

Distribution Code Review Panel

July 2017

Revision of P28 and impacts on Distribution Code

1. Background

Engineering Recommendation P28 Issue 1, *Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom* is an Annex 1 Qualifying Standard in The Distribution Code.

The Grid Code Review Panel (GCRP) and the Distribution Code Review Panel (DCRP) of Great Britain (GB) have sanctioned the revision of Engineering Recommendation P28 by a joint Working Group of various key stakeholders.

The revision of Engineering Recommendation P28 (known as P28 Issue 2) is currently being finalised by the joint Working Group. Although P28 Issue 2 is still subject to amendment the likely impact on technical requirements in the Distribution Code is known.

2. Purpose

The purpose of this Paper is to:

- identify aspects of the Distribution Code that relate to P28 Issue 2;
- outline how existing technical requirements in the Distribution Code are likely to be impacted by P28 Issue 2;
- recommend associated modifications to the Distribution Code for consideration by the DCRP.

A term that is in **bold** font has the same meaning as that term defined in the Distribution Code.

3. Aspects of the Distribution Code Relating to Engineering Recommendation P28

The current issue of the **Distribution Code** (Issue 28 – 1 May 2017) contains a number of aspects relating to Engineering Recommendation P28, which are summarised in Table 1 below.

Table 1 – References to P28 Aspects in the DCode

Item	Reference in DCode	Page in DCode	Text in DCode
1	Annex 1 Qualifying Standards	23	Reference to Engineering Recommendation P28 as an Annex 1 Qualifying Standard.
2	DPC4.2.3.2 Voltage fluctuations (a)	43	Voltage fluctuations shall comply with the limits set out in DGD Annex 1, Item 9 Engineering Recommendation P28, “Planning limits for voltage

Item	Reference in DCode	Page in DCode	Text in DCode
			fluctuations caused by industrial, commercial and domestic equipment in the United Kingdom”.
3	DPC4.2.3.3 Voltage Step Changes	44	<p>The effect of voltage step changes caused by the connection and disconnection of User’s Equipment or Customer’s Demand to or from the DNO’s Distribution System must be considered and be subject to limits to avoid unacceptable voltage changes being experienced by other Customers connected to the DNO’s Distribution System. The magnitude of a voltage step change depends on the method of voltage control, types of load connected and the presence of local generation. Typical limits for voltage step changes caused by the connection and disconnection of User’s Equipment or Customer’s Demand to the DNO’s Distribution System, are $\pm 3\%$ for infrequent planned switching events or outages (in accordance with Engineering Recommendation P28). For unplanned outages such as faults it will generally be acceptable to design to a voltage step change of $\pm 10\%$. The voltage depression arising from transformer magnetising inrush current is a short-time phenomenon not generally easily captured by the definition of voltage step change used above. In addition the size of the depression is dependent on the point on wave of switching, and the duration of the depression is relatively short, in that the voltage recovers substantially in under one second.</p> <p>User’s installations should be designed such that transformer magnetising inrush current associated with normal routine switching operations does not cause voltage fluctuations outside those in Engineering Recommendation P28 (ie a maximum of $\pm 3\%$). To achieve this it may be necessary install switchgear so that sites containing multiple transformers can be energised in stages.</p> <p>Situations will arise from time to time when</p>

Item	Reference in DCode	Page in DCode	Text in DCode
			complete sites including a significant presence of transformers are energised as a result of post fault switching, post maintenance switching, or carrying out commissioning tests on the DNO's Distribution System or on Users' Systems. In these situations it will generally be acceptable to design to an expected depression of around $\pm 10\%$, recognizing that a worst case energization might cause a larger depression, on the basis that such events are considered to be rare and it is difficult to predict the exact depression because of the point on wave switching uncertainty. Should these switching events become more frequent than once per year, then the design should revert to aiming to limit depressions to less than 3%.

4. Impact of P28 Revisions on the Distribution Code

4.1 Scope of P28

The title of P28 Issue 2 has been amended to "Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom". This reflects the broader scope of recommendations in P28 Issue 2 beyond planning limits for flicker and to make clear the application of recommendations to both transmission systems and distribution networks.

DPC4.2.3.2 (a) currently refers the requirement for voltage fluctuations to simply comply with the limits in Engineering Recommendation P28. In addition to stipulating limits, P28 Issue 2 stipulates requirements for the assessment and measurement of voltage fluctuations as well as requirements applying to specific disturbing equipment.

The DCRP may wish to reword DPC4.2.3.2 (a) to require compliance to appropriate requirements as well as limits in Engineering Recommendation P28 Issue 2.

4.2 Voltage Step Changes

The general limit on the magnitude of voltage step changes of $\pm 3\%$, stated DPC4.2.3.3, remains the same in P28 Issue 2. However, P28 Issue 2 now clarifies that the $\pm 3\%$ general limit relates to the voltage change between steady state conditions, referred to as $V_{\text{steadystate}}$, (see Clause 5.3 of P28 Issue 2).

The definition of voltage step change, as stated in DPC4.2.3.3, allows a time up to 5 s after the fault clearance or switching action. P28 Issue 2 does not place a limit on the time for transient decay but states that voltage changes must be within $\pm 3\%$ after 2 s from event initiation.

Limits for voltage fluctuations in between steady state conditions (referred to as V_{\max}) can be greater than $\pm 3\%$ for infrequent events and fall under requirements for Rapid Voltage Changes in P28 Issue 2.

Consequently the DCRP may wish to consider rewording DPC4.2.3.3 concerning voltage step changes to require compliance with the limits for voltage fluctuation in P28 Issue 2.

4.3 Rapid Voltage Changes

DPC4.2.3.3 currently permits a **User** to design for a voltage step change of:

- $\pm 10\%$ for unplanned outages such as faults; and
- around $\pm 10\%$ for energisation of sites with significant presence of transformers as a result of post fault switching, post maintenance switching, or carrying out commissioning tests on the **DNO's Distribution System** or on **Users' Equipment**, on the basis that such switching events are considered to be rare and are not more frequent than once per year.

P28 Issue 2 introduces the concept of Rapid Voltage Change (RVC) where different envelopes prescribe the maximum allowable magnitude and duration of voltage fluctuations for different categories of maximum number of occurrence (see Clause 5.2.2 of P28 Issue 2). These envelopes encompass limits for voltage step changes as defined in the **Distribution Code**.

The proposed envelopes proposed in P28 Issue 2 are replicated below (see Figure 5, Figure 6 and Figure 7).

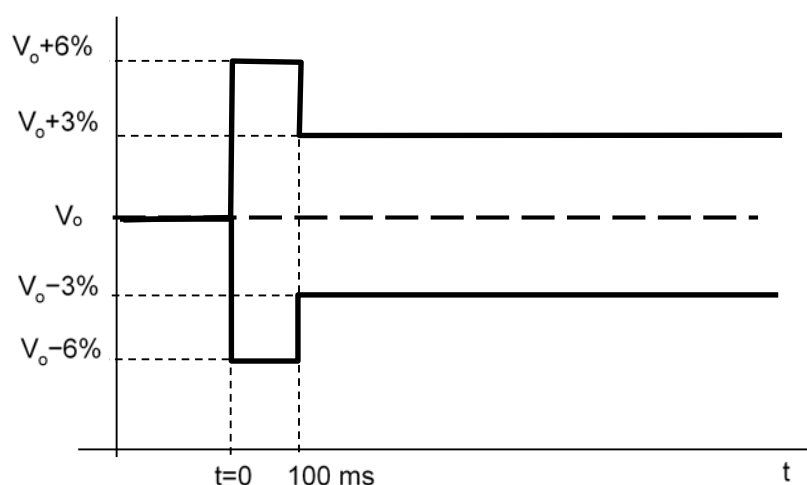


Figure 5 — Voltage characteristic for frequent events (Category 1)

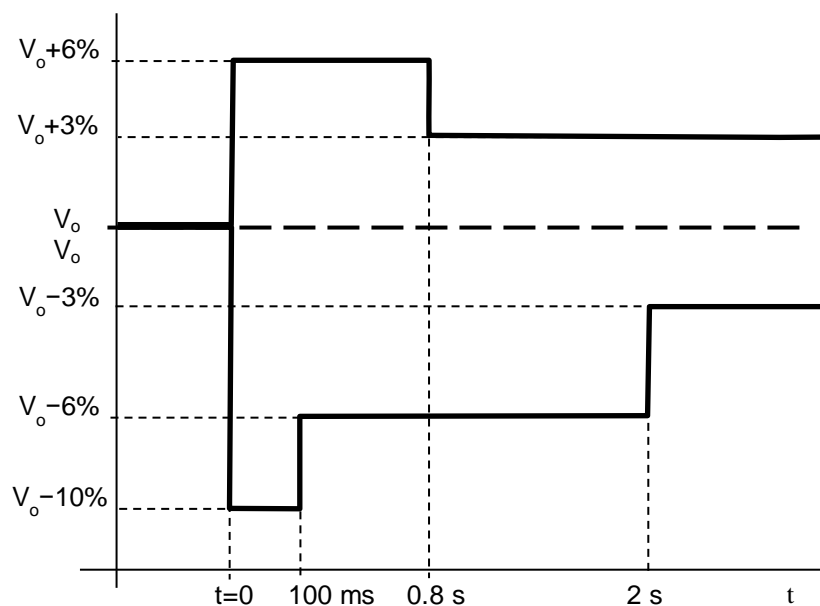


Figure 6 — Voltage characteristic for infrequent events (Category 2)

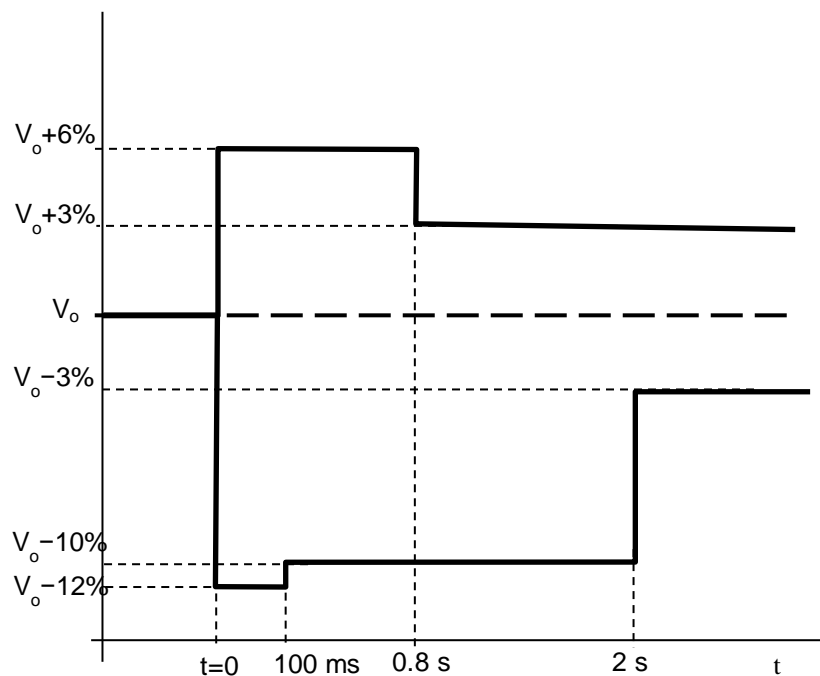


Figure 7 — Voltage characteristic for very infrequent events (Category 3)

The maximum no. of occurrences proposed for each Category of RVC event is shown in Table 4 (replicated from P28 Issue 2)

Table 4 – Planning Levels for RVC

Cat-egory	Title	Maximum number of occurrence	Limits $\% \Delta V_{\max}$ & $\% \Delta V_{\text{steadystate}}$	Example Applicability
1	Frequent events	(see NOTE 1)	As per Figure 5	Any single or repetitive RVC that falls inside Figure 5
2	Infrequent events	4 events in 1 month (see NOTE 2) NOTE: For each event, it is permissible to have up to 4 sub-energisations of the same voltage dip, each separated by at least 10 minutes, providing all switching is completed within a two-hour window	As per Figure 6 $ \% \Delta V_{\text{steadystate}} \leq 3\%$ For decrease in voltage: $ \% \Delta V_{\max} \leq 6\%$ (see NOTE 3) For increase in voltage: $ \% \Delta V_{\max} \leq 6\%$ (see NOTE 4)	Infrequent motor starting and transformer energisation, G59 [4] auto-closing
3	Very infrequent events	1 event in 3 months (see NOTE 2) NOTE: It is permissible to have up to 4 sub-energisations of the same voltage dip, each separated by at least 10 minutes, providing all switching is completed within a two-hour window	As per Figure 7 $ \% \Delta V_{\text{steadystate}} \leq 3\%$ For decrease in voltage: $ \% \Delta V_{\max} \leq 12\%$ (see NOTE 5) For increase in $ \% \Delta V_{\max} \leq 6\%$ (see NOTE 6)	Commissioning, maintenance & post fault switching

NOTE 1: $\pm 6\%$ is permissible for up 100 ms reduced to $\pm 3\%$ thereafter as per Figure 5.
If the profile of repetitive voltage change(s) falls within the envelope given in Figure 5, the assessment of such voltage change(s) shall be undertaken according to the recommendations for assessment of flicker and shall conform to the planning levels provided for flicker.
If any part of the voltage change(s) falls outside the envelope given in Figure 5, the assessment of such voltage changes, repetitive or not, shall be done according to the guidance and limits for RVCs.

NOTE 2: No more than 1 event is permitted per day.

NOTE 3: -10% is permissible for 100 ms reduced to -6% until 2 s then reduced to -3% thereafter as per Figure 6.

NOTE 4: $+6\%$ is permissible for 0.8 s from the instant the event begins then reduced to $+3\%$ thereafter as per Figure 6.

NOTE 5: -12% is permissible for 100 ms reduced to -10% until 2 s then reduced to -3% thereafter as per Figure 7.

NOTE 6: $+6\%$ is permissible for 0.8 s from the instant the event begins then reduced to $+3\%$ thereafter as per Figure 7.

The limits for RVCs proposed in P28 Issue 2 are based on those in the recent GC0076¹ modification to the Grid Code. The key differences between the requirements in P28 Issue 2 and GC0076 are as follows.

- Allowable voltage changes are expressed as a percentage of nominal voltage (V_n) in P28 Issue 2 as opposed to a percentage of the initial voltage (V_o) in GC0076. The intention being to align with the approach taken in National and International Standards.
- For increases in voltage:
 - P28 Issue 2 proposes a limit on the maximum voltage change between two steady state conditions of $\Delta V_{\max} \leq 6\%$ for a maximum duration of 0.8 s from the initiation of a voltage change.
 - GC0076 has a limit of $\Delta V_{\max} \leq 5\%$ for a maximum duration of 0.5 s.
- For decreases in voltage:
 - P28 Issue 2 proposes a time limit of 100 ms from initiation of a voltage change during which the maximum voltage change permitted (-12% for ‘very infrequent events’ and -10% for ‘infrequent events’) can persist.
 - GC0076 has a time limit of 80 ms from initiation of a voltage change during which the maximum permitted voltage change is -12%.
- For increases and decreases in voltage, P28 Issue 2 permits a greater maximum no. of occurrences for Category 3 ‘very infrequent’ events:
 - P28 Issue 2 permits up to a maximum of 4 RVCs in one day (irrespective of type of operation) not more frequent than once every 3 months.
 - Whereas GC0076 permits up to a maximum of 4 RVCs in one day (for commissioning, maintenance and fault restoration) typically not planned more than once per year on average over the lifetime of the connection.
- In P28 Issue 2, the steady state voltage ($V_{\text{steadystate}}$) is reached when the rate of change of system voltage over time is $\leq 0.2\%$ over 1 s compared with $\leq 0.5\%$ over 1 s in GC0076. The lower threshold has been confirmed as being achieved following analysis of voltage changes on the **Distribution Network**.
- P28 Issue 2 introduces an intermediate category of RVC (Category 2) for ‘infrequent events’, where up to a maximum of 4 RVCs in one day not more frequent than once per month are permitted providing the $\Delta V_{\max} \leq -10\%$ for ≤ 100 ms then reducing to $\leq 6\%$ for up to 2 s after initiation of the event (see Figure 6).

¹ GC0076 Grid Code Limits On Rapid Voltage Changes.

The proposed RVC limits in P28 Issue 2 (and associated differences with GC0076) reflect the further work carried out by the P28 joint Working Group and the experience of National Grid in applying RVC limits since GC0076 was implemented in the Grid Code.

The impact of this modification on the current **Distribution Code** requirements would be to allow for a greater no. of RVCs at any point in the system in a year but which would be confined within a 2 hour time window or would be sufficiently spaced apart so as not to result in unacceptable disturbance to other **Customers** or the **Distribution System**. Such a modification would facilitate disconnection and reconnection of complete sites with significant numbers of transformers for infrequent or very infrequent switching operations, including unplanned outages, with the benefits that come from re-establishing distributed generation more quickly after an unplanned outage, e.g. fault outage.

It is understood that a recommendation to accept the proposed RVC limits in P28 Issue 2 is being made by the National Grid representative on the P28 joint Working Group to National Grid with the intention that the Grid Code is further modified to align with the proposed limits in P28 Issue 2.

As the recommendations in P28 Issue 2 clarify the limits that apply for RVC events, such as transformer energisations, and are a refinement of GC0076, the DCRP may wish to consider modifying the relevant text in DPC4.2.3.3 relating to transformer energisation so as to adopt the proposed limits for RVCs in P28 Issue 2.

4.3 Applicability to Operating Conditions and Fault Outages

The scope of P28 Issue 2 relates to voltage fluctuations under normal operating conditions. Normal operating conditions as defined in P28 Issue 2 include credible outages of **User** equipment, under which the **Distribution System** is designed to operate. These include planned outages and fault outages. The limits in P28 Issue 2 are not intended to apply to transient voltage fluctuations between fault initiation and fault clearance or during any reconfiguration of the **Distribution System** immediately following a fault to secure supplies. As such, the DCRP may wish to consider the appropriateness of the wording in DPC4.2.3.3 relating to the $\pm 10\%$ limit on voltage step changes for unplanned outages such as faults.

5. Recommendations for Modification of the Distribution Code

In light of this Paper and the proposed revisions to Engineering Recommendation P28, the DCRP may wish to consider the following recommendations with respect to modifying the **Distribution Code**.

These recommendations are subject to any changes to P28 Issue 2 arising from finalisation by the P28 joint Working Group, public consultation and Report to Authority process to be followed.

5.1 Annex 1 Qualifying Standards

Consideration should be given to updating the reference to Engineering Recommendation P28 to reflect revision from Issue 1 to Issue 2 and the proposed change in title to:

Engineering Recommendation P28 Issue 2

Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom

5.2 DPC4.2.3.2 Voltage Disturbances

Consideration should be given to amending DPC4.2.3.2 (a) to require compliance with appropriate requirements as well as limits set out in in DGD Annex 1, Item 9 Engineering Recommendation P28 Issue 2, “Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom”.

It is recommended that the option in DPC4.2.3.2 (a) remains for the **DNO**, under certain circumstances, to agree to other limits or levels.

5.3 DPC4.2.3.3 Voltage Step Changes

Consideration should be given to amending the title of DPC4.2.3.3 from “Voltage Step Changes” to “Voltage Fluctuations” to align with the title of P28 Issue 2 and the title of CC.6.1.7 of the Grid Code.

Consideration should be given for voltage step changes, as defined in the **Distribution Code**, to comply with the limits for steady state voltage changes ($V_{\text{steadystate}}$) as set out in P28 Issue 2.

Consideration should be given to:

- adopting the limits for voltage fluctuation, in particular those concerning RVCs, set out in P28 Issue 2; and
- replacing the text in DPC4.2.3.3 concerning transformer energisation with a requirement to comply with the requirements and limits for RVCs as stated in P28 Issue 2.

Consideration should be given to adopting the limits for Category 3 ‘Very Infrequent Events’ as set out in Figure 7 and Table 4 of P28 Issue 2 for unplanned outages such as faults, where the **Distribution Code** currently requires design to a voltage step change of $\pm 10\%$.

5.4 Application

Consideration should be given as to whether the limits for voltage fluctuations in P28 Issue 2 for **User’s Equipment** could or should be applied to connection/disconnection of the **DNO’s Eq**