GC0076 Grid Code Limits On Rapid Voltage Changes

What stage is this document at?

01	Workgroup Report
02	Industry Consultation
03	Report to the Authority

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

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

Published on: **10 July 2015**

National Grid recommends:
Implementation of the proposed amendments to the criteria applied to Rapid Voltage Changes in the Connection Conditions which will allow for cheaper connections to the transmission network and better facilitate Objectives i), ii) and ii)

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 document is the Report to the Authority for GC0076 which contains the responses to the Industry Consultations and the National Grid recommendation. The purpose of this document is to assist the Authority in their decision whether to implement the GC0076 proposed changes.

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

Document Control

Version	Date	Author	Change Reference
1.0	06 May 2015	Graham Stein and Dr Forooz Ghassemi	Draft Report to the Authority
2.0	10 July 2015	Graham Stein and Dr Forooz Ghassemi	Final Report

1 Executive Summary

1.1 This document describes proposals to modify Grid Code limits on Rapid Voltage Changes. The proposals 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 network customers.

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 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.

1.4 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.

1.5 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.

1.6 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. A second Industry Consultation[3] was published on 17 February 2015 for 20 business days. Nine responses were received with a majority in support of the proposed changes. Further improvements were suggested and the proposals have been changed to improve alignment with Engineering Recommendation P28 for certain types of events.

National Grid Recommendation

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

1.8 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

[3] The February 2015 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=39676

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 (i.e. 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 in developing the proposals in this document.

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 (e.g. 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 (e.g. 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 (i.e. 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).

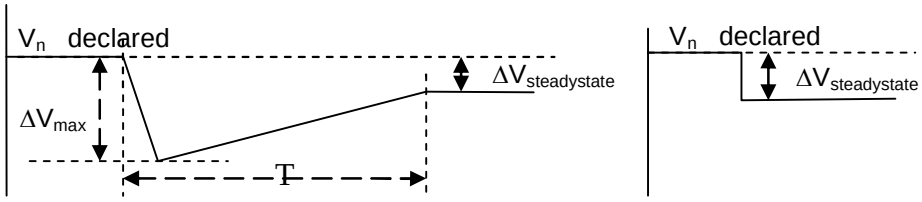

Figure 1: RVC Characterisation

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 0.5 seconds, 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 It is understood 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 $\Delta V = \pm 12\%$ 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.

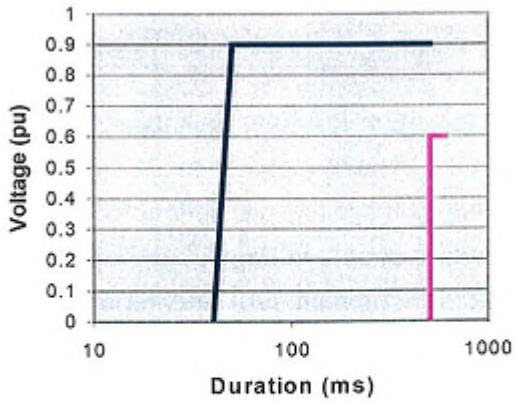

Figure 2: Sample measured maximum and minimum sensitivities of a variable speed drive

(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 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} (Flicker Severity levels) over one week [3]. In order to provide an additional assurance, the proposal set out in this document 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	$\%\Delta V_{max} \leq 1\%$ & $\%\Delta V_{steadystate} \leq 1\%$

Category	Maximum number of occurrences	$\%\Delta V_{max}$ & $\%\Delta V_{steadystate}$
2	$\frac{3600}{\sqrt[0.304]{2.5 \times \%V_{max}}}$ occurrences per hour with events evenly distributed	$1\% < \%\Delta V_{max} \leq 3\%$ & $\%\Delta V_{steadystate} \leq 3\%$
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 3)

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

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

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

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 specified within the current Grid Code requirements. Category 2 limits have been aligned with Figure 4 of Engineering Recommendation P28.

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 3.

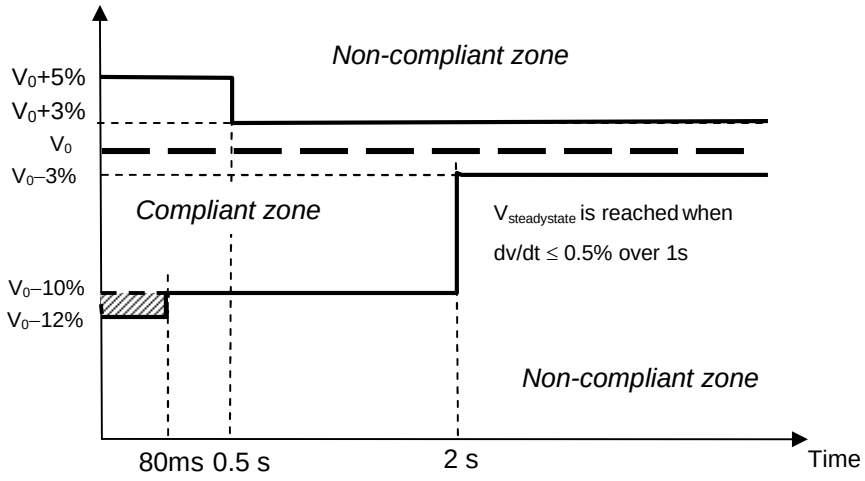

Figure 3: Limits for Category 3 Rapid Voltage Changes

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 proposal.

4 Consultation Responses

4.1 National Grid has consulted Authorised Electricity Operators (AEOs) twice on this issue. The first consultation was published on 02 April 2014 and was open for 20 business days. A second Industry Consultation was published on 17 February 2015, again for 20 business days. National Grid would like to thank all of the respondents for their comments.

Responses to the first GC0076 Consultation

4.2 The table below provides an overview of the 7 responses received to the first GC0076 consultation. Copies of the responses are included in Annex 2.

Ref	Organisation	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)

Table 2: Responses to the First GC0076 Consultation

National Grid Comments on Responses

4.3 National Grid's representatives' comments on the seven responses received are summarised below. In a number of cases, comments and suggestions were incorporated in changes to the original legal text proposed. 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 was amended to 4 occurrences per hour to be consistent with ER P28.

4.11 Suggested changes and improvements to table CC6.1.7 were included in the revised proposals. Table 3 below is the version presented in the first consultation document. Table 4 is the amended version included in the legal text the second consultation. One response had highlighted that times were missing from the x-axis of the Figure CC.6.1.7 which was corrected.

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 3: Table CC6.1.7 in First 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 4: Table CC6.1.7 in Second Consultation

4.12 One of the responses to the first consultation 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 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 the time of the second consultation, National Grid's view was 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 to the first consultation 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.

Responses to the second GC0076 Consultation

4.16 The table below provides an overview of the 9 responses received to the second GC0076 consultation. Copies of the responses are included in Annex 2.

Ref	Organisation	Supportive	Comments
GC0076(2)-CR-01	RES Limited	Yes	• Notes applicability of proposals to Transmission Companies
GC0076(2)-CR-02	ScottishPower Renewables Limited	No	• Limits too restrictive • Mis-alignment with ER P28
GC0076(2)-CR-03	Electricity North West	Yes	• Do not think it is appropriate to write limits into the bilateral agreement
GC0076(2)-CR-04	EdF Energy	Yes	
GC0076(2)-CR-05	Highlands and Islands Partnership	Yes	• Important to align Grid Code, Distribution Code and ER P28
GC0076(2)-CR-06	DONG Energy	Yes	• Any limits in bilateral agreements need to be justified • 5% is too low for an upper limit
GC0076(2)-CR-07	Western Power Distribution	Mixed	• Supports proposals in principle but lack of a complete view of sensitive equipment suggests a more conservative approach should be applied • Remains concerned over potential impact
GC0076(2)-CR-08	Northern Powergrid	Yes	• Suggested corrections and improvements
GC0076(2)-CR-09	SHE Transmission	Yes	• Support for changes but recognition that some sensitive processes may be affected • Query on consideration of LCC HVDC

Table 5: Responses to the Second GC0076 Consultation

National Grid Comments on Responses

4.17 National Grid representatives' comments on the 9 responses received are summarised below.

4.18 A number of responses highlighted that the revised proposals were overly simplistic and potentially restrictive for Category 2 voltage changes, and that they could be better aligned with Engineering Recommendation P28. The revised proposals had retained the simplicity of the original proposals but discussions with respondents revealed examples where undesirable effects might arise.

4.19 In order to achieve the best alignment possible with current practice, it is proposed that the number of occurrences for Rapid Voltage Changes in Category 2 should be expressed using an equation derived from ER P28 Figure 4, as expressed Table 6 below.

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	$\frac{3600}{\sqrt[0.304]{2.5 \times \%V_{max}}}$ occurrences per hour with events evenly distributed	$1\% < \%\Delta V_{max} \leq 3\%$ & $\%\Delta V_{steadystate} \leq 3\%$
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)

Table 6: Proposed Table CC.6.1.7

4.20 Some remaining concerns were expressed in one response over the potential impact of the proposals on customers with processes sensitive to voltage changes. National Grid's view is that proposals will not significantly increase the risk of disruption. Specific concerns were raised by one respondent with respect to variable speed drive sensitivity.

4.21 National Grid recognises that there are potential combinations of circumstances which could affect variable speed drives in the way described but that the combinations are very unlikely to occur and that the information available suggests there is an adequate margin in equipment between equipment susceptibility and the effect of the proposed limits. A significant factor here is that none of the known causes of voltage changes on the transmission network that meet the criteria in the proposed table CC.6.1.1.7 cause a balanced voltage change, as they are all a function of timing across phases. However, there is value in further research in this area as is being carried out in the review of Engineering Recommendation P28. Any recommendations made by the P28 Workgroup could be considered in future Grid Code changes if appropriate. Further information in this area is provided in Annex 4 of this document.

4.22 The applicability of the provisions was also raised by two respondents. The first of these was concerned that applying the proposed criteria equally to network licencees as well as network users would lead to inefficient network design and operation and was a change to existing practice.

4.23 National Grid's view is that although the current provisions have sometimes been interpreted as if they are only applicable to network users, there is in practice no distinction. It is possible that this interpretation arises from use of the term "Load" in the current text which could be taken to refer to customer demand but is defined more broadly as "The Active, Reactive or Apparent Power, as the context requires, generated transmitted, or distributed."

4.24 It is also worth noting that there are in practice only a limited set of circumstances where the proposed changes have an effect on transmission network equipment. This is a feature of equipment ratings, network strength and current design requirements.

4.25 Current design requirements limit "voltage excursions other than steps" to 3%, which is equivalent to the proposed Category 2. This means that no new network investment would be triggered by the proposed change in this regard. Known examples of voltage changes (or voltage change risks assessed in the design of a connection), of larger than 3% on the transmission network have been associated with energisation of transformers in excess of 500MVA, typically associated with generator connections. Network transformers are generally smaller than this, with ratings up to 240MVA, and the largest reactors planned for the transmission network are 200MVA. Both of these types of network equipment would be expected to meet the new Category 2 requirements which are equivalent to the existing provisions. Under the proposed changes, larger items of equipment would be accommodated within the restrictions of Category 3. The proposed changes will therefore remove the need for additional investment in new connection and network designs to ensure that a 3% limit is not breached in any circumstance.

4.26 The other respondent who raised applicability of the proposed changes welcomed the fact that treatment of network licensees and network users was equitable having raised this question in response to the first GC0076 consultation (see paragraph 4.7).

4.27 Discussions over the applicability of the proposals highlighted a further question of consistency with the limits of 10% and once per year set in the Distribution Code (DPC4.2.3.3 Voltage Step Changes). Although not raised as a concern in consultation responses, this had been considered in the development of proposals. National Grid's view is that the proposed Grid Code requirements are not sufficiently different to the Distribution Code requirements to cause a conflict and that the proposed Grid Code requirements reflect the current view of the needs of transmission networks and users, which may be different to the needs of distribution networks and customers (due to various factors such as numbers and types of users, network characteristics etc.).

4.28 One respondent recommended that the limit on voltage increase of 5% was unnecessarily low. National Grid's research indicates that 5% is an appropriate maximum value with respect to current equipment capabilities.

4.29 Another respondent asked if the impact of short voltage dips on Line Commutated Convertor based High Voltage Direct Current Converters had been considered in the development of the proposed changes. National Grid can confirm that this was considered and notes that DC Convertors are required to meet the more onerous requirements associated with Fault Ride Through.

4.30 Two respondents raised the concern first put forward in response to the first GC0076 consultation over the use of limits in Bilateral Agreements to manage sites affected by a number of Users. National Grid believes that this feature provides an appropriately limited degree of flexibility in application of the proposed changes which helps address some of the concerns raised by other parties. One of the respondents asked for clarification of whether limits would be on the number of occurrences rather than levels. National Grid can confirm the proposed changes with regard to parameters which can be specified in Bilateral Agreements are intended to be restricted to the number of occurrences. The proposed legal text has been amended to remove a single instance of the word "level" which has been replaced by the word "number".

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.

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 13.

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) $\%\Delta V_{steadystate} = \left| 100 \times \frac{\Delta V_{steadystate}}{V_0} \right|$

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 and $\Delta V_{steadystate}$ is the absolute value of the difference between $V_{steadystate}$ and V_0;

(iv) 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;

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

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

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

(viii) 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**; and

(ix) 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 number than specified in Table CC.6.1.7 to ensure that the total number of voltage 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	$\lvert \%\Delta V_{max} \rvert \leq 1\%$ & $\lvert \%\Delta V_{steadystate} \rvert \leq 1\%$
2	$\frac{3600}{\sqrt[0.304]{2.5 \times \%V_{max}}}$ occurrences per hour with events evenly distributed	$1\% < \lvert \%\Delta V_{max} \rvert \leq 3\%$ & $\lvert \%\Delta V_{steadystate} \rvert \leq 3\%$
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

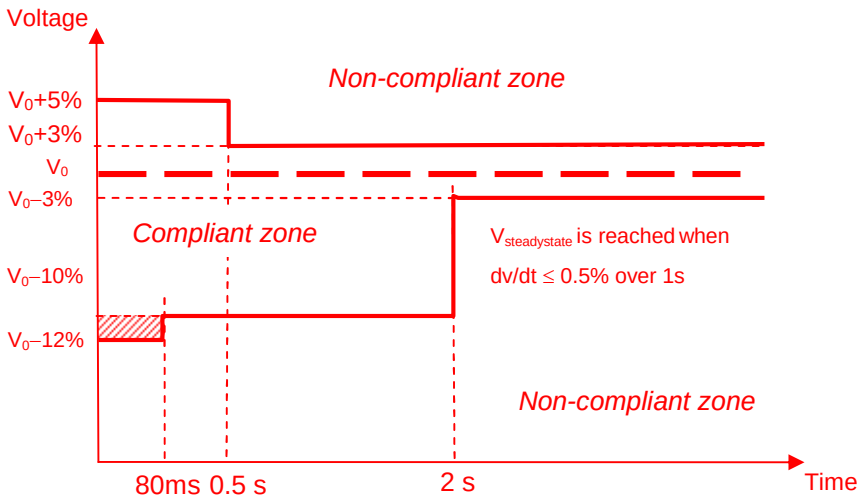

Figure CC.6.1.7 -
Time and magnitude limits for a category 3 Rapid Voltage Change

(b) For voltages above 132kV, **Flicker Severity (Short Term)** of 0.8 Unit and a **Flicker Severity (Long Term)** of 0.6 Unit, for voltages 132kV and below, **Flicker Severity (Short Term)** of 1.0 Unit and a **Flicker Severity (Long Term)** of 0.8 Unit, as set out in **Engineering Recommendation** P28 as current at the **Transfer Date**.

Annex 2 - Consultation Responses

Responses to the first GC0076 Consultation

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

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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

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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.*

Responses to the second GC0076 Consultation

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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 you support the proposed implementation approach?	*Yes, subject to comments below.*
Do you believe that GC0076 better facilitates the appropriate Grid Code Objectives?	*Yes, subject to comments below.*
Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	*Yes, subject to comments below.*
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	*No comment*
Please provide any other comments you feel are relevant to the proposed change.	*RES welcomes the fact that the consultation document notes that the proposals* ***"apply equally to transmission companies as they do to Users"****.* *The consultation document considers the flicker effects of the proposed voltage change limits and these are described in section 3.23 and states that* ***"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." *Other standards (e.g. G5/4) accept 95th percentile limits as sufficient without requiring a further margin. Therefore I suggest that no more than 7 per day would be a suitable limit for Category 3 Rapid Voltage Changes in Table CC.6.1.7* *It is not clear from the consultation document sections 3.24 and 3.25 what magnitude of EHV to LV flicker transfer coefficient was assumed for the derivation of the recommended Rapid voltage Change magnitudes and occurrence limits in table CC.6.1.7* *It is not clear what voltages were considered when proposing the limits set in table CC.6.1.7. Are the proposed limits described in table CC.6.1.7 suitable for application at Points of Common Coupling at all relevant voltages? Relevant voltages would include Supergrid Voltages in England and Wales and 132kV in Scotland, but may also include other voltages (CC.6.3.4 envisages direct connection of generators to the Onshore Transmission System at 33kV and below). Should the same EHV to LV flicker transfer coefficient apply to all these voltages when deriving limits for table CC.6.1.7?*

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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:	*Isaac Gutierrez* *Igutierrez2@scottishpower.com* *+44 (0)141 614 3104* *Mobile: +44 (0)7809 704 278*
Company Name:	*ScottishPower Renewables Limited*
Do you support the proposed implementation approach?	*No*
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.*
Do the proposed changes set	The limits are clear but this modification requires

clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	identifying the type of user connected to the transmission network to better assess the allowed frequency of voltage changes during a period of time. SPR is concerned of the increase in capital costs that these modifications are introducing in the developing and construction of transmission connected onshore Power Park Modules (PPM)
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	No, as SPR is not aware of any disruption caused with the frequency of voltage dips as per current grid code requirements.
Please provide any other comments you feel are relevant to the proposed change.	As known by National Grid an onshore PPM is formed by a number of individual wind turbines each of these having a step-up transformer. These transformers during individual energisation will produce a voltage dip at the point of common coupling (PoCC). The PPM developer carry out studies in order to estimate the best and more economical time delay between wind turbines transformer energisations so the PPM is compliant with the 3% limit for voltage fluctuations in England and Wales and the Engineering Recommendations P28 in Scotland (as per current Grid Code requirements) . The frequency of voltage dips as per new categorisation shown in *Table CC.6.1.7 - Limits for Rapid Voltage Changes* of the proposed grid code changes does not allow for fast energisation or re-energistaion of an onshore PPM. To meet these new requirements the PPM developer is being forced to introduce equipment such as pre-insertion resistors so these new limits are met at the PoCC. Using such equipment in multi radial circuits large onshore PPM introduces high complexity in the PPM control and switching operations. If for any unforeseen reason difficulties are encountered during the energisation of PPMs using pre-insertion resistors for example, the PPM circuits energisation process will need to be re-started taking offline those circuits that were energised due the need of discharging the pre-insertion resistors which could be time consuming and uneconomical for a PPM developer. This solution can be effective for small PPM connected to weak distribution networks but completely

	impractical for transmission connected PPMs SPR also believes that this modification could compromise security and quality of supply in the transmission network as any large onshore PPM that goes offline for any unforeseen event/reason will not be able to re—energise as quick as desired (due to frequency of voltage dips limits) in order to support with its ancillary services (i.e. reactive power, frequency response) the transmission network

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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 you support the proposed implementation approach?	We generally support the modification and approach. However we do not think it is appropriate to extend NG's apparent control of the switching regime into Bilateral Agreements. All such agreement are with licensed parties who need to comply with the Grid Code, so agreeing reasonable approaches through normal operational liaison in keeping with the Grid Code requirements should be sufficient. We suggest the following change to the draft legal text: **NGET** will consider if there is a need 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. If so this will be achieved through normal operational liaison.
Do you believe that GC0076 better facilitates the appropriate Grid Code Objectives?	Yes, subject to the suggestions above. *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*

Deleted: 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

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	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.*
Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	Yes
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	No
Please provide any other comments you feel are relevant to the proposed change.	Care should now be taken to ensure that the Joint GCRP/DCRP working group reviewing P28 align with the Grid Code

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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:	***Andy Vaudin*** ***andrew.vaudin@edfenergy.com***
Company Name:	***EDF Energy***
Do you support the proposed implementation approach?	***YES***
Do you believe that GC0076 better facilitates the appropriate Grid Code Objectives?	***Yes to all*** *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.*
Do the proposed changes set	***YES***

clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	***N/A***
Please provide any other comments you feel are relevant to the proposed change.	

1965 50 2015
HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

grid.code@nationalgrid.com 17 February 2015

Dear Graham

Highlands and Islands Partnership Response to GC0076 Consultation on: Limits for Rapid Voltage Changes

Highlands and Islands Enterprise (HIE) is the Scottish Government's agency responsible for economic and community development across the North and West of Scotland and the islands.

HIE along with its local partners: the democratically elected local authorities covering the north of Scotland and the islands: Shetland Islands Council, Orkney Islands Council, Comhairle nan Eilean Siar, Highland Council and Argyll & Bute Council make representations to key participants on behalf of industry to influence the way in which grid construction is triggered, underwritten then accessed and charged for in the region. We are pleased to respond to the above consultation and hope that you find our comments useful.

Responses to consultation questions

Question 1: Do you support the proposed implementation approach
We support the proposed implementation approach as set out in the consultation document. We believe that the proposed changes provide a clearer set of limits for Rapid Voltage Changes which takes into account the need for a wider range of allowed voltage fluctuations at certain times such as commissioning and energisation after a fault outage, and that this helps to avoid the installation of expensive mitigating equipment which will rarely be used. We also appreciate the proposal to set out limits for all transmission system Users and remove the different requirements for Users in Scotland from those in England and Wales.

Question 2: Do you believe that GC0076 better facilitates the appropriate Grid Code Objectives?
We believe that GC0076 better facilitates all of the applicable Grid Code objectives set out in the consultation document. By providing a set of limits that are consistent throughout GB, the change will promote an efficient and coordinated system for electricity transmission and distribution. The change will also facilitate competition in the generation of electricity by providing a more appropriate set of limits for generators connecting to the system for the first time who would currently be required to provide additional equipment if the limit of 3% could

not be met. As set out in the consultation document, the proposed change is consistent with international standards and practice.

Question 3: Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?
We consider that the proposed changes provide additional clarity in expanding on the limit conditions and hence set clearer limits for Rapid Voltage Changes. We do however consider it worth clarifying whether for the Category 2 and Category 3 limits there needs to be a certain amount of time between each occurrence of voltage change as it is currently restricted to a certain number of occurrences per hour in the case of Category 2 or per day in the case of Category 3. Engineering Recommendation P28 provides a limit on the time between each occurrence depending on the magnitude of the voltage change, and there is therefore a slight misalignment between the two.

Question 4: Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?
We are not aware of any examples which could be used as evidence to amend the proposal set out in the consultation document. We are however aware of the difficulties our stakeholders such as renewable generators face in interpreting and complying with the Grid Code and Engineering Recommendation P28.

Question 5: Please provide any other comments you feel are relevant to the proposed change.
For generators in Scotland, the requirements set out in Engineering Recommendation P28 set out similar limits to the proposal for the number of occurrences that are allowed for voltage changes of a certain size. This proposal also provides a further category of limits for events such as commissioning, maintenance and fault restoration. These wider limits reduce the need for generators to install additional equipment in order to comply with Engineering Recommendation P28 during these events, reducing the overall cost for projects and promoting the connection of renewable generation. We consider it essential that the Grid Code and Engineering Recommendation are properly aligned.

Further to the above, and given many of the issues faced in respect of rapid voltage fluctuations are in fact at distribution level, and that this includes embedded Grid Code compliant projects, we consider it is important that the standards applied at transmission are equally applied at distribution in so far as this is appropriate. Noting also that Engineering Recommendation P28 is referenced at Distribution through the Distribution Code and other means we consider it important to also align the Grid Code, Distribution Code and Engineering Recommendation P28 in so far as this is appropriate.

We note that there are other non-alignment issues between Grid Code compliant embedded projects and the requirements of distribution, e.g. the need for a reactive power range and associated voltage control system within the Grid Code which may not be useable on an embedded project.

As a further point of note we consider it essential that any amendments to the codes align with incoming European codes and this should be confirmed or otherwise addressed.

I hope that you find these comments useful and look forward to viewing outcomes in due course.

Yours sincerely,

Gavin MacKay
Senior Development Manager, Energy Policy & Strategic Projects
Highlands and Islands Enterprise

In partnership with:
Shetland Islands Council
Orkney Islands Council
Comhairle nan Eilean Siar
Highland Council
Argyll & Bute Council

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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:	*Sridhar Sahukari/Nicola Barberis Negra* *Email: SRISA@dongenergy.co.uk, NIBNE@dongenergy.co.uk*
Company Name:	*DONG Energy*
Do you support the proposed implementation approach?	*Yes*
Do you believe that GC0076 better facilitates the appropriate Grid Code Objectives?	*Yes in general.* *With respect to the proposed draft text for CC.6.1.7 and especially regarding additional constraints in BCA's- We agree that as there could be multiple number of Users connecting a single site, and it may be required to limit the number of voltage changes so that the cumulative effect remains within the limit.* *However, it is to be clarified that there will only be limit on the number of occurrences and not the magnitude itself. The modification to the GC should also mention a clear responsibility of System Operator providing justification (through studies, statistical examples, etc.) on why any specific User has more stringent requirements at one specific site.*
Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	*For the avoidance of doubt, V_0 should be clarified as pre-event steady state (operating) voltage and can be different than system nominal voltage.*
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal	*None.*

presented in this consultation?	
Please provide any other comments you feel are relevant to the proposed change.	*The proposal goes into depth with regard to the drop in voltage and its impacts. However, enough information is not provided for the voltage rise and why the voltage rise limit is given to be only 5% for T<0.5s. Due to the increase of long HVAC cable connections especially in case of Round 3 offshore windfarms, we request the proposal should include more details on voltage rise and also to consider increasing the overvoltage limit up to at least 10%.*

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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:	S Scarbro Primary System Design Western Power Distribution Avonbank Feeder Road Bristol BS2 0TB Tel: 0117 933 2166 Email: sscarbro@westernpower.co.uk
Company Name:	Western Power Distribution
Do you support the proposed implementation approach?	Broadly, yes, as an interim measure while EREC P28 does not include Rapid Voltage Change (RVC) limits. Please see concerns below.
Do you believe that GC0076 better facilitates the appropriate Grid Code Objectives?	Including the Onshore Transmission System and setting absolute limits, rather than Planning Limits or Customer Emission Limits that apply to design and system performance may be contrary to the economic design principle. Please see concerns below.
Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	Yes but please see concerns below.
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	The precise response of sensitive customer equipment to large RVC is not completely clear. We cannot be fully confident that there will be no impact. If LV statutory voltage levels are dropped (i.e. from -6% to -10%) or target operating voltage levels are dropped to try and save energy losses then any impact on sensitive customer equipment may be increased in the future. Possible impact is discussed below. Published studies relating to

	unbalanced RVC tolerance/voltage dips (used interchangeably below) are somewhat limited. Customer variable speed drives can be very sensitive to voltage dips. The DC bus undervoltage protection level can be factory set at 75-85% of the nominal value. The drive sensitivity to voltage dips depends on various factors including the DC bus capacitor; a balanced dip gives a different response to an unbalanced one due to the different charging of the DC bus. For balanced dips the drive trip threshold on the AC input can be in the range of 0.6-0.9 x nominal voltage. If the pre-dip voltage is lower than nominal then for a given dip size as a percentage of pre-dip voltage the sensitivity is increased. Sensitivity can also be increased when voltage distortion reduces peak voltage. Given this, a balanced rapid voltage change of 10% applied directly to a sensitive drive could cause a drive trip if reduced pre-dip voltage is present or voltage distortion is present. For a rapid voltage change at Onshore Transmission System level the transfer coefficient, T, to utilisation voltage levels may be 1 or less. If T is less than 1 then this will mitigate the impact to some extent. For unbalanced RVC, as per transformer magnetising inrush, the impact should be less as compared with balanced RVC although in the absence of detailed information it seems necessary to assume the more onerous balanced RVC/dip. If we assume T = 1 then the minimum drive sensitivity that works with a RVC of 10% and 0.94 per unit pre-dip LV voltage is [1-0.1] x 0.94 = 0.846 per unit. This is lower than the most sensitive drive trip threshold and so disruption might occur. If instead we use the transfer coefficients in Table B.1 of PD IEC TR 61000-3-7 of 0.82 x 0.91 then the answer is [1-(0.1x0.82x0.91)] x 0.94 =0.870 per unit; this is still below the most sensitive drive trip threshold. Due to Customer installation internal voltage drop there is the possibility that the drive starts at 0.9 per unit (i.e. further 4%); in that case then the answer is [1-(0.1x0.82x0.91)] x 0.90 = 0.833 per unit. Note also that there is the possibility that the statutory voltage range may be reduced by a

	further 4%. In this case the calculation above would be [1-(0.1x0.82x0.91)] x 0.86 = 0.796 per unit. Overall, therefore, we conclude that the proposal may possibly affect sensitive drives. The proposal does not distinguish between balanced and unbalanced RVC. For the worst case of maximum transformer magnetising inrush the associated RVC is unbalanced and sensitivity to these unbalanced RVC will be better than balanced RVC; consequently, this may not be problematic in practice when transfer coefficients are taken into account; further, Table 1 in the proposal restricts the operating conditions when the 10% RVC is permitted so this will also help minimise any disruption.
Please provide any other comments you feel are relevant to the proposed change.	We have the following concerns: • The permitted change is larger than the international indicative planning levels given in PD IEC TR 61000-3-7 (i.e. 10% compared with the 3-5% in Table 6). A more conservative approach may be wise (e.g. 6%) for the scope limited to customer equipment. • The limits really belong in EREC P28. However, we recognise that EREC P28 may be some time from publication and so an interim solution is required. • The limits should be Planning Levels as per PD IEC TR 61000-3-7. Including them in the Grid Code with the proposed legal text changes their status to absolute limits. This is contrary to ESQC Regulations 2002, Regulation 3, which requires prevention of interference, so far as is reasonably practicable, thereby balancing cost and benefit. This may lead to uneconomic design. • The proposal extends the scope of CC.6.1.7 from RVC caused by fluctuating Loads only to all RVC, including those produced by the Onshore Transmission System itself (e.g. System transformers). Furthermore, the limits are absolute and

	apply to both planning and system performance. Thus, they conflict with both international and European practice as per PD IEC TR 61000-3-7 and BS EN 50160. The former gives Planning Limits, with some flexibility in the accompanying text, and individual customers are provided with Emission Limits derived from the Planning Limits. BS EN 50160 excludes various operating conditions recognising that it can be better to maintain supply at the expense of reduced power quality in some circumstances. Thus, we would recommend not expanding the scope in this way and to limit it to Customer equipment only. Expanding it to include the Onshore Transmission System may drive additional expenditure for abnormal events of irregular occurrence.

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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 you support the proposed implementation approach?	Yes – the improvements incorporated in this second consultation are helpful and should limit any adverse impact on customers. 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.
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.
Do the proposed changes set clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	Yes
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	No
Please provide any other comments you feel are relevant to the proposed change.	1) 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. 2) In the second column of Table CC6.1.7, the word 'No' in rows 2 and 3 should have a capital 'N' 3) In the last paragraph of CC6.1.7 (vii) add the word voltage so that the sentence reads'….the total number of voltage changes at the….'

Grid Code Industry Consultation Response Proforma

GC0076 Grid Code Limits on 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 **17 March 2015** 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:	Richard Lowe richard.lowe@sse.com
Company Name:	SHE Transmission
Do you support the proposed implementation approach?	Yes
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);* Clarity on RVC criteria should help promote a level playing field for generator 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* *(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.*
Do the proposed changes set	Yes

clear limits for Rapid Voltage Changes? If not what do you suggest should be modified to improve their clarity?	
Can you provide any example(s) of disruption caused by the Rapid Voltage Changes and the mechanism by which this occurred which could be used as evidence to amend the proposal presented in this consultation?	While hard to be specific, we are aware of some historical instances of users being affected by voltage disturbance. Where LCC converter technology is used, then short duration voltage dips in the range 10-15% can cause converter blocking. Has this been considered?
Please provide any other comments you feel are relevant to the proposed change.	While the research supporting this paper gives evidence that users should not be adversely impacted, we remain concerned about the potential impact on some users with sensitive processes or equipment. If this proposal is implemented, there will be an increased requirement to monitor the network such that non-compliant events can be detected and/or User complaints investigated.

Annex 3 - References

List of literature surveyed in the development of this proposal:

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Annex 4 - Variable Speed Drives

Background

Issues were raised with respect to the susceptibility of Variable Speed Drives to Rapid Voltage Changes in consultation response (GC0076(2)-CR-07). This note provides further background to the conclusions drawn in the Consultation Responses section of this report.

Issues Raised

The respondent raised concerns mainly in three areas:

1. The susceptibility of drives to -12% voltage change when the pre-event voltage is at nominal voltage;

2. The susceptibility of drives to -12% voltage change when the pre-event voltage is at the minimum of the statutory voltage i.e. nominal voltage−6% which may in future be increased to nominal voltage−10%; and

3. Susceptibility of other equipment and processes to −12% voltage change. In particular reference to interference with protection requirement for embedded generators in ER G59 has been made.

Response to Issues Raised

Equipment Characteristics

Research into standard practices in design of commercial drives in the market showed that the normal practice for LV drives is that they are designed for the nominal voltage of 380V to 480V ±10%. Some products are designed to 380V to 480V +10%/−15%. Considering a nominal voltage of 400V in UK, this suggests drives can operate continuously for 85.5% of the nominal voltage.

National Grid was also informed that the protection of drives is set at 81% of 380V level which corresponds to 76.95% of the system nominal voltage of 400V.

Although it is perceived to be extremely rare, assume the LV network voltage is at its lowest possible level of 90% of nominal voltage of 400V when a voltage change of 12% occurs. The retained voltage in this case would still be above the drive protection setting.

National Grid was further informed that most drives take advantage of the load inertia to reduce their susceptibility to excessive and prolonged voltage changes.

When the voltage changes are asymmetrical, the sensitivity of drives to voltage changes reduces as the other phases voltages support the drive to continue for longer time.

The medium voltage drives have tolerance of ±10%. However de-rating, which is normal and standard industry practice is used. This increases to −30% of nominal voltage. National Grid's research of the market place showed that all major suppliers of drives in the market have this capability.

Network Voltage Relationship

Furthermore, as part of the contribution to ENA ER P28 revision Workgroup, NGET has carried out an extensive study using the GB model to determine transfer coefficients from EHV to lower voltages for disturbances in the EHV network. The study involved modelling transformer energisation events at 400kV,

275kV and 132kV and to record the voltages that are produced at other voltage levels. This was carried out for a number of sites and 99-percentile of transfer coefficients was taken. Table 1 shows the result of the study. IEC 61000-3-7 also provides indicative transfer coefficients. These are shown in Table 2.

It can be seen that considering the transfer coefficients, for a disturbance in the EHV system only 80% and 70% of the voltage changes are transferred to respectively 33kV and 11kV which in turn means that a large margin exists for equipment at those voltage levels to operate without disruption.

Voltage Level	T_r
EHV towards 132 (kV)	0.85
EHV towards 66 (kV)	0.85
EHV towards 33 (kV)	0.80
EHV towards 11 (kV)	0.70
132 towards 66 (kV)	0.95
132 towards 33 (kV	0.90
132 towards 11 (kV)	0.75

Table 1- Transfer Coefficients from EHV and 132kV to Lower Voltages

Voltage level	T_{PstAB}
220 kV towards 70 kV	0,82
70 kV towards 15 kV	0,91
15 kV towards 230 V	0,98 – 1,0

Table 2- Indicative Transfer Coefficients in IEC 61000-3-7

Consistency with ER G59

The shaded area of −12% for 80ms in the Proposal GC0076 (Figure CC.6.1.7) is consistent with the ±12% voltage change stipulated in NETS SQSS. The duration of the maximum allowable depth (Vo-12%) has been specified in coordination with fast acting voltage controllers. The other consideration was coordination with ER G59 requirement for protection of embedded generation to avoid inappropriate trips of generators.

Figure 1 shows the ER G59 Stage 1 and Stage 2 requirements. It also illustrates the proposed voltage change criteria in GC0076 when the pre-event voltage is at nominal level.

According to Proposal GC0076 the reference voltage is the pre-event voltage, V_o. For V_o of 90% of nominal voltage V_n then the allowable voltage change is $0.12\times0.9V_n=0.108V_n$, thus the retained voltage would be 79.2% of V_n. For V_o=90% of V_n, the voltage must recover to 81% of Vn within 80ms, thus above the ER G59 protection level. Figure 2 shows the ER G59 Stage 1 and Stage 2 requirements and proposed voltage change criteria in GC0076 when the pre-event voltage is at 90% of the nominal. It can be seen that the requirement in GC0076 is still above the ER G59 requirement and thus would not cause trips.

Note that the voltage changes depicted in Fig 1 and Fig 2 have been shown without considering the transfer coefficients from EHV to lower voltages. Therefore the green lines in Fig 1 and Fig 2 should be raised according to the transfer coefficients, providing larger margins between the GC0076 voltage change limits and the ER G59 protection requirements. For example, for a pre-event voltage of 90% of the nominal a maximum allowable voltage change in EHV is 10.8%.

According to the transfer coefficients given in Table 1, the embedded generators at 132kV would sense only 0.85×10.8=9.18% voltage change, which is less than the Stage 2 limit in ER G59.

Therefore, it can be demonstrated that the limits proposed in GC0076 do not conflict with the voltage related Loss of Mains protection requirements of ER G59.

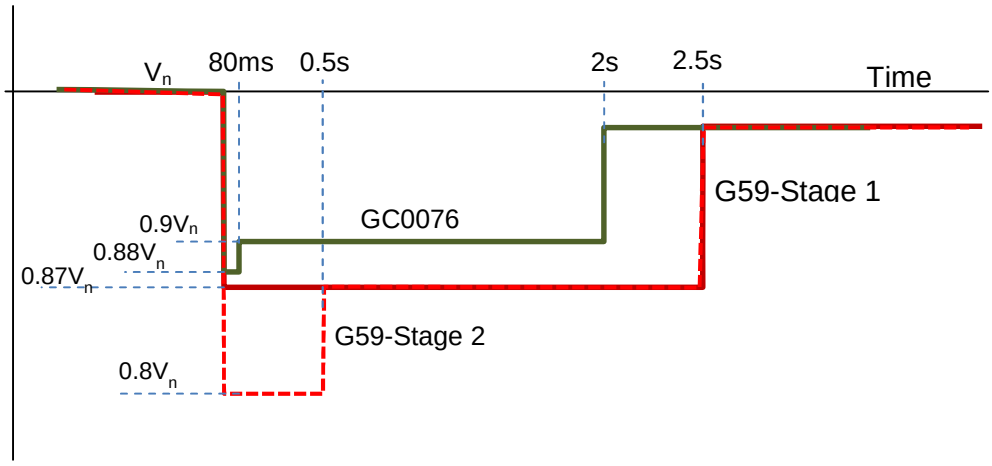

Fig 1: Stage 1 and Stage 2 Protection Requirement in ER G59 for Under-Voltage Protection and GC0076 Requirement for Pre-Event Voltage at Nominal Level

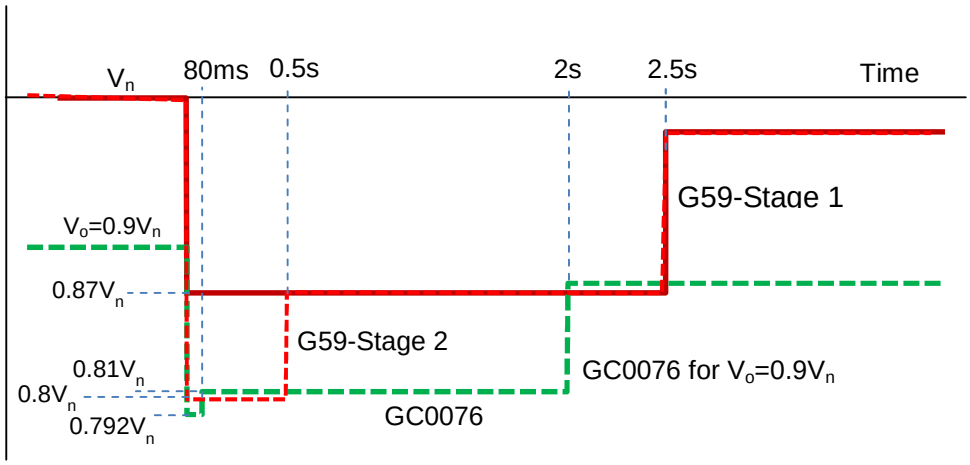

Fig 2: Stage 1 and Stage 2 Protection Requirement in ER G59 for Under-Voltage Protection and GC0076 Requirement for Pre-Event Voltage at 90% of Nominal

<u>Voltage Change Dependency on Pre-event Voltage</u>

If the pre-event voltage is lower than the nominal, e.g. $0.9V_n$, then the percentage voltage change generated by all events is always smaller than the voltage change created if the voltage were at the nominal, assuming all other system parameters are the same.

Consider an equipment energisation which produces a voltage change of ΔV_n% for energisation at nominal voltage of V_n. For a pre-energisation voltage of $V_o=V_n-kV_n=(1-k)V_n$, where k=0 to 0.1, the voltage change would be $\Delta V=\Delta V_n-\delta V$ where $\frac{\delta V}{\Delta V_n} \geq k$. For example, if k=0.1 (i.e. $V_o=0.9xV_n$) then $\delta V \geq 0.1\times\Delta V_n$ which means that the voltage change for pre-energisation voltage of $0.9V_n$ would be at least 10% smaller than the voltage change if the pre-energisation voltage was V_n. Note; some equipment energisation are non-linear phenomena, e.g. transformer energisation, and therefore the relationship between δV and k would be non-linear,

however, $\frac{\delta V}{\Delta V_n}$ cannot be smaller than k. Conversely, for $V_o=(1+k)V_n$, $\Delta V=\Delta V_n+\delta V$, which means the voltage change would be higher than that at the nominal voltage.

NGET performed studies to examine the effect of pre-event voltage on the voltage change. Two autotransformers of 400/132/13kV and 275/132/33kV voltage ratings were considered. The MVA rating for the former is 240/240/60MVA and for the latter is 120/120/55MVA. The tests were performed for maximum and minimum short circuit levels of 20 and 8 GVA respectively.

Figure 3 shows the percentage change in the voltage change for different energisation voltage with respect to the voltage change due to energisation at the nominal voltage for 400kV transformer. Figure 4 shows the same for 275kV transformer both for the source fault level of 8GVA.

It can be seen that if the network voltage is at the lowest level of 90% of the nominal prior to the energisation the voltage changes are about 17% smaller than the voltage changes produced by the nominal voltage.

Therefore, the energisation at lower voltages is always less severe than the energisation at the nominal voltage.

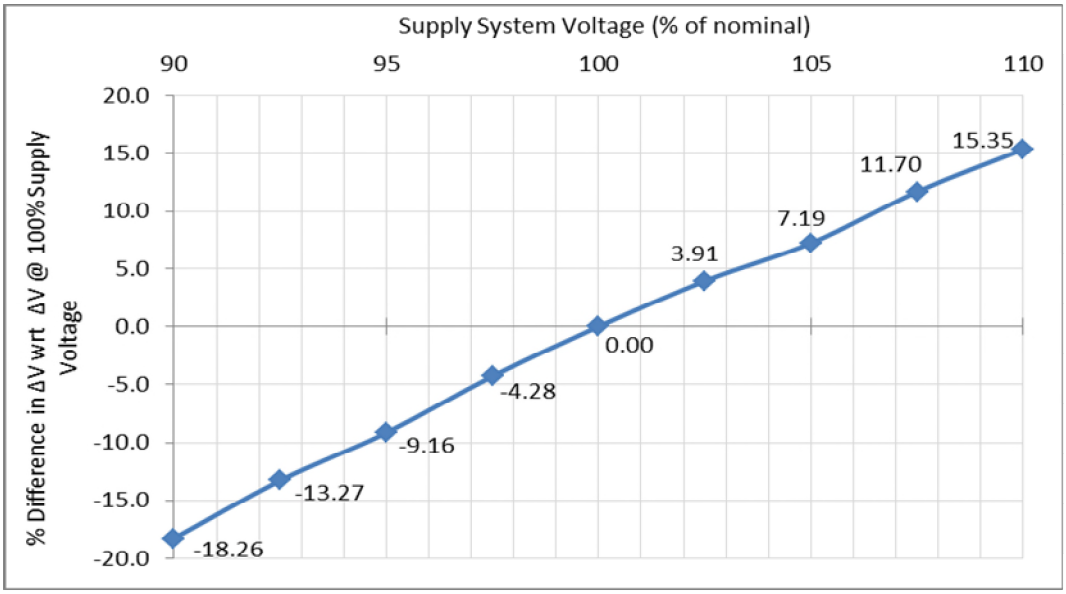

Fig 3: Difference in ΔV at V_o and at 100% Supply Voltage vs Supply Voltage for 400kV Transformer

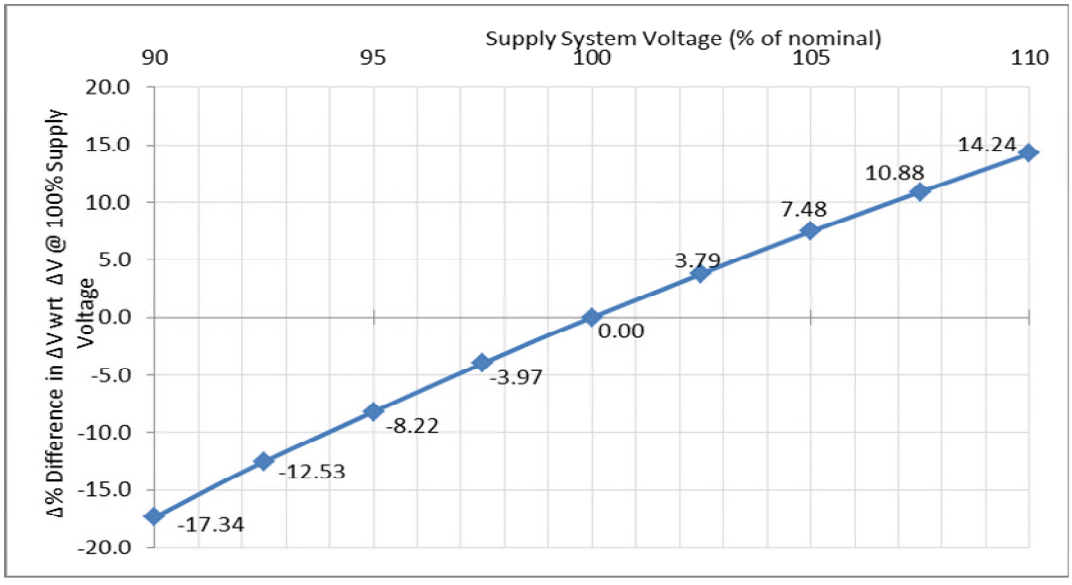

Fig 4: Difference in ΔV at V_o and at 100% Supply Voltage vs Supply Voltage for 275kV Transformer