



**Title:** Consultancy Support for the Evaluation of Engineering Recommendation G12/4

**Client:** Ofgem

**Report N<sup>o</sup>:** 8863-01-R1

**Date:** 16 January 2014



## DOCUMENT HISTORY AND STATUS

<b>CONFIDENTIALITY (Confidential or not confidential):</b> Confidential	
<b>Project No.:</b>	8863
<b>Project Name:</b>	Consultancy Support for the Evaluation of Engineering Recommendation G12/4
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<b>Issued by:</b>	TNEI Services Ltd

Revision	Date issued	Reviewed by	Approved by	Date Approved	Revision Type
R0	11/10/2013	Bharti Patel	Anna Ferguson	11/10/13	Preliminary Draft
R1	16/01/2014	Anna Ferguson	Anna Ferguson	16/01/14	First Issue

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## CONTENTS

<b>1</b>	<b>INTRODUCTION .....</b>	<b>4</b>
1.1	BACKGROUND .....	4
1.2	REFERENCE MATERIAL .....	4
1.3	STRUCTURE OF THIS REPORT .....	5
<b>2</b>	<b>REVIEW OF ER G12/4 .....</b>	<b>6</b>
2.1	OVERALL SUITABILITY FOR PURPOSE .....	6
2.2	APPROPRIATENESS OF THE PROCESS .....	7
2.3	RELATIONSHIP TO PREVIOUS ENGINEERING RECOMMENDATIONS .....	8
2.3.1	<i>References</i> .....	8
2.3.2	<i>Definitions</i> .....	9
2.3.3	<i>Substation Earthing</i> .....	10
2.3.4	<i>Cross Sectional Area of Neutral Conductor</i> .....	10
2.3.5	<i>Branches and Service Lines</i> .....	10
2.3.6	<i>Values of Earth Electrode Resistance</i> .....	11
2.3.7	<i>Electrode Separation Distance</i> .....	11
2.3.8	<i>Size of Bonding connections</i> .....	11
2.3.9	<i>Protective Neutral Bonding (PNB)</i> .....	11
2.3.10	<i>Conditions for consumers with existing SNE earth</i> .....	12
2.3.11	<i>Labels and Notices</i> .....	13
2.3.12	<i>Special Situations</i> .....	13
2.3.13	<i>Traction Applications</i> .....	13
2.3.14	<i>Construction and Demolition Sites</i> .....	14
2.3.15	<i>Swimming Pools</i> .....	15
2.4	INTERFACE WITH DISTRIBUTION CODE PROVISIONS .....	16
2.5	ERRORS IN DIAGRAMS AND TYPOGRAPHICAL MISTAKES .....	17
2.6	COMPLIANCE OF ER G12/4 WITH ELECTRICITY ACT OBJECTIVES .....	17
<b>3</b>	<b>CONCLUSIONS .....</b>	<b>18</b>
3.1	SUITABILITY OF ER G12/4 FOR REPLACING G12/3 UNDER THE DISTRIBUTION CODE .....	18
3.2	COMPLIANCE OF ER G12/4 WITH ELECTRICITY ACT OBJECTIVES .....	18
3.3	CRITICAL RECOMMENDATIONS .....	18
3.3.1	<i>Protective Neutral Bonding (PNB)</i> .....	18
3.3.2	<i>Conditions for consumers with existing SNE earth</i> .....	19
3.3.3	<i>6.2.5 Swimming Pools and other basins</i> .....	20
3.4	ADDITIONAL RECOMMENDATIONS .....	21
3.4.1	<i>Labels and Notices</i> .....	21
3.4.2	<i>Installation of Electrodes along branches</i> .....	21
3.4.3	<i>Construction and Demolition Sites</i> .....	21
	<b>APPENDICES .....</b>	<b>23</b>
	APPENDIX 1 - MAPPING OF G12/3 TO G12/4 .....	23
	APPENDIX 2 - CONSULTANTS' RESPONSE TO WORKING GROUP COMMENTS .....	28

# 1 Introduction

## 1.1 Background

This report has been prepared by TNEI and Atkins in response to a request from Ofgem for assistance with the evaluation of Engineering Recommendation G12/4, “Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks”. This Engineering Recommendation (EREC) has been produced by a Working Group (WG) co-ordinated by the Energy Networks Association (ENA) to supersede EREC G12/3.

The report presents the findings of our review of G12/4 and the associated Report to the Authority that was produced by the DNOs to accompany the new EREC.

## 1.2 Reference Material

A report entitled “Requirements for the application of protective multiple earthing to low voltage networks - a review of Engineering Recommendation G12/3”, has been submitted to Ofgem by the DNOs in relation to the proposed changes to the D Code and G12/3.

The report contains a summary of the proposed amendments, with significant supporting background information in the appendices, including:

Appendix 1 - Working group Terms of Reference

Appendix 2 - Proposed ER G12/4

Appendix 3 - Proposed Distribution Code Changes

Appendix 4 - Consultation Paper DCRP\_12\_04\_07

Appendix 5 - Consultation Responses and WG observations

Appendix 6 - Working Group membership



### 1.3 Structure of this Report

Section 2 of this document comments on the following points:

- the relationship between G12/4 and the previous document, G12/3, noting particular points of difference between the two Engineering Recommendations;
- the compliance of ER G12/4 with Electricity Act objectives; and
- the impact of the revised G12/4 on the Distribution Code.

Section 3 presents a review of the issues raised in the Report to the Authority, including comments submitted by respondents to the consultation process that was undertaken by the WG in the course of producing the new document.

Section 4 summarises the conclusions of our work regarding the key questions of:

1. the suitability of G12/4 for replacing G12/3; and
2. whether G12/4 meets the objectives defined in the Electricity Act.

This section also presents the Consultants' recommendations.

The appendices to this report are structured as follows:

- Appendix 1 contains details of the mapping of the content of G12/3 onto the content of G12/4 and identifies new material in G12/4;
- Appendix 2 summarises those issues relating to G12/4 on which two or more respondents raised queries during the consultation process, or where the Working Group did not accept the comments raised.

## 2 Review of ER G12/4

### 2.1 Overall suitability for purpose

The Report to the Authority describes the drivers for change to G12. They include:

- The need to develop clearer guidance to DNOs on when PME supplies can be provided to Traction Operators in order to achieve a more consistent approach across the UK;
- The publication and development of other standards in the years since the publication of G12/3, including the IET Wiring Regulations and European Standards. These standards also provide technical guidance on low voltage PME supplies.

The Terms of Reference for the Distribution Code Review Panel (DCRP) G12 Working Group (WG) state that the review should consider these items, as well as a number of other areas.

It is clear that these items have been addressed. For example, G12/4 has a significantly more detailed section discussing the special situation of auxiliary LV supplies associated with railways and tramways.

The structure of G12/4, subsequent to introductory sections, is as follows:

- General Requirements for all PME networks, including suitable earthing conductors, electrodes, and requirements for overall resistance to earth;
- General Requirements on the consumer's side of a PME installation;
- Special requirements for specific situations including traction applications, temporary installations and street furniture.

This is followed by two appendices which provide supporting information on the general earthing requirements for non-traction supplies from the Electricity Safety, Quality and Continuity Regulations (ESQCR), and the specific earthing design considerations relating to AC and DC electrified traction systems in the UK.

The structure of G12/4 is very similar to the document it is replacing, and is considered to be suitable for purpose. The details within key sections of the document have undergone significant revision. These detailed changes have been reviewed, and are discussed in this report.

## 2.2 Appropriateness of the Process

In their report to the Authority, the DNOs outline the measures taken to make sure that this consultation process has had representation from a wide and suitable range of stakeholders, including:

- Setting up a Working Group to undertake the review (comprising all DNOs, an IDNO representative and direct representation from the rail industry);
- Consulting widely with stakeholders and bringing proposals to a wide audience; and
- Having a period of public consultation.

Eight responses to the public consultation were received from customers, manufacturers and installers associations, showing reasonable engagement from industry. It is noted that the DCRP unanimously supported the proposals put forward in the Report to the Authority.

It is the Consultants' view that a reasonable balance of comments was received. Responses to the public consultation were obtained from:

- One Manufacturers' Association;
- One Traction Customer;
- One Meter Administrator;
- Five "Other", i.e. UK Lighting Board, Electricity Safety Council, Association of Meter Operators, Highway Electrical Association (HEA) and Rail Safety and Standards Board (RSSB).

The majority of the comments have been accepted by the Working Group. Those that were not accepted are discussed in Section 3.4. In each case an explanation has been given for the cases in which comments were rejected.

## 2.3 Relationship to previous Engineering Recommendations

The majority of the recommendations contained within G12/3 have been transferred to G12/4, although there have been significant changes to the details of the interface protection and type testing requirements. A detailed mapping analysis on a paragraph basis is given in Appendix 1. The main points are summarised below.

### 2.3.1 References

A total of seventeen references have been removed from the revised standard. Thirteen new references to British and European standards and ENA publications have been added. Table 2-1 captures the specific changes.

**Table 2-1: References removed and added**

References removed from G12	References added
Electricity Supply Regulations (no longer in use)	The Electricity Safety Quality and Continuity Regulations 2002 (SI 2002 No. 2665), as amended
	The Electricity at Work Regulations 1989 (SI 1989 No. 635), as amended
BS 6346 Specification for PVC insulated cables for electricity supply	BS 7870-5: LV and MV polymeric insulated cables for use by distribution and generation utilities.
BS 7671 Cathodic protection	BS EN 50122-2: Railway applications. Fixed installations. Protective provisions against the effects of stray currents caused by d.c. traction systems
BS 6551 Protection of structures against lightning	BS EN 62305: Protection against lightning
COP 34 & COP 35 HMSO The use of electricity in mines and quarries HS(G) 41 Petrol filling stations	IEC/TS 60479-1: Effects of current on human beings and livestock. General aspects
TS 43-14 Conductor fittings and associated apparatus for use with lv aerial bundled conductors	TS 43-13: Aerial bundled conductors insulated with cross-linked polyethylene for low voltage overhead distribution
TS 43-94 Earth rods and their connectors BS 951 Earthing Clamps	EREC C93: Type approval tests for mechanical connections to metallic sheaths of cables
ER P20/1 Earthing Policy for consumer's installations	EREC G87: Guidelines for the provision of low voltage connections to multiple occupancy buildings
ER P22 Code of practice procedure for advising customers on the unsuitability of water pipe for use as earth electrodes	EREP 123: Guidelines for managing the interfaces between utility services and light rapid transit systems



References removed from G12	References added
ER P23 Consumers earth fault protection for compliance with the IEE Wiring Regulations for Electrical Installations	BS 7909: Code of practice for temporary electrical systems for entertainment and related purposes
ER P25 The short-circuit characteristics of Public Electricity Suppliers low voltage distribution networks	BS EN 50122-1: Railway applications. Fixed installations. Protective provisions relating to electrical safety and earthing
ET 113 Notes of guidance for the protection of private generating sets for operation in parallel with Electricity Board Distribution Networks	EREC G83: Recommendations for the connection of type tested small-scale embedded generators (up to 16A per phase) in parallel with low voltage distribution systems
ER G39/1 Model code of practice covering public lighting and other street furniture ER P04/1 Services to BT public telephones	

### 2.3.2 Definitions

The revised G12/4 now includes a chapter of definitions at the beginning of the standard, as is customary for all recent ERECs. The majority of the definitions in G12/4 are taken from the Electricity Safety, Quality and Continuity Regulations (ESQCR) and the Wiring Regulations BS 7671. Four new definitions are introduced as follows:

1. Aerial Bundled Conductor (ABC)

The acronym ABC is used in several places throughout the document. It was commented by respondents to the consultation that readers may not be familiar with this acronym and so the inclusion of a definition is helpful.

2. Branch

A branch and service line are now defined, as these are critical to the requirements of Protective Neutral Bonding as specified in Section 4.11 of the DNOs' report.

3. Protective Neutral Bonding (PNB)

The definition of PNB appears to have changed in the revision of this document. G12/3 (1995) includes the following interpretation (definition):

*PNB refers to the technique of using the supply neutral conductor directly from the transformer to provide a protective earthing facility to a single customer. The neutral is earthed at one point only normally at or adjacent to the customer's installation.*

Instead G12/4 includes the following definition:

*PNB refers to the situation where there is only one point in a network at which consumers' installations are connected to a single source of voltage. In such a case, the supply neutral conductor connection to earth may be made at that point or at another point nearer to the source of voltage.*

According to this new definition:

- The number of customers' installations is no longer limited to one;
- The point of earthing can be at a distance (not specified in the definition) from the customers' installations.

#### 4. Caravan

The definition of a Caravan is not taken from BS 7671, although this does include a separate definition. In general, however, the essence of the wiring regulations definition is carried through to the G12/4 definition. The G12/4 definition is wider, as it also includes mobile and residential park homes.

### 2.3.3 Substation Earthing

The requirement that the HV and LV earths must be segregated if the combined earth impedance exceeds 1 ohm has been dropped as this was a requirement of the 1988 Electricity Supply Act. The need to segregate the systems is now based on the Rise of Earth Potential (ROEP), which can be calculated by undertaking earthing studies for a specific site. The maximum ROEP of 430V is consistent with EA TS 41-24.

### 2.3.4 Cross Sectional Area of Neutral Conductor

For single phase and split phase, the revised G12/4 now introduces specific minimum cross sectional areas for the neutral conductor of:

- 10mm<sup>2</sup> for copper conductors
- 16mm<sup>2</sup> for aluminium conductors

These reflect the minimum size of main protective bonding conductors for PME supplies given in Table 54.8 of BS 7671. Previously, the only requirement was that the CSA of the neutral conductor was not less than that of the phase conductor.

### 2.3.5 Branches and Service Lines

A branch is defined as a sub-division of a distributing main from its end furthest from the source of voltage to its junction with the distributing main.

G12 states that a branch may be classified as a service line provided that:

- it connects no more than four consumers' installations, of which one or more has a PME earthing terminal; and

- it is no more than 40 metres in length from its point of connection to the distributing main.

Figure 4.4 includes one case of a service line dedicated to a single customer's installation with "no maximum length". This seems to contradict the limit of 40m given in section 3.2 for a service line.

### 2.3.6 Values of Earth Electrode Resistance

The requirement for LV earth electrodes to have sufficiently low resistance so that HV protection operates correctly has been carried forward, but reference to a specific maximum value of 40 Ohms has removed. As a result, earthing studies will need to be performed in accordance with EA TS 41-24. This is more appropriate given the possible variation of local soil conditions.

### 2.3.7 Electrode Separation Distance

The minimum separation distance between any two electrodes has been increased from 3m or the depth of the electrode to two times the depth of the electrode. This now aligns with guidance in BS 7430.

### 2.3.8 Size of Bonding connections

The minimum size of bonding connection to link boxes and network feeder pillars and the connection between the cable sheath and neutral conductor at a SNE or CNE cable joint has been increased from 16mm<sup>2</sup> copper to 32mm<sup>2</sup> copper.

This change does not appear to be directly taken from BS 7670; however, it is in line with the trend of increased CSA requirements for earthing conductors not protected against corrosion.

### 2.3.9 Protective Neutral Bonding (PNB)

G12 states that PNB may be adopted if the number of consumers and their distance from the connection to earth meet the same restrictions as those applied to a branch. However, the definition of a branch included in section 3.2 only include restrictions for a branch that can be classified as a service line.

Section 3.2 specifies the maximum length of a service line from its point of connection to the distributing main (but this is not a distance from the connection to earth as implied in 4.11). Therefore, the reference made in section 4.11 to section 3.2 could lead to misinterpretations.

It is suggested that in order to avoid misunderstandings, section 4.11 should include the following restrictions:

- Maximum number of customers' installations;
- Distance between the common connection point of the customers' installations and the supply substation;

If the number of customers' installations is limited to 4 and the length of the distance between the common connection point of the customers' installations and the supply substation is limited to 40m then this can be considered as equivalent to Case B shown in Figure 4.4.

### 2.3.10 Conditions for consumers with existing SNE earth

Historically, many distributed networks contained Separate Neutral and Earth (SNE) conductors when G12/3 was published in 1995. Section 5 now makes provision for customers with SNE installations on a network where a Combined Neutral and Earth (CNE) cable is introduced. The remaining condition on SNE installations is that the neutral is continuous back to the supply substation and therefore the currents are returned to the substation. The metallic sheath of the cable must have sufficiently low resistance to control the rise of potential to acceptable levels under open circuit conditions.

It is stated that this criterion will be met provided the resistance to earth of the sheath or individual earth electrode is 20 ohms or less. This guidance value has been increased from 10 ohms to 20 ohms. One danger with this approach is that the 20 ohm value is taken to be the default value and that the rise of potential is not calculated and proved to be safe.

It is the consultants' view that in the event of a neutral break the 20 ohm value will not be sufficient to cause the operation of protection devices other than residual current circuit breakers which at the time of SNE installations were not a requirement under BS7671 and the pre-dating IEE Wiring Regulations. Also, the voltage produced on the earth under these conditions has the potential to exceed the safe touch voltages within BS EN50522 with no disconnection time.

In comparison with the PME condition, Section 4.7 specifies the earth resistance applicable to PME systems as compliant with ENATS 41-24 and not exceeding 20 ohms. Section 5.2.1 excludes the option of providing a PME earth if the installation is not designed to BS7671. BS7671 has addressed earthing issues historically by the use of supplementary bonding and within the existing regulations by the requirement for residual current devices. The combination of the 20 ohm requirement within the supply network and the BS7671 requirements within the installation would require a dual failure within the overall system before a dangerous voltage would have the possibility of causing harm.

Therefore, it is difficult to see how the 20 ohm resistance value in section 5.1 can provide safety in the event of a neutral failure. We would need to examine any evidence that the authors of this revision may have to support the following statement included in Section 5.1:

*“By experience this criterion will be met provided the resistance to earth of the metallic sheath is 20 ohms or less or an individual earth electrode is provided with a resistance of less than 20 ohms”*

If this evidence is not available we would suggest excluding the “By *experience this criterion will be met ... 20 ohms*” clause hence leaving only the “*sufficient to limit the rise of potential under open circuit neutral conditions*” clause.

### 2.3.11 Labels and Notices

Section 5.4 currently suggests that installers *should* label the service position at a consumer’s installation where PME services are available. It was raised in one response to the consultation documents that this should be mandatory practice, and the *should* replaced with *shall*. In the interest of good safety practice it is suggested by the consultants that this practice could be made mandatory, and the *should* replaced with *shall*.

### 2.3.12 Special Situations

This section now includes an explanation of the potential dangers of PME earthing, if adopted in unsuitable locations or situations. This is a helpful addition as it reinforces the need for clear guidance as given in this EREC.

### 2.3.13 Traction Applications

This section has been entirely revised in order to differentiate between the requirements of:

- AC electrified traction systems;
- DC electrified traction systems;
- Sites with both AC & DC traction systems.

Previously, a fixed limit of the acceptable voltage (25 volts) on the return path of the traction system was applied in all three cases with little or no guidance as to how compliance with this limit could be ensured.

#### AC electrified traction systems

The 25 volt limit is retained, but in addition it is made clear that an earthing study must be performed or design standards must ensure that the rise of earth potential must also be limited to the acceptable values as specified by TS 41-24. The critical values are incorporated into G12/4 for easy reference.

Rail electrical safety standard BS EN 50122-1 and Low Voltage Power Supplies standard GL/RT1255 were specifically referenced in the consultation draft, but responses from the Railway Safety and Standards Board raised concerns that as these standards do not apply uniformly across all rail sectors, reliance on them for compliance could be misleading. In response, the WG has removed direct reference to them in this section; however they remain referenced in the *NOTE* for information.

#### DC electrified traction systems



The 25 Volt limit is not retained in relation to DC traction systems. Instead it is specified that for a PME supply to be provided, neither pole of the traction system may be directly connected to earth, and the rails or conductors are adequately insulated from earth. BS EN 50122-2 is now referenced as the relevant rail standard to ensure adequate protection from DC stray currents and that no voltage is picked up by the neutral/earth at the point of supply.

It is noted in G12/4 that these requirements are based on the recognition that any stray currents that do exist should become quickly apparent to the railway operator through regular inspections of structures and earthing systems, as more current will flow through these elements than the DNO LV earthing system.

This is considered to be a reasonable approach, as there is now an increased understanding of the electrolytic corrosion caused by DC currents, and so the regular inspection of current paths for signs of corrosion is common practice. In BS EN 50122-2, provisions are even given for the continuous monitoring of rail potential, to assess stray current.

#### Sites with both AC & DC traction systems

This requirement has been simplified significantly, as G12/4 now simply states that a PME earth terminal shall not be provided if a site has both AC and DC traction systems.

It is clear that the revised G12/4 offers improved guidance for DNOs about the safe and acceptable conditions under which a PME earth can be supplied to traction customers. This was a key driver for change in the review process.

#### **2.3.14 Construction and Demolition Sites**

It is acknowledged that the requirements of a PME system are not generally practical on construction sites; however G12/4 now includes guidance on the types of earthing system that would be acceptable instead. Two options have been included:

1. TN-S supply from a dedicated transformer
2. TT supply with RCD protection

In the consultation draft, a third option was also presented, providing a TN-S supply via an isolation transformer. This option was removed following responses to the consultation which highlighted that an isolation transformer is not required, as the protective separation provided by an isolating transformer can also be provided by a suitable power transformer.

It is suggested by the Consultants that the isolation transformer is still a valid solution and provides a useful additional option in the case that there is no dedicated power transformer on site. It is suggested the wording of an isolating transformer be removed however to reflect an isolating transformer or power transformer could be used.

It is suggested with the reintroduction of this section, 6.2.2.3 it will also be required to re-word the requirements of voltage rise. In line with the previous user comments it is suggested the wording *'the voltage rise on the site earth is less than 50V'* is replaced with *'the product  $R_A \times I_{\Delta n}$  is less than or equal to 50 V, as required by BS 7671'*.

### 2.3.15 Swimming Pools

The guidance for the provision of PME to buildings and locations containing swimming pools and other basins has been expanded to provide *"Competent persons enquiring about the suitability of PME for swimming pool supplies"*.

The following guidance suggests that it is acceptable to provide a PME supply and it is then the electrician's decision as to whether or not to utilise the PME terminal for all or part of the installation. It is further explained that it is acceptable to use a PME earthing system, TT system or combination of these systems, depending on the exact arrangements and segregation of the pool installation within the location.

The references to BS 7671 are slightly confusing with regard to the TT system and requirements for RCDs. In general, this topic is specified well in BS 7671, Section 702, and it is considered that the wording on this section could be simplified by referring to BS 7671 for full installation details, in order to avoid ambiguities between G12/4 and BS7671.

## 2.4 Interface with Distribution Code provisions

The Distribution Licence conditions require the Distribution Code to satisfy various requirements in respect of Low Voltage Networks as given in Table 2-2:

**Table 2-2: Distribution Licence Condition Requirements**

Licence condition requirements	Discussion in respect of LV Network Earthing
<p>The Code must cover all material technical aspects relating to connections to and the operation and use of the licensee’s Distributions System or (so far as is relevant to such operation and use) the operation of electric lines and electrical plant connected to that system.</p>	<p>G12/4 is referenced by The Distribution Planning and Connection Code (DPC). G12/4 covers the License condition requirement for the DNO to provide such information, as may be reasonably required, on the design and other characteristics of the DNO’s Distribution System.</p>
<p>The Code must include a Distribution Planning and Connection Code that must contain:</p> <ul style="list-style-type: none"> <li>• Planning conditions that specify the technical and design criteria and procedures that are to be applied by the licensee in the planning and development of its distribution system and taken into account by persons having a connection or seeking a connection to that system in the planning and development of their own plant and systems;</li> <li>• Connection conditions that specify the technical, design and operational criteria to be complied with by any person having a connection or seeking a connection to the licensee’s distribution system.</li> </ul>	<p>G12/4 covers the design practice for Protective Multiple Earthing, as it affects connection conditions.</p>
<p>The Code must be designed (so far as is consistent with the first two requirements) to:</p> <ul style="list-style-type: none"> <li>• Permit the development, maintenance and operation of an efficient, co-ordinated and economical system, for the distribution of electricity; and</li> <li>• Facilitate competition in the generation and supply of electricity</li> </ul>	<p>G12/4 provides guidance to Connectees and Distribution Network Operators (DNOs) regarding the requirements for the application of protective multiple earthing to low voltage networks to enable this licence requirement to be met.</p>

In the process of revising G12/3, some editorial changes have been made to the Distribution Code. These changes have been presented in the Report to the Authority (Appendix 3). The issue summary at the end of the Distribution Code summarises the revisions between versions. The change required for the proposed G12/4 is cited as being:

*Replace G12/3 with G12/4 in Annex 1, DPC4.3.2 - Design Principles, DPC4.4.2 - Earthing*



As noted in the Report to the Authority (section 5.2), the changes replacing the references to G12/3 are editorial, and do not have any impact on the interpretation of the Code.

## 2.5 Errors in diagrams and typographical mistakes

There were no editorial errors and typographical mistakes identified in G12/4 during the course of this review.

## 2.6 Compliance of ER G12/4 with Electricity Act objectives

A key requirement of ER G12/4 is that it supports Ofgem in meeting its obligations under the Electricity Act; any conflicts between the recommendations of ER G12/4 and Ofgem's obligations are therefore to be avoided.

The most relevant of Ofgem's duties to the areas of activity covered by G12/4 are:

- To promote competition in the generation and supply of electricity - Section 3A(1) of the Act; and
- To protect the public from dangers arising from the generation, transmission or supply of electricity - Section 3(5)(b).

Note that the Electricity Act, when originally enacted, contained a duty on the Authority to protect the interest of consumers in respect of quality of supply (Section 3(3)(a)(iii)). This clause is not in the revised Section 3A of the Electricity Act; the revisions to the duties of the Authority were set out in the Utilities Act 2000. The quality of supply is covered by the licence obligations of the DNOs.

ER G12/4 has an important role to play in the second of these areas, for a number of reasons:

- *Provisions for the earthing of low voltage networks are crucial to maintain the safe operation of the distribution networks and thus to protect the public adequately.*

In the majority of areas the new Engineering Recommendation G12/4 is considered to deliver all of the above requirements. Where there were concerns in specific areas, these have been highlighted in this report and are summarised in Section 0 below.



## 3 Conclusions

### 3.1 Suitability of ER G12/4 for replacing G12/3 under the Distribution Code

It is the Consultants' view that a reasonable balance of comments was submitted, the majority of which have been accepted by the Working Group. There were no comments received from DNOs or Network Rail, however both these groups were represented fully on the Working Group.

Following the WG consideration of and response to the recommendations in Section 0 below, G12/4 removes a number of inconsistencies and shortfalls which were present in G12/3 and generally provides a simpler, more standardised approach to the connection of SSEG.

Section 3.3 summarises the issues that were considered by the Consultants to be critical to the compliance of G12/4 with the objectives set out in the Terms of Reference. Section 0 contains additional suggestions for areas of improvement, but these points are not critical to the suitability of ER G12/4 for replacing G12/3.

### 3.2 Compliance of ER G12/4 with Electricity Act objectives

The new Engineering Recommendation G12/4 is considered to meet all of the above requirements and is consistent with the Authority's principal objectives under The Electricity Act.

### 3.3 Critical Recommendations

These issues were considered by the Consultants to be critical to the compliance of G12/4 with the objectives set out in the Terms of Reference.

*These recommendations have now been discussed with the working group and their comments and final responses are included below. The consultants are satisfied by the final responses of the working group that each of these issues has been resolved.*

#### 3.3.1 Protective Neutral Bonding (PNB)

G12/4 states that PNB may be adopted if the number of consumers and their distance from the connection to earth meet the same restrictions as apply to a branch. However, the definition of a branch included in section 3.2 only includes restrictions for a branch that can be classified as a service line.

Section 3.2 specifies the maximum length of a service line from its point of connection to the distributing main (but this is not a distance from the connection to earth as implied in 4.11). Therefore, the reference made in section 4.11 to section 3.2 could lead to misinterpretations.

It is suggested that in order to avoid misunderstandings, section 4.11 should include the following restrictions:

- Maximum number of customers' installations
- Distance between the common connection point of the customers' installations and the supply substation

Working Group proposed wording: *“PNB may be adopted if the number of consumers is 4 or less and their distance from the connection to earth is 40m or less.*

*The LV neutral conductor shall be connected to an earth electrode at a point remote from the transformer, between the transformer and the supply terminals of the consumer(s). The distance between the connection to earth and the consumers' intake shall be 40m or less; however in order to minimise the risk of voltage rise in the event of a broken neutral this connection should be made as close as is practicable to the consumers' supply terminals. The metallic sheaths of any LV cables shall also be connected to the earth electrode. The resistance of the earth electrode shall not exceed 40 ohms”*

This change is accepted by the consultants.

### 3.3.2 Conditions for consumers with existing SNE earth

One of the conditions for SNE installations remaining on a network where a Combined Neutral Earth (CNE) cable is introduced is that the metallic sheath of the cable has sufficiently low resistance to control the rise of potential to acceptable levels under open circuit conditions.

It is stated that this criterion will be met provided the resistance to earth of the sheath or individual earth electrode is 20 ohms or less. One danger with this approach is that the 20 ohms is taken as the default value and the rise of potential not calculated and proved to be safe.

It is the consultant's view that In the event of a neutral break the 20 ohm value will not be sufficient to cause the operation of protection devices other than residual current circuit breakers which at the time of SNE installations were not a requirement under BS7671 and the pre-dating IEE Wiring Regulations. Therefore it is difficult to see how the 20 ohm in section 5.1 can provide safety in the event of a neutral failure.

The Consultants would need to examine any calculations/earthing model/site measurements that the authors of this revision may have to support the following statement included in the referred section:

*“By experience this criterion will be met provided the resistance to earth of the metallic sheath is 20 ohms or less or an individual earth electrode is provided with a resistance of less than 20 ohms”*



If these calculations are not available, the Consultants would suggest excluding the 'By experience this criterion will be met ... 20 ohms' clause hence leaving only the 'sufficient to limit the rise of potential under open circuit neutral conditions' clause.

Working Group proposed wording: "By experience this criterion will be met provided the resistance to earth of the metallic sheath is 10 ohms or less or an individual earth electrode is provided with a resistance of less than 10 ohms. Where in specific circumstances the 10 ohm value cannot be achieved, a value of up to 20 ohms is acceptable where it can be shown by calculation that any voltage rise on the neutral conductor of the 3 phase cable is limited to 100V."

This change is accepted by the consultants.

### 3.3.3 6.2.5 Swimming Pools and other basins

As this topic is well specified in BS 7671, Section 702, it is suggested that the wording in this section can be simplified as follows in order to avoid ambiguities between G12/4 and BS7671.

It is the suggestion of the Consultants to replace all text by the following paragraph:

*"Locations containing swimming pools and other basins are considered to be 'Special Locations' within BS 7671, Section 702. The electrical installation, the supply system and the earthing system shall comply with the requirements included in BS7671, Section 702."*

Working Group proposed wording:

"NOTE: This Section is for guidance of Network Operators only.  
(continue with existing text)"

This change is accepted by the consultants.

### 3.4 Additional Recommendations

These recommendations are not critical to the suitability of ER G12/4 for replacing G12/3; however the Consultants suggest that they are considered by the WG.

#### 3.4.1 Labels and Notices

Section 5.4 currently suggests that installers *should* label the service position at a consumer's installation where PME services are available. It was raised in one response to the consultation documents that this should be mandatory practise, and the *should* replaced with *shall*. In the interest of good safety practice it is suggested by the consultants that this practice could be made mandatory, and the *should* replaced with *shall*.

Working Group proposed wording: “Where PME facilities are available to a consumer, a label shall be affixed at the service position drawing attention to the fact that the service is connected to a network having protective multiple earthing.”

This change is accepted by the consultants.

#### 3.4.2 Installation of Electrodes along branches

Figure 4.4 includes one case of a service line dedicated to a single customer's installation with “no maximum length”. This seems to contradict the limit of 40m given in section 3.2 for a service line. It is the consultant's suggestion that the working group address this apparent conflict, by including the maximum length.

Working Group response: We do not feel a change is necessary to the existing Figure 4.4.

The working group has clarified that there is no maximum length for a service line, only upon branches classed as service lines. This explanation is accepted by the consultants.

#### 3.4.3 Construction and Demolition Sites

In the consultation draft, the options were presented for earthing arrangements on construction and demolition sites. One of these options was to provide a TN-S supply via an isolation transformer. This option was removed following responses to the consultation which questioned the need specifically for an isolating transformer.

The Consultants' view is the comments were not correctly interpreted by the working group. The comments suggest that it is not specifically an isolation transformer which is needed and in fact any power transformer could be used provided the required voltage for the site is provided by the power transformer.

It is suggested by the Consultants that the isolation transformer is still a valid solution and provides a useful additional option in the case that there is no dedicated power transformer on site. . It is suggested the wording of an isolating transformer be removed however to reflect an isolating tranformer or power transformer could be used.

It is suggested with the reintroduction of this section, 6.2.2.3 it will also be required to re-word the requirements of voltage rise. In line with the previous user comments it is suggested the wording:

*‘the voltage rise on the site earth is less than 50V’*

is replaced with

*‘the product  $R_A \times I_{\Delta n}$  is less than or equal to 50 V, as required by BS 7671’.*

Working Group proposed wording:

*“The following sections specify the types of earthing systems that can be used for temporary construction and demolition site supplies. As it is usually impractical to comply with the bonding requirements of BS 7671, a PME supply should not be offered, except for the supply to a fixed building of the construction site. The following sections specify the types of earthing system that can be used.*

*In addition to the arrangements shown in 6.2.2.1 and 6.2.2.2, if the site does not have a dedicated transformer, ie the transformer supplies other consumers or other parts of the LV network, it is still possible to provide a TN-S earthing system within the boundary of the site via a suitable isolating transformer.*

*The transition from a temporary to a permanent supply must be taken into account, and both supplies should be considered during the design and planning stages. Refer also to BS 7375.”*

This change is accepted by the consultants.

## Appendices

### Appendix 1 - Mapping of G12/3 to G12/4

Existing document (G12/3) G12/4 applicable paragraphs		Comments
<b>Foreword</b>		
	para 1	NEW paragraph in G12/4 (paragraph 1) including effective date, approval authority and approved abbreviated title.
1 para 1	para 2	Now references ESQCR in place of Electricity Supply Regulations
<b>1 Scope</b>		
2 para 1	1 para 1	Similar to G12/3, but now refers to DNOs in place of PES.
<b>2 References</b>		
	2 para 1	NEW Introductory paragraph.
		Removed the following references: Electricity Supply Regulations (no longer in use) TS 43-14 Conductor fittings and associated apparatus for use with lv aerial bundled conductors TS 43-94 Earth rods and their connectors ER G39/1 Model code of practice covering electricity safety in the planning, installation, commissioning and maintenance of public lighting and other street furniture. Etc.
		Added nine new references to British and European standards.
<b>3 Definitions</b>		

	New Section	Added significant number of defined terms. Comments on individual terms have been captured in the Review of the Report to the Authority and editorial comments.
<b>4. Requirements for PME Networks</b>		
4.1	4.1	No Change
4.2	4.2	The requirement to segregate if the combined impedance exceeds 1 ohm has been dropped as this was a requirements of the 1988 Electricity Supply Act.
4.3.2	4.3	Re-worded to include all protective devices
4.3.1 para 1	4.3.1 para 1	No change
4.3.1 para 2	4.3.1 para 2	Minimum CSAs for the supply neutral added
	New NOTE	Note to describe terms “single phase 3 wire” and “split phase”
4.3.3 para 1	4.3.2 para 1	No change
4.3.3 para 2	4.3.2 para 2	Specific requirements about compression joints etc. removed
4.3.3 para 3	4.3.2 para 3	No change
4.4.1	4.4.1 para 1	Fixed maximum resistance to earth at any point on the neutral of 20 Ohms has been REMOVED.
	4.4.1 para 2	New requirement to install a neutral/earth electrode at the boundary point between network operators.
4.4.2	4.4.2	Relaxation of earth requirements for a ‘branch’ is now restricted to those classified as ‘service lines’
4.5	4.5 para 1	No change
4.5.1	4.5 para 2	No change
4.5.2	4.5 para 3	No change
4.5.3	4.5 para 4	Wording changed to clarify requirement to bond earth and neutral on remote sections of SNE distributing mains in order to convert to PME.
4.5.4 para 1	4.5 para 5	No change



Fig 1	Fig 4.4	Diagram moved from end of document to relevant place in text.
Fig 2	Fig 4.5	Diagram moved from end of document to relevant place in text.
4.5.4 para 2	4.5 para 6	No change
4.6 para 1	4.6 para 1	No change
4.6.1	REMOVED	
4.6.2	4.6 para 2	No change
4.6.3	4.6 para 3	20 Ohm maximum resistance requirement moved to section 4.7
Note	Note 1	No change
	Note 2	NEW comment
4.6.4	4.6 para 4	No change
4.6.5	4.6 para 5	No change
4.8.1	4.7	40 Ohm substation neutral earth resistance requirement has been REMOVED. Instead values in TS 41-24 are referenced.
4.8.2	REMOVED	
4.8.3	4.7	
4.8.4	REMOVED	Assumption that overall resistance is equivalent to individual electrode resistances in parallel has been REMOVED.
4.7 para 1	4.8 para 1	No change
4.7 para 2	4.8 para 2	Separation distances between electrodes changes from 3m or 1x electrode depth to 2 x electrode depth.
4.9 para 1	4.9 para 1	No change
4.9 para 2	4.9 para 2	Wording change and reference to table updated
	4.9 para 3	NEW guidance that it is not acceptable to use short-time equivalent ratings in calculating the required CSA of a PME earthing conductor.
Table	Table 4.9a	Minimum copper equivalent CSA for Bonding connection to link boxes and feeder pillars, and connections between sheath of SNE cable and neutral of CNE cable INCREASED to 32mm <sup>2</sup>

	4.9 para 4	NEW table included to cover equivalent copper CSA for commonly used Al DNO incoming cables
Table 1	Removed	Bonding connection between earthing terminal and metal structures and pipes in customers installation now dealt with in Wiring Regulations.
4.10	4.10	Removed reference to 1 Ohm resistance (same reason as 4.2)
	4.11	NEW section on Protective Neutral Bonding See section 3 for full discussion
<b>5 Customers' Installations</b>		
Section 5	Section 5	Consumers to replace "Customers" in heading
5.1 para 1	5.1 para 1	No change
5.1 para 2	5.1 para 2	Re-formatted for clarity New standard reference IEC/TS 60479-1 Individual electrode max resistance INCREASED from 10 Ohms to 20 Ohms
5.1 para 3	5.1 para 3	
5.1 para 4	5.1 para 4	Resistance to earth of metallic sheath of SNE cable INCREASED from 10 ohms to 20 ohms
5.1 para 5	5.1 para 5	No change
	5.2.1	NEW simplified conditions for when a PME earth terminal CANNOT be offered to consumers.
5.2.1	5.2.2	No change
5.2.2	5.2.3	Reference to BS5951 has been replaced by EREC C93
5.3	REMOVED	Requirement for equipotential bonding is covered in compliance with the wiring regulations
5.4	5.3	No change
5.5.1	REMOVED	Comment regarding Neutral Links not being removed has been deleted.
5.5.2	5.4	No change

6 Special Situations		
6.1	6.1 Para 1	New explanation of impact of PME in unsuitable situations added
6.1.1	6.1 Para 2	No change
	6.1 Para 3	NEW -
6.2	6.2	NEW introduction - adding that this list of special situations is not exhaustive
6.2.1	6.2.1	This section has been entirely revised to differentiate between the requirements of: <ul style="list-style-type: none"> <li>• General</li> <li>• AC electrified traction systems</li> <li>• DC electrified traction systems</li> <li>• Sites with both AC &amp; DC traction systems</li> </ul>
6.2.2	6.2.2	This section has been revised to include additional guidance on the types of earthing system that can be used on a construction site (as PME is not usually practical) <ul style="list-style-type: none"> <li>• TN-S from dedicated transformer</li> <li>• TT with RCD protection</li> <li>• Transition to permanent supply</li> </ul>
6.2.3	6.2.3	Revised to specifically to preclude the use of PME with exhibition stands, temporary structures at fairs and mobile or transport units.

## Appendix 2 - Consultants' Response to Working Group comments

It was noted that in comparison with previous consultations, the WG gave an explanation for rejecting comments, rather than simply stating that they have been rejected. This was extremely helpful for the review process.

Comments from the consultation responses that have not been accepted are detailed in Table A.2.

Technical comments with more than one comment on the same issue are discussed below.

### Street Electrical Fixtures with load of 500kW and over

Three independent respondents raised concern that the limit of 500kW was arbitrary and that there should be some latitude for small increases in load above this level without the requirement to re-design the earthing of the installation.

All three comments were not accepted on the basis that the 500kW limit corresponding to a 100 Ohm minimum electrode resistance can be calculated to give the same voltage rise as a 2 kW load with a 20 ohm earth electrode. This is a legitimate engineering comparison and importantly maintains a safe level of rise of earth potential.

In addition the working group have clarified the requirements by illustrating the necessary maximum electrode resistance for a range of loads from 500w to 5kW, illustrating the relationship between electrical load and resistance to earth in order to maintain a safe level of potential voltage rise.

**Table A.2 Consultants Response to Consultation Responses which were rejected by the Working Group**

Stakeholder	Clause/ Subclause	Type of comment (General/ Technical/ Editorial)	COMMENTS	Proposed change	OBSERVATIONS OF THE SECRETARIAT on each comment submitted
UKLB	2	<b>G</b>	The UK lighting board (UKLB) agree that there has in the past been a lack of consistency in the type of connection provided at similar sites to due to differing interpretations of the existing requirements by different DNO engineers. From that perspective the UKLB welcome an initiative to clarify the regulations.	Suggest this section identifies the benefits to all consumers (and not just 'Rail') of these amendments	Not accepted. The benefits are in improved guidance on special situations; update the documents in line with changes in standards since the last revision and closer alignment with the IET wiring regulations.
UKLB	2	<b>G</b>	There is no economic appraisal of this revision. Will UK plc benefit overall? What are the projected additional costs for DNOs and customer?	There should be an economic appraisal of the revision such that there is clarity about the changes in terms of overall cost and the cost to individual parties. This should form part of an sustainability assessment	Not accepted. There have been no significant changes to the technical requirements so the revision is cost neutral.
UKLB	2	<b>G</b>	There is no environmental appraisal of this revision. Will implementation require more or less materials? (I am assuming line losses will remain constant, but this should also be assessed from a Carbon emissions point of view)	There should be an environmental appraisal of the revision such that there is clarity on the environmental impact of the proposed changes. This should form part of an sustainability assessment	Not accepted. There have been no significant changes to the technical or material requirements with the result that the revision does not have an environmental impact.
UKLB	2	<b>G</b>	There is no societal impact appraisal of this revision. Will implementation result in a greater or reduced level of safety overall. (From a UKLB perspective, there is a concern that consideration has not been given to the possibility there may be an overall increase in risk to our workforce, see below)	There should be a societal impact appraisal of the revision such that there is clarity on the overall safety impact of the proposed changes. This should form part of an sustainability assessment	Not accepted. There have been no significant changes to the technical or installation requirements with the result that the revision does not have social impact
ESC	2	<b>E</b>	Remove reference to edition to future-proof document	Delete 'Seventeenth Edition'	Not accepted, 17th edition contained the current regulations at the time of the review

ESC		T	You apply a different meaning to the term 'caravan' to that given in BS 7671	Clarify that you use a different definition of caravan to that used in BS 7671	Not accepted. This is already clarified by the note, i.e. the definition would have a double asterisk if taken from BS 7671.
TfL	Figure 4.4	technical	Since 2003 TfL have installed for all traffic signals an earth electrode at the feeder pillar to ensure PME service is made available and to minimise danger to public.	Include customer earth electrodes on diagrams and consider the additional contribution towards safety of a PME network.	Not accepted. Fig 4.4 shows minimum requirements to be compliant.
ESC	Fig 4.5	Line not phase	Replace 'phase' with 'line conductor' to read 'line conductor normally open'	Not accepted. See earlier comments on line 205.	ESC
ESC	4.9 Table 4.9a	E	In row 2 of table, should read line not phase	Make 'line conductor'	Not accepted. See earlier comment on line 205.
ESC			The table commences at 35mm – what about smaller services?	It might be clearer to include a top line saying "less than 35mm ... with 16mm earth"	Not accepted. The current table is aligned with other reference documents. The table refers to typical sizes of three-phase cables.
AMO PDAL (part)		G	Meter Operators frequently find cut-outs which are not labelled as PME. When ENA asked on ER requirement the response was that the ER only used the term "should" which means the distributor does not always have to place a label. This leaves the method of earthing available to a customer ambiguous. This is a serious concern for meter operators who are left uncertain what type of earthing (if any) is provided to the customer	On all new and service alterations or cut-out changes the distributor should always explicitly label every cut-out to identify the type of earthing available: CNE, SNE or no earth available. The meter operator and/or customer representative can then connect (or not) to the distributor provided earth connection. This is particularly important when connecting customers in 'special situations'	Not accepted, as this is not considered practical. It is the policy of most Network Operators to fit a label. If uncertain of the earthing arrangement, a competent person should be contacted

TfL	451	Technical	<p>This doesn't mention the UKPN practice of using a grading electrode to raise the potential of the surrounding ground thus reducing the touch potential to the earthed metalwork.</p> <p>Practically, installing a 70mm<sup>2</sup> bare copper electrode 500mm deep and 500 around the perimeter of a feeder pillar is difficult in a London street. The clause seems to force the customer to use Class2 feeder pillar to get PME earth. However, A class 2 pillar will not offer any safety to earth metalwork beyond the feeder pillar even if an RCD is used.</p>	<p>Include the practice of using UKPN "grading electrode" or not</p>	<p>Not accepted. As this is a National Document it cannot include the practices of all Network Operators - they will each have their own earthing policy based on this generic document and tailored for their specific requirements.</p>
TfL	461	Technical	<p>Perhaps traffic signals could be included in special conditions. It is possible for a traffic signal controller, being intelligent equipment, to disconnect its load and reduce the risk of dangerous potential on all associated earthed metalwork.</p>	<p>ADD Intelligent equipment.</p> <p>Where equipment includes voltage monitoring or similar such that under neutral fault conditions the connected load may be reduced to less than 500w in 0.4sec.</p>	<p>Not accepted. Whilst this may be an interesting technical solution the technology is currently unproven for use for this specific purpose so it cannot yet be included in National Documentation</p>
AMO PDAL (part)	475	T	<p>May wish to make explicit that this applies to cut-out and meter panels. Meter panels are provided by distribution businesses.</p> <p>Clarity requested with regard to bullet (c) – is this with regard to railways only or in general on every PME supply position. If general; this is an issue as most multi-occupancy site positions have metal MSDBs (i.e. BEMCO, Ryefield) so many sites would not be compliant.</p>	<p>Include explicit reference to meter panels</p>	<p>Not accepted. This is part of sub-clause 6.2.1, which relates only to railways and tramways.</p>
ESC	568	6.2.2	<p>The word 'temporary' seems superfluous</p>	<p>Delete the word 'temporary'</p>	<p>Not accepted. The supply may be for the final installation or a future one</p>

ESC	6.2.31.1	T	<p>The text relating to exhibitions, shows and stands does not align fully with requirements in Regulation 711.411.4 of BS 7671, which states:</p> <p>‘Except for a part of an installation within a building, PME earthing facility shall not be used as the means of earthing for an installation falling within the scope of this section except:</p> <p>(i) Where the installation is continuously under the supervision of a skilled or instructed person, and</p> <p>(ii) The suitability and effectiveness of the means of earthing has been confirmed before the connection is made.’</p>	Align text with BS 7671 requirement	Not accepted. This requirement is in G12/3 and Network Operators believe the exceptions in (1) and (ii) are too difficult to implement and maintain.
ESC	6.2.4 696	E	IET Guidance Note 5 is just one of many publications that provide some guidance	Delete reference to just one specific source of guidance	Not accepted, as it is the most relevant source of guidance
AMO PDAL	824	T	<p>May also wish to include a reference to IGE/G/5 – gas in flats <a href="http://www.igem.org.uk/technical-standards/standards/general.aspx">http://www.igem.org.uk/technical-standards/standards/general.aspx</a> This describes earthing in respect of gas pipes.</p>		Not accepted, as not deemed necessary.
HEA	861	General	<p>The heading makes reference to electrical load of “500W or less”. This conflicts with both the strict wording of the relevant SI and the wording and intent of the NMO Guidance issued in 2012. The key test is predictability of the load - not whether it is less than 500W</p>	Replace “Street lighting and road signs with electrical load of 500W or less” with “Street lighting and road signs with a predictable load”	Not accepted. The 500W limit has been arrived at through technical considerations and has to remain an absolute requirement.



UKLB	861 & 916	General	Where does the 500W limit come from? Ditto the 2kW threshold. These have cost implications for consumers, so some latitude would allow for a more efficient implementation of objectives. For example, if A LHA upgrades 5 street lights from circuit watts of 90W to 105W, do I really need to redesign my cable network?	Can the limits be explained and justified?  Can there be some flexibility rather than have these fixed and absolute limits? This will facilitate sensible management of the risk in terms of keeping costs proportional to the risk.	The load and any other earth return path act in parallel to limit the rise of voltage under broken neutral conditions. A 20 ohm return path in parallel with a 2kW load will limit the rise in voltage to the same value as a 500W load in parallel with 125 ohms which is the earth resistance of a typical earth rod in average soil conditions. The 2kW/20 ohm values were given as a G12/3 requirement. The earthing design would need to be reviewed in the scenario suggested.  No change proposed.
PDAL	861	T	There is no technical difference as a result of 500W or in the ESQCR. The reference to 500W should be removed.		Not accepted. The 500W limit has been arrived at through technical considerations and has to remain an absolute requirement.
TfL	866	Technical	TfL traffic signal practice is to provide an earth electrode at the Main Earth Terminal to ensure minimised danger of potentials on earthed metalwork where PME service is provided.	ADD - An earth electrode shall be provided at every feeder pillar supplying Traffic signals and shall be connected to the Main Earth Terminal. (to allow for testing) .	Not accepted. It is only relevant if the resistance of the earth rod is chosen to match the load.
HEA	6.2.14	Technical	As written, the document would require an earth electrode even if only one item of equipment is connected to another via a distribution cable	Replace “An earth electrode shall be provided at the end of every service supplying more than one street lamp or road sign.” with “Earth electrode(s) shall be provided at the last or penultimate street lamp or road sign where necessary to ensure the earth loop impedance value is satisfactory”	Not accepted, as the existing wording is considered clear. The requirement for the earth rod is not primarily to do with the earth loop impedance.
TfL	898	Technical	Diagram 6.2.14b: Reference should be made to a max 2kW based on 6.2.15 if this is intended	ADD  Note load not exceeding 2kW	Not accepted, as the 2kW max limit is not necessary. Extend table 6.2.15 to add 1kW, 3kW 4kW and 5kW with values of 60,14,11 and 9 ohms.  Add note to Table 6.2.15 to the effect that by agreement with the Network Operator it may be permissible to take into account the contribution from distributed earths in specific situations.

TfL	900	Technical	Perhaps a diagram for traffic signals should be included and if required show an Earth electrode on the furthest pole(s), which ever that might be (but not all)	ADD Diagram showing earth electrode at end of longest cable run and if large installation include other supplementary earth electrodes around the site.	Not accepted, as too specific.
PDAL	907	T	Many of the examples described would be covered in 6.2.14. So remove as add confusion		Not accepted. The split between 6.2.14 and 6.2.15 is intentional and there should not be any overlaps.

**Table A.2 Consultants Response to Consultation Responses which were rejected by the Working Group**