WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

Company Directive

STANDARD TECHNIQUE: SD5R/2

Earth Fault Loop Impedances and Phase to Neutral Loop Impedances at LV Installations

Author: Seth Treasure / Andy Hood

Implementation Date: January 2018

Approved by

Policy Manager

Date: 15 January 2018

IMPLEMENTATION PLAN

Introduction

This document specifies the requirements for the maximum impedance values permitted for WPD connections.

Main Changes

The maximum phase to neutral impedance values were reduced in ST: SD5R/1 to limit the impact of low carbon technology (e.g. electric vehicle chargers, heat pumps, embedded generation etc.) on power quality. Table 1 Note 8 has been added to the latest version of the document, ST: SD5R/2, to clarify the requirements where an existing LV circuit is modified.

Impact of Changes

The changes are relevant to all staff involved with the design, installation and metering of low voltage connections.

Implementation Actions

Managers responsible for staff involved in the design, installation and metering of low voltage connections shall ensure the relevant are aware of, and follow the requirements of this document.

Implementation Timetable

This policy is implemented with immediate effect.

REVISION HISTORY

Document Revision / Review Table		
Date	**Changes / Comments**	**Author**
January 2018	• Note 8 has been added to Table 1	Andy Hood
December 2017	The maximum Phase to Neutral impedance values for new and substantially modified networks have been amended	Andy Hood Seth Treasure

1.0 INTRODUCTION

This document specifies the requirements for earth fault loop impedance and phase to neutral loop impedance within Western Power Distribution's (WPD's) LV Network.

Impedance (Z) is the sum of resistance (R) and reactance (X). Resistance and reactance are displaced by 90^{o} from each other and hence are added using Pythagoras Theorem as shown below:

$$Z = \sqrt{(R^2 + X^2)}$$

Earth fault loop impedances and phase to neutral impedances determined at the Connection Point will be identical in systems that utilise a combined neutral and earth conductor over their entire length. Such systems include those utilising Protective Multiple Earthing (PME) and Protective Neutral Bonding (PNB).

2.0 DERIVATION OF MAXIMUM LOOP IMPEDANCES

2.1 General

Two types of loop impedance are considered, Phase to Neutral Loop Impedance (PNLI) and Earth Fault Loop Impedance (EFLI).

2.1.1 Phase to Neutral Loop Impedance (PNLI)

The phase to neutral loop impedance (PNLI) of the network affects the voltage rise / drop caused by connected load and has a significant impact on power quality, including voltage disturbances (flicker and rapid voltage changes), voltage distortion (harmonics) and voltage unbalance. It also affects losses in the network.

2.1.2 Earth Fault Loop Impedance (EFLI)

Typical maximum earth fault loop impedances (EFLIs) within WPD's existing network are in accordance with ENA ER P23.

It should be noted that the IET Wiring Regulations (BS7671) does not specify maximum values for EFLI, however it does, in some cases, specify maximum fault clearance times for the customer protection.

The EFLI of a network affects the sensitivity and operating time of protection (fuses, MCBs etc.). WinDebut checks that substation fuses are capable of operating within 60 seconds.

It should be noted that WinDebut assumes the network utilises a combined neutral and earth conductor. Where this is not the case, for example, where we use separate neutral and earth conductors or where TT connections are provided the earth fault loop impedances obtained from WinDebut will actually be Phase to Neutral Loop Impedances.

2.1.3 PME (TN-C-S) and PNB Connections

For new and substantially modified PME and PNB systems the neutral and earth connections are bonded together at the connection point and so the PNLI and EFLI will be identical.

2.1.4 SNE connections (TN-S) and SNE connections derived from a CNE network

For SNE connections and SNE connections derived from a CNE network, the PNLI may be lower than the EFLI. This is because the earth conductor (i.e. the protective conductor) may, over part of its length, be derived from cable sheaths or earth wires which have higher impedance than the neutral conductor.

2.1.5 Directly Earthed (TT) Connections

WPD do not provide an earth terminal at directly earthed (TT) connections and so maximum EFLI values are not specified. The customer's electrical installer is responsible for installing and maintaining a separate earth electrode and earth terminal and they must ensure the EFLI meets the protection requirements detailed within the wiring Regulations.

2.2 Metered Connections

2.2.1 General

The design requirements for metered connections are specified in ST: SD5A (domestic connections), ST: SD5C (multi-occupancy buildings) and ST: SD5E (commercial and industrial connections). Customer earthing requirements are specified in ST: TP21E.

2.2.2 Maximum PNLI for Metered Connections

Maximum PNLI values for metered connections are specified in Table 1. The requirements depend on the date the LV circuit was originally designed and whether the circuit is fed from a ground mounted transformer or a pole-mounted/pad-mount transformer. The type of earthing at the connection does not affect these requirements.

WinDebut has been set to flag up (refer) an issue when the maximum loop resistance exceeds 0.19Ω (where services are not modelled) and 0.22Ω (where services are modelled). These resistance values have been determined to ensure that the phase to neutral loop impedance values do not exceed 0.25Ω at the connection point/s (i.e. at cut-out/s).

2.2.3 Maximum EFLI for Metered Connections

EFLI requirements for new and substantially modified metered connections are also specified in Table 1 and depend on the earthing type and fuse rating offered at the connection. Where maximum values are specified, these are based on 5s cut-out fuse operating times.

Cut-out Fuse Rating	Maximum Phase to Neutral Loop Impedance (PNLI)		Maximum Earth Fault Loop Impedance (EFLI)		
	Designed from 01/01/2018[1][8]	Designed prior to 01/01/2018[2][8]	PME / PNB Connection	SNE[3] Connection	Directly Earthed (TT) Connection
Domestic type cut-outs fuses[5][6]:					
≤ 60A	0.25 Ω	0.35 Ω[4]	As per PNLI requirement	0.73 Ω	N/A
80A	0.25 Ω	0.35 Ω[4]		0.52 Ω	N/A
100A	0.25 Ω	0.35 Ω		0.38 Ω	N/A
J Type heavy duty cut-out fuses					
100A	0.25 Ω	0.35 Ω[4]	As per PNLI requirement	0.54 Ω	N/A
160A	0.25 Ω	0.28 Ω		0.28 Ω	N/A
200A	0.22 Ω	0.22 Ω		0.22 Ω	N/A
250A	0.17 Ω	0.17 Ω		0.17 Ω	N/A
315A	0.13 Ω	0.13 Ω		0.13 Ω	N/A
350A	0.12 Ω	0.12 Ω		0.12 Ω	N/A
400A	0.10 Ω	0.10 Ω		0.10 Ω	N/A
500A[7]	0.07 Ω	0.07 Ω		0.07 Ω	N/A

Table 1 Maximum Loop Impedance Values for Metered Connections

Notes

Note 1 Applies to LV circuits that were originally designed or significantly modified on, or after 1st January 2018.

Note 2 Applies to LV circuits that were originally designed prior to 1st January 2018.

Note 3 Also applies to SNE connections connected to a combined neutral and earth (CNE) network.

Note 4 The 0.35 Ω value may be increased to 0.47 Ω where the LV circuit is fed from a pole-mounted or pad-mount transformer.

Note 5 Includes the customer facing fuses in a WPD owned MSDB.

Note 6 Also applies to metered street furniture connections fed via 'street lighting' type cut outs.

Note 7 500A supplies are only available from connections to ground mounted substations.

Note 8 Where a circuit that was originally designed prior to 01/01/2018 is extended or one or more new connections are added, the phase to neutral impedance of the modified circuit shall be i) no higher than the highest impedance of the existing circuit or ii) no higher than the limit defined for circuits designed from 01/01/2018, whichever value is higher.

2.3 Un-metered Connections

2.3.1 General

The design requirements and earthing requirements for un-metered connections are specified in ST: SD5P and ST: TP21E, respectively.

2.3.2 Maximum PNLI for Unmetered Connections

The Electricity (Unmetered Supply) Regulations 2001 only allows a connection to be unmetered where its load is predictable and it is either rated at less than 500W or it is impractical (technically or financially) to meter. Given this, the load connected at an unmetered connection is normally rated below 2.2A. Despite the low level of current, unmetered connections could still have an impact on the network voltage and on power quality, particularly where several unmetered connections are supplied from the LV circuit.

The maximum PNLI values for un-metered connections are specified in Table 2 and cater, to some extent, for the power quality impact. Further analysis may be needed where multiple unmetered connections are being supplied.

2.3.3 Maximum EFLI for Unmetered Connections

EFLI requirements for new and substantially modified unmetered connections are specified within Table 2 and depend on the earthing arrangement offered. Where a maximum ELFI value is specified, this is based on a fuse operating time of 5s, which is in line with the requirements for outdoor lighting installations defined in BS7671 (EIT Wiring Regulations).

Cut-out Fuse Rating	Maximum Phase to Neutral Loop Impedance (PNLI)	Maximum Earth Fault Loop Impedance (EFLI)		
		PME / PNB Connection	SNE[3] Connection	Directly Earthed (TT) Connection
Street lighting type cut-out (i.e. 25A cut-out)				
6A	1.50 Ω	As per PNLI requirement	13.50 Ω	N/A
10A	1.38 Ω		7.10 Ω	N/A
16A	0.86 Ω		3.80 Ω	N/A
20A	0.69 Ω		2.70 Ω	N/A
25A	0.55 Ω		2.10 Ω	N/A
Domestic type cut-out (i.e. 100A cut-out)				
≤ 60A	0.47 Ω	As per PNLI requirement	0.73 Ω	N/A
80A	0.47 Ω		0.52 Ω	N/A
100A	0.38 Ω		0.38 Ω	N/A

Table 2 Maximum Loop Impedance Values for Unmetered Connections

3.0 PROVISION OF INFORMATION

Customers and/or electrical contractors may request the maximum EFLI loop impedance at a customer installation. We are obliged under the Electricity Safety, Quality and Continuity Regulations 2002, to provide this information to anyone who can show a reasonable cause for requiring it, when asked to do so.

3.1 Earthing Terminal provided by WPD

Where WPD provides the customer with an earth terminal, the Planner should in most cases, quote the relevant "typical maximum earth fault loop impedance" value specified in National Engineering Recommendation P23.

LV metered connections supplied from a small pole mounted transformer (e.g. less than 16kVA single phase), or via a long length of cable or overhead line sometimes have earth fault loop impedances above the typical figures in P23.

The typical figures in P23 do not apply to street lighting connections where long lengths of small section cable are sometimes used.

Where necessary, values of EFLI can be checked / confirmed by:

- Windebut (for PME connections only), using the motor starting tool. It is important to choose a single phase motor when determining the EFLI.
- Manual calculation (for SNE connections) where cable/line data is available.
- Measurement (using an appropriate earth fault loop impedance tester)

In practice, measurements taken close to WPD transformers or on circuits with particularly low impedances are often highly inaccurate.

Once the earth fault loop impedance has been measured or calculated, the higher of this figure and the value specified in P23 shall be quoted to the customer.

3.2 No Earthing Terminal provided by WPD

For connections where WPD do not provide an earth terminal, i.e. directly earthed (TT) connections, the EFLI will be dependent on the resistance of the customer's earth electrode and the substation earth electrode resistance. BS7671 specifies that the customer's earthing electrode must be less than 1660 ohms where a 30mA RCD is installed, although a value less than 200 ohms is recommended.

If WPD is asked to provide the loop impedance at an installation where an earthing terminal is not provided, WPD should quote a figure for the "external loop impedance, not including the customer's earth electrode". The Planner must make it clear to the customer that the earthing resistance of his/her earth electrode is not included.

Where the connection is made to a substation that is suitable for PME connections, a typical maximum value of 21 ohms shall be quoted (which takes account of the resistance of the substation earth electrode). If the substation is not designed to provide PME connections, a figure of 40 ohms applies.

In such cases it is recommended that the customer, or customer's electrical installer, measures the overall earth fault loop impedance with an appropriate loop impedance tester.

LOOP IMPEDANCE DIAGRAMS

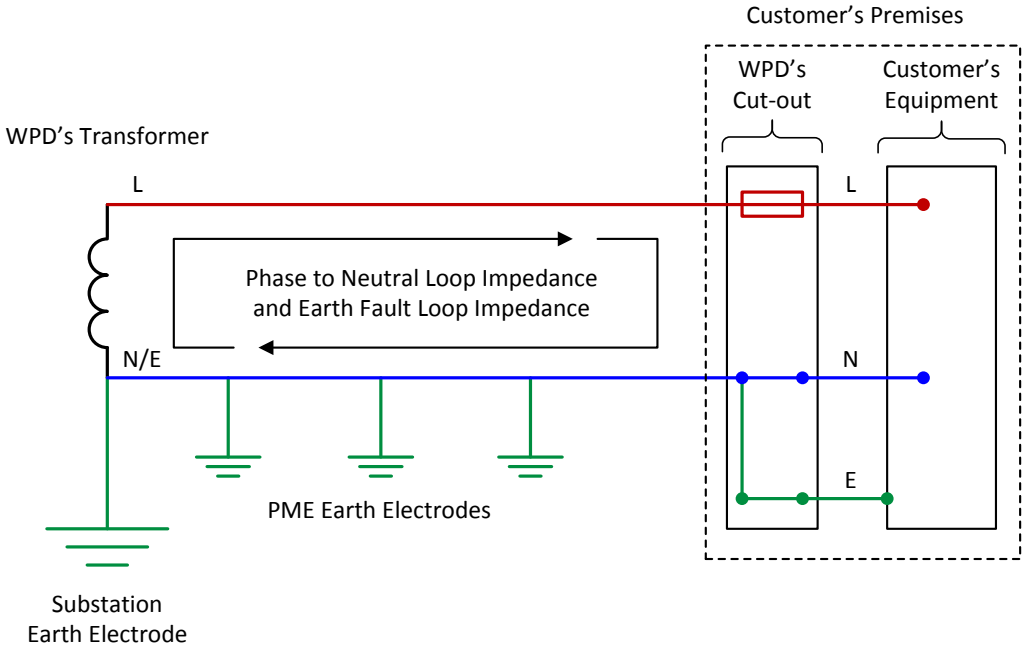

Figure A1 Loop Impedance at a PME Connection

Note: The Earth fault Loop Impedance at PME connections is the same as the Phase to Neutral Impedance.

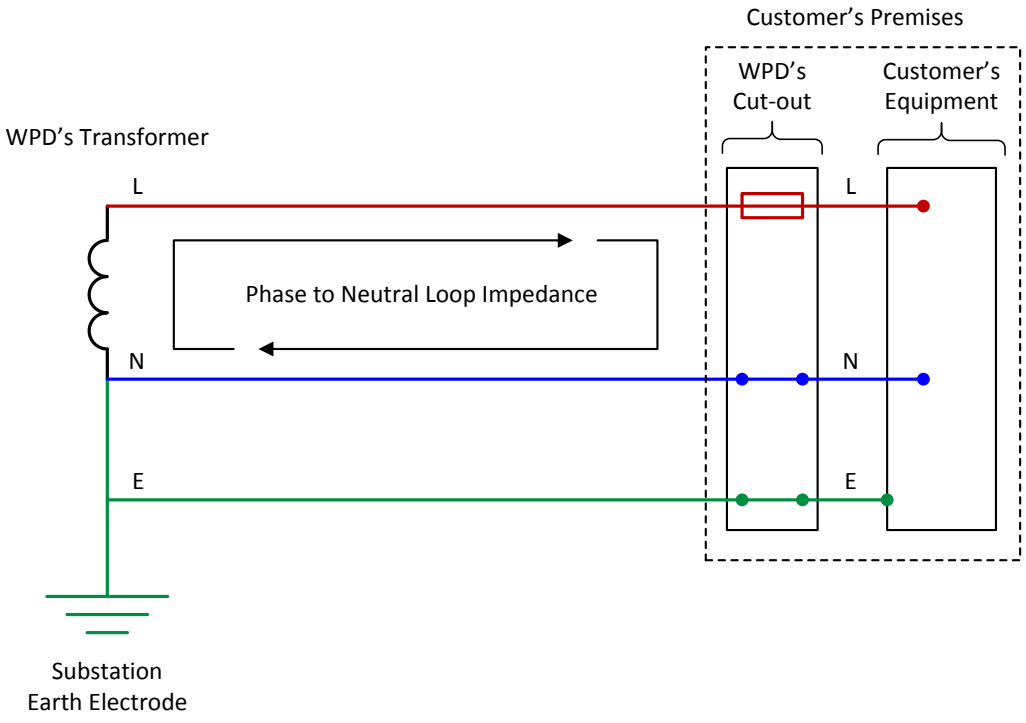

Figure A2 Phase to Neutral Loop Impedance at a SNE Connection

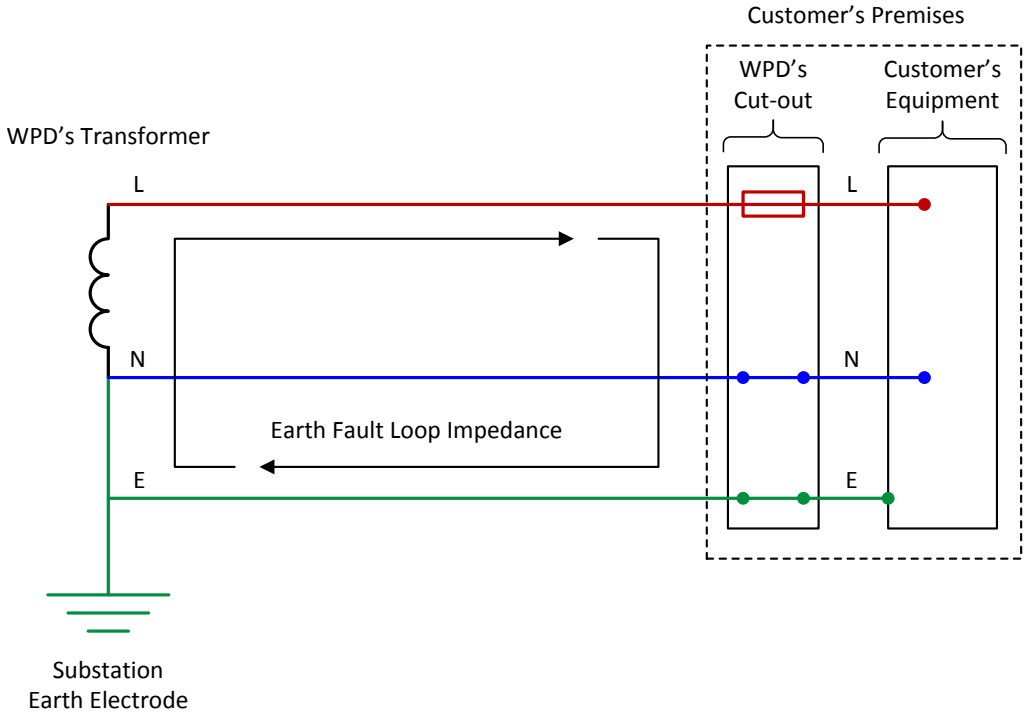

Figure A3 Earth Fault Loop Impedance at a SNE Connection

Note, the earth fault loop impedance is typically greater than the phase to neutral impedance due to the earthing conductor having a smaller cross section area and having connections with greater impedances.

APPENDIX B

SUPERSEDED DOCUMENTATION

This document supersedes ST:SD5R/1 dated December 2017 which has now been withdrawn.

APPENDIX C

ASSOCIATED DOCUMENTATION

BS7671:	IET Wiring Regulations
ST: SD5A	Low Voltage Domestic Connections
ST: SD5C	Low Voltage Connections to Multiple Occupancy Buildings
ST: SD5P	Design of Unmetered Connections
ST: SD6F	Dealing with Potentially Disturbing Electrical Loads/Equipment
ST: SD6J	Connection Design - Potentially Disturbing Electrical Equipment Rated ≤75A/phase Subject to Conditional Connection
ST: TP21E	Provision of WPD Earth Terminals to LV Customer LV Installations
POL: NC4	Relating to the Giving of Consent to Other Parties to Make or Alter a Connection between a Consumer's Installation and the WPD LV Distribution System
ST: NC5A	Required Inspections and Tests of a LV Service Prior to Connection
ENA EREC P23	Customer's Earth Fault Protection for Compliance with the IEE Wiring Regulations for Electrical Installations

APPENDIX D

KEY WORDS

Earth Fault, Loop Impedance, Cut-out, IET Wiring Regulations, BS7671, PME, SNE, TT