 May 2014** to Grid.Code@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:	*Craig Howarth* *craig.howarth@scottishpower.com* *07725410337*
Company Name:	*ScottishPower Renewables*
Do the proposed changes facilitate efficient connection arrangements for large electrical components (eg transformers)? If not, why do they fail to do so?	The proposed changes would have a significantly detrimental impact for the connection of onshore windfarms, particularly those that are considered to be large. The proposed amendment would limit the energisation of not only grid transformers but individual WTG transformers to a maximum of 4 per day where the 1% change in voltage is exceeded which is the case for energisation of most WTG transformers. For a large windfarm this would have a hugely detrimental impact, e.g. a windfarm with 60 WTG's using standard equipment and transformers would potentially take 15 days to be energised based upon the present proposals. P28 also allows the users to accurately assess the minimum time acceptable between switching events that will result in voltage dips. According to the proposed wording it is possible to cause 4 rapid voltage changes with no consideration of the time between.
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	Based upon the conclusions within the consultation document the evidence presented indicates that the present P28 requirements of 3% do not present any issues to electrical equipment. Item 3.9 makes note that a percentage of the population can notice a change in light level for a 2% change in voltage however there no suggestion of any associated problem that is caused by such a change in voltage and the associated change in light level.
Should the proposed changes cover the whole of the onshore	The proposed changes should be limited to clarifying the existing clause which is specific to

Transmission System, or should different criteria be applied to the networks in Scotland (P28 for example) or to different voltage levels.	connections in England & Wales connected to the Transmission system. All other regional and voltage levels should be exempt from the amendment, the purposes of which should be to clarify the existing requirement.
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen at lower voltages?	
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	If the changes were to be implemented unilaterally then the example of a 60 WTG windfarm, connected to the Transmission system in Scotland clearly demonstrates the significance that the proposed amendment would have to the connection of WTG transformers. Figure 1 below clearly shows the impact that the change would have, pretty much regardless of where the PoCC was determined to be. Taking the worst case scenario with the PoCC at the LV side of the grid transformers it can be seen that the voltage change would exceed the allowable 1% limit. This would therefore mean that post an outage of the windfarm, regardless of the cause, whether due to fault or a planned outage, the time require to restore the windfarm to full capability would be 15 days. Taking the best case scenario this would be reduced to 7.5 days.
Do the criteria applicable to Voltage Changes in Category 3 strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	
Are there other adverse consequences of the proposed change?	As already stated, if implemented as proposed the changes would have a significantly detrimental impact to the connection of most windfarms, regardless of their size or location.

	The consultation document alludes to additional equipment that could be installed to mitigate the issues however the scale and additional associated cost to do so considering the extent that this would be required is a factor that could prove prohibitive for many schemes.
Do you believe that GC0076 better facilitates the appropriate Grid Code objectives?	The perceived purpose of the proposed change would be to better clarify the requirement for users connected to the T network in England & Wales however rather than achieving this aim, instead would impose unnecessary obligations upon connections that were previously not obligated under this clause.
Please provide any other comments you feel are relevant to the proposed change.	The consultation fails to mention clearly whether existing plant would be exempt from the proposed change. Although item 3.28 states 'for new connections', nowhere is it stated that the proposed changes would be time bound and therefore not applied retrospectively. See Further info below

Figure 1

- The maximum number of turbine transformers that can be energised simultaneously is three, if the limit of 3% is not to be exceeded at the Point of Common Coupling. Voltage dips are summarised below:

Number of Turbines Simulataneously Energised	Voltage Dips (pu) [redacted]		
	132kV	132kV	33V
1	1.0	1.2	2.3
2	1.8	2.1	4.4
3	2.6	3.0	6.2
4	3.3	3.8	7.9

- The minimum time interval between switching events, to remain compliant with ENA ER P28, is below:

Number of Turbines Simulataneously Energised	Voltage Dip at [redacted] 132kV (pu)	Minimum Time Between Switching Events (seconds)	Minimum Time Between Switching Events (minutes)
1	1.0	20	0.33
2	1.8	150	2.50
3	2.6	450	7.50
4	3.3	-	-

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **30 April 2014** to Grid.Code@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
Do the proposed changes facilitate efficient connection arrangements for large electrical components (eg transformers)? If not, why do they fail to do so?	Yes
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	Yes
Should the proposed changes cover the whole of the onshore Transmission System, or should different criteria be applied to the networks in Scotland (P28 for example) or to different voltage levels.	Not sure
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen at lower voltages?	No
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	No
Do the criteria applicable to Voltage Changes in Category 3	Yes

strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	
Are there other adverse consequences of the proposed change?	Are limits to number of switching events for fault clearance appropriate? Could this not result in delays to customer's supplies being restored if the maximum number of allowable operations have been used.
Do you believe that GC0076 better facilitates the appropriate Grid Code objectives?	*For reference the applicable Grid Code objectives are:* *(i) to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity;* *(ii) to facilitate competition in the generation and supply of electricity (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);* *(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* *(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.*
Please provide any other comments you feel are relevant to the proposed change.	Are the categories in table CC.6.1.7. not more associated with the voltage changes rather than the number of events. Attached is a suggested alternative table.

Suggested table CC.6.1.7

Category	Anticipated Voltage change due to proposed switching operation $\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$	Maximum permitted number of operations (n)
1	$\%\Delta V_{max}$ < =1% & $\%\Delta V_{steadystate}$ <=1%	No Limit
2	1% < $\%\Delta V_{max}$ <= 3% & 1% < $\%\Delta V_{steadystate}$ <= 3%	Up to 2 per hour but no more than 4 per day
3	3% < $\%\Delta V_{max}$ <= 12% & 1% < $\%\Delta V_{steadystate}$ <= 3% (see Figure CC6.1.7)	Up to 4 per day Due to Commissioning, Maintenance and Fault Restoration

Grid Code Industry Consultation Response Proforma

GC0076 Rapid Voltage Changes

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 **02 May 2014** to Grid.Code@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:	*Tony Berndes* *Tel: 0117 933 2101* *Email: tberndes@westernpower.co.uk*
Company Name:	*Western Power Distribution*
Do the proposed changes facilitate efficient connection arrangements for large electrical components (eg transformers)? If not, why do they fail to do so?	*Yes, but at the possible expense of other sensitive Users.*
Do the proposed changes protect the interests of users affected by Rapid Voltage Changes? If not why do they fail to do so?	*No. We anticipate that some customers with processes that are sensitive to voltage dips will be affected.* *The immunity of some User equipment is with respect to voltage at the equipment rather than percentage change in voltage. Equipment may be operating at the lower end of its operating range and, when a rapid voltage change occurs the voltage at the equipment may exceed its tolerance resulting in maloperation and disruption to sensitive Users.* *Consider the case of undervoltage protection for a 3-phase 400V variable speed drive set at 85% of the rated voltage, giving effectively a 340V setting. The statutory voltage limits in the ESQC Regulations 2002 for a 3-phase low voltage system equate to 376V and 440V, giving an available operating range for distribution network design purposes of 376V-440V. A network is designed to ensure that at full load with minimum generation that the 376V lower limit is not infringed. Thus, prior to a voltage dip the voltage at the supply terminals could be as low as 376V and still be within statutory voltage limits. A rapid voltage*

	change of 12% on the upstream EHV system could reduce the voltage at the customer supply terminals well below the protection setting and hence operate the undervoltage protection. If such an event is infrequent then this could be acceptable. However, the proposal GC0076 would permit such events to be frequent (i.e. 4 per day) during commissioning, maintenance and fault restoration. Note that there are a number of issues that may affect the above in practice; for instance, voltage within a customer installation may be lower than at the supply terminals, typically distribution networks operate with some margin within the permitted range (although there is increasing pressure to shift the range downwards to reduce losses), rapid voltage changes may not be balanced, transformation through transformers etc. *Note also that the proposed change as given in Table 1 Category 3 seems inconsistent with the strict regime given by the SQSS Table 6.2 where 12% voltage changes are only permitted for rare faults (i.e. loss of double circuit overhead line, loss of a section of busbar or mesh corner or loss of a supergrid transformer).*
Should the proposed changes cover the whole of the onshore Transmission System, or should different criteria be applied to the networks in Scotland (P28 for example) or to different voltage levels.	*No comment.*
Are there further technical considerations to be taken into account, for example in the relationship between voltage changes on the Transmission System and voltage changes seen at lower voltages?	*Yes. See above.* *Note also that a rapid voltage change of 12% would qualify as a voltage dip as per the EN50160. Permitting such dips as per Table 1, Category 3 of GC0076 would increase the number of dips and reduce the perceived quality of the network.*
Is there any evidence that Users will be inappropriately adversely affected by the proposed changes? If so please provide it.	*Yes. We have experience of customers that are sensitive to voltage dips and there is published information implying sensitivity to dips of just over 10% of rated voltage. Given this, taking account of the minimum statutory voltage of -6% applicable below 132kV then simplistically a rapid voltage change of around 4.26% could be problematic.*
Do the criteria applicable to	*No. See above. The permitted rate of occurrence of such events under Category 3 is too frequent in*

Voltage Changes in Category 3 strike an appropriate balance between the needs of Users causing Rapid Voltage Changes and those subject to the consequences of them?	*our view.*
Are there other adverse consequences of the proposed change?	*Although the proposed rate in Table 1 Category 3 does not equate to a flicker problem, the flicker would nevertheless be visible and perceived power quality may be adversely affected even if it is not annoying.*
Do you believe that GC0076 better facilitates the appropriate Grid Code objectives?	*Possibly not.*
Please provide any other comments you feel are relevant to the proposed change.	*Note that in testing equipment under GC0076 reference [6] and [7] that the % change specified is related to the rated voltage of the equipment. Thus, this equates to immunity tested with a given voltage. See above.* *Given the above concerns we hold the view that the limits in Table 1 need to be modified such that the maximum change permitted is reduced to 10% and the maximum number of occurrences is changed to align with the Distribution Code; namely, once per year (DPC 4.2.3.3) under commissioning, maintenance and fault restoration.* *To move to a more liberal regime than this would require a fuller understanding of the increase in disruptive voltage changes for Users and its economic impact. This has to be balanced against the cost of compliance with the more onerous design regime implied by more strict limits.* *As stated above, this proposal would be a radical change from the philosophy of SQSS Table 6.2 whose underlying principle is to allow a 12% change for 'rare' events, to allowing 4 such events per day.*

Annex 3 - References

List of literature surveyed in the development of this proposal:

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