Electricity Policy Document 283

Issue 5 Feb 2024

Low Voltage Design

Amendment Summary

ISSUE NO. DATE	DESCRIPTION
Issue 1 **November 2021**	Major revision. Eleven LV planning documents have been combined into a single entity to provide a complete reference for LV design. Document now in a modular format with links added throughout the document to aid navigation. Documents combined: EPD283 LV Network System Design CP226 LV Network Design CP227 LV AFFIRM workbook ES230 Connection of Low Carbon Technologies ES210 Third Party Connected New Connections ES211 Third Party Connected Street Furniture ES212 New Whole Current Meter Connections up to 60kVA ES213 New Connections for Housing Developments ES214 New LV Connections up to 300kVA ES215 New Connections up to 1500kVA CP331 Protection of LV Underground and Overhead Distributors CP332 LV Service Connections & Application of PME The only change in content is in Module 2 section 2.7 to summarise power quality assessments requirements previously briefed to teams. Prepared by: Peter Twomey Approved by: Policy Approval Panel and signed on its behalf by Steve Cox, Engineering and Technical Director
Issue 2 **June 2022**	Document amended to reflect changes which were made and approved in CP226. Specifically, section 6 Removal of Looped Services added. Prepared by: Peter Twomey Approved by: Policy Approval Panel and signed on its behalf by Steve Cox, DSO Director
Issue 3 **January 2023**	Unlooping policy for connection of Low Carbon Technologies defined in Module 1 section 4.9 Looped Services Connect & manage policy defined in Module 3 section 6.4 Domestic Heat Pumps and Electric Vehicles Charge Points. Prepared by: Peter Twomey Approved by: Policy Approval Panel and signed on its behalf by Paul Turner, PAP Chair.

Issue 4 **May 2023**	LCT connection triage process modified to include a check on the maximum demand for a dwelling on a looped supply that is connecting a heat pump or electric vehicle charge point. If this maximum demand exceeds 60A the HP / EVCP cannot remain connected to services looped at the cut out. Domestic Whole Current Metered Heat Pumps and Electric Vehicles Charge Points Prepared by: Peter Twomey Approved by: Policy Approval Panel and signed on its behalf by Steve Cox, DSO Director
Issue 5 **Feb 2024**	Guidance on cut out ratings added in Cut out rating - guidance to assist the LCT connection triage process. Concept of LV network zones added in LV Network zones and feeding areas.. This policy deprecates the overextension of LV networks into LV networks of adjoining distribution substations in urban and suburban areas. Requirement to include forecast ED2 LCT uptake in network design added in Uptake of Low Carbon Technologies in ED2. Guidance on when network studies are required for heat pump and electric vehicle clusters added in Multiple Installations. Policy for allowing EV charge points to connect to unmetered street furniture introduced in EVCP connected to unmetered supplies (UMS) Earthing arrangements for public EV charge points modified to allow use of PME earthing facilities in accordance with changes in BS 7671 in Public EVCPs and also Supplies to Electric Vehicle Charge Points (EVCPs) Prepared by: Peter Twomey Approved by: Policy Approval Panel and signed on its behalf by Paul Turner, PAP Chair.

Contents

1 Introduction

The general principles contained within this Electricity Policy Document (EPD) shall be applied to all new work on the Low Voltage (LV) Networks of Electricity North West Limited (herein after referred to as Electricity North West). The decision as to whether existing Networks shall be brought into line with this EPD when reinforcements or material alterations are carried out (including asset replacement work and new connections) will depend on individual circumstances and each case shall be actively considered.

This document is one of the following suite of documents relating to Network Design.

(a) EPD279 - Distribution System Design - General Requirements

(b) EPD280 - Distribution System Design - 132kV Network

(c) EPD281 - Distribution System Design - 33kV Network

(d) EPD282 - Distribution System Design - 11/6.6kV Network

(e) EPD283 - Distribution System Design - Low Voltage Network

This document shall be read in conjunction with EPD279.

2 Scope

This document describes the general distribution network design principles, at low voltage, which shall be used by staff of Electricity North West Limited as service provider and any Independent Connection Provider. It will assist network designers in discharging their responsibilities for compliance with The Electricity Safety, Quality and Continuity Regulations 2002, Electricity Distribution Licence - Condition 5, The Distribution Code and appropriate safety legislation. Additional information and guidance are available, in Module Two, to staff and contractors employed by Electricity North West Limited.

3 Definitions

For the purpose of this document the following definitions apply:

ABC	Aerial Bundled Conductor
ADMD	After Diversity Maximum Demand
AI	Aluminium Conductor
BNO	Building Network Operator
Branch	A sub-division of a distributing main from its end furthest from the source of voltage to its junction with the distributing main. 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.
BS	British Standard
Caravan	A trailer leisure accommodation vehicle, or: A motor caravan or motor home, or: A mobile home or residential park home if certain conditions apply; namely, if any metalwork connected to the earth terminal is within reach of a person in contact with the general mass of earth or they are not permanently sited or not permanently connected to water/sewerage services.
Certificate of Registered Design	A certificate awarded by Electricity North West Limited signifying its approval to a Registered Design
CNE	Combined Neutral Earth
Compact Substation	A ground mounted transformer with Integral 11/6.6kV 'On Load' Isolation by means of either a switch-fuse or circuit breaker with feeder earthing facility, and LV fuses, enclosed in one cabinet. The design is NOT enclosed by a fence GRP or other housing.
CP	Code of Practice
CRMS	Control Room Management System
Design Proposal	A design for Owner's Works which is not listed in the Schedule of Registered Designs, but uses specifications, standards and procedures which meet Electricity North West Limited general requirements.
Distributing Main	A low voltage electric line which connects a distributor's source of voltage to one or more service lines or directly to a single consumer's installation

DNO	Distribution Network Operator
Downstream Section or Upstream Section	A section immediately downstream or upstream of the present section. (Each present section may be connected to only one upstream section; however, it may be connected to several downstream sections.)
EA	Electricity Association
EATS	Electricity Association Technical Specification
Electric Line	Any line which is used or intended to be used for carrying electricity for any purpose and includes, unless the context otherwise requires: any equipment connected to any such line for the purpose of carrying electricity; any wire, cable, tube, pipe, insulator or other similar thing (including its casing or coating) which surrounds or supports, or is associated with, any such line".
Electricity North West	For the purpose of this document this shall mean Electricity North West Limited, operating within its licensed area.
ENA ER	Energy Networks Association Engineering Recommendation
EPD	Electricity Policy Documents
ER	Electricity Association Engineering Recommendation
EREC	Engineering Recommendation
ES	Electricity Specification
ESQCR	Electricity Safety, Quality and Continuity Regulations 2002
EV	Electric Vehicle
Exit Point to the User	A point or points on the Owner's Works at which a connection is made to the User's electrical installation(s).
FP	Feeder Pillar (street pillar)
HP	Heat Pump
HV	11kV or 6.6kV
Installer	The Owner or the contractor appointed by the Owner, who will design, install and commission (but not energise) the proposed Owner's Works.
LB	Link-box
Low Voltage (LV)	A Voltage Less than 1000V
MAD	Minimum Average Demand – as used in CP221
MEN	Multiple Earthed Neutral

Minimum Fusing Current	The minimum fault current required to pass through the fuse, in order to cause the fuse to blow within the maximum time allowed by Module Ten - Protection of LV Underground and Overhead Distributors and HV Protection of Distribution Transformers (100s for underground cable, 10s for overhead lines, with the alternative 30s for ABC).
Network	The electricity distribution network owned and operated by Electricity North West Limited.
New Connection	The first connection to a new or newly refurbished property
Node	A point on the modelled network where a significant change takes place. This will generally be at the substation, a change in cross-sectional area of conductor, a change in line type, a branching point, an end or, when considering disturbing loads, a Point of Common Coupling.
NRSWA	New Roads and Street Works Act 1991
Outline Plan of Works	Outlines of the proposed cables, plant, overhead lines, ancillary equipment and buildings, as appropriate, including the system components and their electrical characteristics, describing the Owner's Works, which it is intended shall be adopted by Electricity North West Limited.
Owner	The Owner of the new Works, prior to their adoption by Electricity North West Limited. This will, in most cases, be the party requiring the construction of the works, for the purpose of providing a new, or increased supply of electricity.
Owner's Works	The Works constructed for the Owner by the Installer, for the purpose of providing a new, or increased supply.
Pad Mounted Substation	Ground Mounted Transformer with Integral 11/6.6kV 'Off Circuit' Isolation and 11/6.6kV and LV fuses, enclosed in one cabinet. The design is NOT enclosed by a fence GRP or other housing.
PCC	Point of Common Coupling
PES	Public Electricity Supplier
PME	Protective Multiple Earthing
PNB	Protective Neutral Bonding. This 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.
Present Section	That section of the modelled network being considered or to which a particular calculation directly relates.
Primary Substation	33/11kV or 33/6.6kV substation with all the equipment enclosed within a building or perimeter fence.
PSCC	Prospective Short Circuit Current
RCD	A Residual Current-operated Device or circuit breaker.

Registered Design	A design previously submitted by an Installer, which uses specifications, standards and procedures which have been approved by Electricity North West Limited, and which has been awarded a Certificate of Registered Design.
Service Line	An electric line which either connects a street electrical fixture, or no more than four consumers' installations in adjacent buildings, to a distributing main.
Schedule of Registered Designs	A schedule maintained by Electricity North West Limited for each Installer, listing all previously approved Owner's Works, which have been awarded a Certificate of Registered Design.
Section	A length of the modelled network, between two nodes. Each section is denoted by a single letter or a two-letter combination, e.g. "ZA", "ZB" etc.
SNE	Separate Neutral and Earth
S/S	Substation
Street Electrical Fixture	A permanent fixture which is or is intended to be connected to a supply of electricity and which is in, on, or is associated with a highway.
Substations & Transformers	The ESQCR define substation as: "substation" means any premises or enclosed part thereof which contains equipment for either transforming or converting energy to or from high voltage (other than transforming or converting solely for the operation of switching devices or instruments) or for switching, controlling or regulating energy at high voltage, but does not include equipment mounted on a support to any overhead line; The above definition is used in this EPD. Compact and Pad Mounted Transformers, therefore, fall within this definition of "substation."
Supply Neutral Conductor	The neutral conductor of the Network but does not include any part of a customer's installation.
TN-C	A system in which neutral and protective functions are combined in a single conductor throughout the system
TN-C-S	A system in which the neutral and protective conductors are combined in a single conductor in part of the system
TN-S	A system having separate neutral and protective conductors throughout the system
Totem Pole Transformer	A pole mounted transformer that is connected via an 11/6.6kV cable and not connected to any overhead conductors. (The support to a Totem Pole Transformer should be regarded in every respect as being a support to an overhead line.)
TT System	Supply system whereby the exposed-conductive-parts of the installation are connected to earth electrodes electrically independent of the earth electrodes of the source
Unit Substation	A ground mounted transformer with individual 11/6.6kV Switchgear and LV Fuse Board all enclosed within a GRP housing, building or perimeter fence.
User	The User of electricity supplied through the Owner's Works.

4 Module One Low Voltage Network

Contents

4.1 General

Currently distribution transformers are purchased with a voltage ratio of 11kV or 6.6kV/433/250V. This allows for a full load busbar voltage of 415/240V. In 1994, regulations were amended, and the declared voltage as stated in the ESQCR is now 400/230V. However, Electricity North West Limited will continue to operate its electricity distribution Network at 415/240V.

Low voltage distribution networks shall be designed on the radial feeder principle. Cable distributors shall be constructed entirely of cable size 300mm^2 SAC. The distributor shall have a maximum voltage drop of 7% between network substation busbars and any customer's terminal. 185mm^2 SAC or 95mm2 SAC may only be used for:

- Fault repair or minors works up to 30 metres in length where the existing conductor size is equivalent or smaller
- Rising and lateral mains where it is impractical to install 300mm^2
- Service cables feeding termination equipment rated less than 400A, for example a 95mm^2 cable may be used to supply a 200A distribution board.
- Feeders from transformers of 200kVA or less
- Terminations where it is not possible to connect 300mm^2 SAC, for example wall boxes
- Mains extensions for service cables longer than 30m

A 415/240V substation busbar voltage shall be used in all calculations.

All new LV distribution networks and extensions to existing networks shall be designed on the principle of a MEN system using CNE conductors to provide PME terminals at customers' premises in accordance with EPD332 - Customer Installation Earthing. Exceptions may be permitted, where the practicality or expense of installing the required additional connections with earth are prohibitive. In such cases, the approval of the Network Planning Policy Manager, Electricity North West Limited shall be obtained for the installation of SNE systems.

The LV Network shall be designed to take account of the permissible overload ratings of transformers feeding them.

Single-phase loads at LV shall be so distributed as to provide a balanced three-phase network.

The declared voltage is required to be 400/230V plus 10% minus 6%, unless otherwise agreed with the customer.

Motor loads shall be connected in accordance with ENA ER P28.

ABC shall be the preferred overhead line construction method. Open wire lines shall be used only when relevant planning consents have been refused for the use of ABC.

The rules set out in Electricity North West Limited's Distribution Licence concerning the apportionment of the costs of connection and any associated reinforcement shall be adhered to.

Prospective Short Circuit Current

For connections derived from a single 1000kVA transformer the maximum PSCC, at the customer's terminals, is not expected to exceed the following values:

- Three phase = 27kA
- Single phase = 16kA

For an unusual connection derived from a transformer with a capacity greater than 1000kVA the actual PSCC shall be calculated.

Further guidance on the determination of PSCC can be obtained from ENA ER P25/2 for single phase and three phase connections.

There shall be only one exit point per property and any exceptions shall be referred to the Network Planning Policy Manager, Electricity North West Limited.

The cores of multicore LV mains shall not be 'bunched' or 'paired' to increase the current rating, improve voltage regulation or reduce loop impedance.

All phases of a cable shall be energised, i.e. part energisation of the cable is not acceptable, unless as part of transitional arrangements for conversion of the network to three phase, or unless three phases are not available at the point of connection.

Unless agreed, in writing, with the Network Planning Policy Manager, Electricity North West Limited, the maximum connection capacity, for whole current metered connections, shall be:

- Single-phase 20kW.
- Three-phase 60kW.

Link boxes may be installed to provide isolation of sections of LV mains in areas prone to flooding. This will allow unaffected sections of mains to remain energised and maintain supply to customers outside the flood zone.

4.2 Substations

The LV Network shall be derived from ground-mounted substations, designed and equipped in accordance with ES352, or pole-mounted transformers as described in CP430.

Where the transformer rating in the substation is greater than 200kVA, all LV fuseways shall be 'tailed out' using cables of 300mm^2 SAC up to the point where they connect on to an existing main. This includes the fuseways that are not required for immediate use but could potentially be used. They shall be 'tailed out' for a length of between 3m and 5m. All work shall be in accordance with EPD201 - Recovery and Identification of Idle Assets. In particular for all 'spare' cables, the ends of the tails shall be shorted and capped. The fuseway contacts shall be shrouded and clearly and indelibly labelled, "Caution - Shorted capped end." As far as is reasonably practicable, tails shall be laid within land controlled by Electricity North West Limited, but with their capped ends outside the operational enclosure.

Development of the LV Network shall be based on substations sited as near as practicable to the centre of the load block to be connected, but see EPD279, subsection 4.7.7.

Transformers shall be sized to match the calculated demand, or to achieve other requirements such as voltage regulation. Otherwise, excess transformer capacity, above the smallest standard transformer size that can accommodate the load, shall not be installed.

Connections for housing sites shall generally be from ground mounted transformers sized in accordance with the above.

Totem pole transformers shall be used only as described in EPD282.

4.3 Interconnection

For maintenance purposes, limited interconnection may be provided at each substation.

The facility to connect mobile generation either to the busbar or to an individual distributor shall be provided in all cases, to assist with post-fault restoration.

Interconnecting mains shall not be tapered in size and shall utilise a minimum cable size of 300mm^2 aluminium.

There shall be no more than 200 customers connected from one three-phase LV distribution board fuseway, during normal operation.

4.4 LV Network zones and feeding areas.

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In built up areas such as large villages, towns and cities, LV networks are fed by a number of distribution substations. Each of these substations feeds the geographic area around it, with the size of each zone constrained by design limits such as voltage drop and earth loop impedance. The characteristics of these zones are largely based on the results of research carried out in the 1970s by the Electricity Council and publications such as ACE Report 49 and ENA Engineering Report P5.

These characteristics optimise the utilisation of cables and transformers. Over extension of LV feeders reduces thermal utilisation because voltage drop becomes the dominant constraint to current carrying capability. Overextension of feeders outside of a substation's network zone into an adjoining network zone to accommodate new connections is undesirable and shall be avoided where reasonably practical.

Example network zones are illustrated in Figure 1 below.

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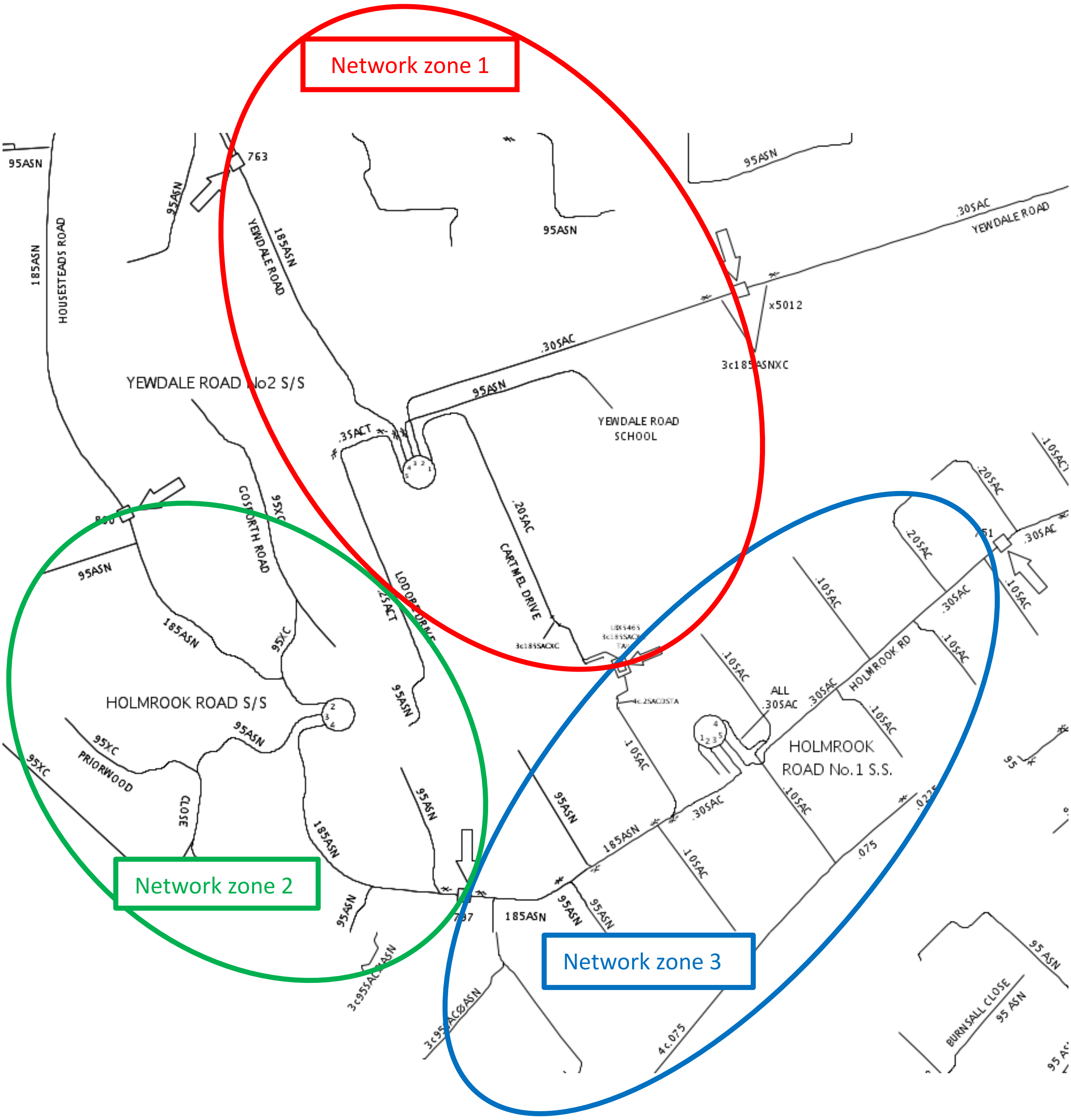

Figure 1 - Example network zones.

4.5 New Housing

The design of LV networks for new housing estates shall be in accordance with Module Seven.

All LV service terminations shall comply with ES212 - New Whole-Current Metered Connections up to 60kVA.

The maximum capacity, for single-phase domestic connections, shall be in accordance with section 4.1.

In order to minimise voltage drops on distributors, successive service connections shall be made to the distributor's phases in the sequence L1, L2, L3, L3, L2, L1, etc. The phase distribution of services shall be shown in any design.

Looped underground services shall not be used for new housing connections.

The positioning of network substations shall normally give the most economic scheme of development taking into account the cost of both mains and substations. Generally, a substation sited on the property building line will satisfy these criteria.

Where the most economic site cannot be obtained, a commercial view shall be taken in respect of an alternative site. This may include the granting, free of charge, of easements etc.

Notwithstanding the requirements of subsection 4.6, it may be necessary to take customer requirements into account; see EPD279, subsection 4.7.7.

Every effort shall be made to install all 11/6.6kV and LV mains cables in public land which is subject to the New Roads and Street Works Act 1991. If mains cables are laid in unpaved service strips alongside residential roads, the first householders or tenants shall be sent notices informing them of Electricity North West Limited's rights of access to those cables.

For cables and lines, installed in other than public land, easements shall be negotiated. Where an easement cannot be obtained, a wayleave shall be agreed. Under no circumstances shall cables or lines be installed in non-public land without written rights of access.

The minimum service cable size shall be 35mm^2 solid single aluminium phase core CNE and shall be laid in a duct complying with ES400D4, between the boundary of the customer's premises and the service position. Approved service cables are specified in ES400C8. Ducting arrangements are described in Electricity North West Limited Electrolink Publication No. 5 - Outdoor Meter Reading Facilities.

The service cable length shall not exceed 30m, measured from the cut out to the point of connection to the LV main. Where, exceptionally, this length is to be exceeded, evidence shall be available that voltage drop, and flicker criteria are met and that the risk arising from unprotected service cable length has been assessed in each individual case. In order to reduce this risk, the maximum practical length of any such long service cable, including a three-phase cable, shall be installed in a continuous duct.

The calculated voltage drop from the cut out to the point of connection to the LV main, at the maximum allowable load, shall not exceed 2%. The total voltage drop from the substation to the customer's terminals shall be as described in subsection 4.2.

4.6 Connections to and within Multiple Occupancy Premises

Electricity North West Limited will act as a DNO and in specific circumstances will act as a BNO.

Where ownership is unclear or unknown, Electricity North West Limited will instigate a regime of inspection, maintenance, and condition assessment.

Where ownership is unknown or unclear and where condition assessment indicates replacement is required, Electricity North West Limited shall instigate the installation of replacement assets to modern standards and arrange decommissioning and making safe the old assets. On completion of works, Electricity North West Limited shall offer ownership of the installation to the Building Owner. If the Building Owner declines

Electricity North West Limited shall take ownership of the new installation and take responsibility for all future maintenance. The final ownership arrangements shall be detailed in a new Connection Agreement, issued by Electricity North West Limited, superseding all previous agreements and coming into effect at the time of first energisation of the new installation. Electricity North West Limited shall not be obliged to remove the old assets, carry out maintenance to the building, or otherwise make good the structure of the building. Only where it is clearly defined that Electricity North West Limited own the existing assets will Electricity North West Limited assume responsibility for removing assets. This will not include maintenance or otherwise making good the fabric of the building except for where damage has been caused as a result of the removal of the assets.

Where a building owner refuses consent for access or the upgrading of assets, and those assets are confirmed as Electricity North West Limited assets the procedure for access is provided for in Schedule 6 of the Electricity Act 1989.

Electricity North West Limited's preference is for the Building Owner to act as a BNO for all new and refurbished installations which are designed in accordance with arrangements in this Engineering Specification ES287, Connections to Multiple Occupancy Buildings and ES400 RL1, Installation of Low Voltage Rising and Lateral Mains and Services.

Electricity North West 's obligations and duties as a DNO remain unchanged regardless of whether or not it acts as a BNO.

Connections to multiple occupancy premises shall be in accordance with ES287.

4.7 Street Lighting

Connections to new street lighting columns and other street electrical fixtures shall be made in accordance with Module 5, in particular:

The maximum load on a standard street lighting service connecting street furniture shall not exceed 5kW.

All new street lighting services, not exceeding 15m in length, shall be 4mm^2 copper core cable.

New street lighting services in excess of 15m in length shall utilise a minimum conductor size of 35mm^2 aluminium core cable. The cable shall, if appropriate, be tapered to 4mm^2 no more than 2m from the street furniture.

The length of service cable between the Network main and street furniture shall not exceed 30m.

The calculated volt drop from the cut out to the point of connection to the LV main, at the maximum allowable load, shall not exceed 2%. The total volt drop from the substation to the customer's terminals shall be as described in subsection 4.2.

Services looped from the bottom of a cut-out, i.e. connected directly to the incoming terminals, shall not be permitted.

Switch-Cores and Switch-Wires

No new street-lighting service shall be connected to a switch-core or switch-wire. No existing street-lighting service connected to a switch-core or switch-wire shall be transferred to a new street-lighting column, except a like-for-like replacement, e.g. necessitated by a road traffic accident. No such switch-core or switch-wire shall be continuously energised. As they become redundant, switch-cores and switch-wires shall be permanently de-energised and, in the case of overhead wires, removed from the poles, as suitable opportunities arise.

Control equipment for street-lighting switch-cores and switch-wires shall not remain in substations, where lighting authorities should not have access. Every effort shall be made to establish alternative control points in lighting columns etc.

Where, because of any kind of work on the Network, the continuity of a switch-core or switch-wire cannot be maintained, a new continuously energised service shall be installed downstream of the break, free of charge to the lighting authority. The lighting authority shall then at its own cost supply and install any necessary control equipment to maintain control of the switch-core/wire. The by-passing of repairs, diversions, link-boxes etc with separate service cables to maintain the continuity of switch-cores is prohibited.

4.8 Overhead Lines – Attachments Owned by Others

There exist many instances of non- Electricity North West Limited equipment having been attached to overhead line supports, LV wood poles in particular. These attachments are owned by British Telecommunications plc (BT) (telephone lines), street lighting authorities (lighting brackets) and the Post Office (posting boxes). Following the fatality of a BT linesman, working on a joint-user pole, it is no longer Electricity North West Limited policy to sustain such arrangements. See EPD473 - Policy for Overhead Line Standards.

The arrangements by which these attachments were made are covered by ENA ER EB/BT2, ENA ER L13-2 and ENA ER L22/1.

No new attachment of non- Electricity North West equipment shall be made.

Where existing attachments are affected by work on Electricity North West Limited lines, the following shall apply:

Where a single support is replaced, e.g. because of decay or damage, the attached equipment may be transferred to the replacement support;

Where an Electricity North West Limited line is to be refurbished, replaced or removed, the owners of the attached equipment shall make alternative arrangements for their equipment; in such cases a minimum of 6 months' notice of the work shall be issued to all affected parties, in accordance with ENA ER EB/BT2.

Where street-lighting brackets are affected by such a proposal, one new service connection, to a lighting column or distribution pillar, will be installed at Electricity North West Limited's expense for each LV overhead line distributor affected by the refurbishment or replacement proposal.

4.9 Protection

Protection of LV underground and overhead distributors shall be designed in accordance with Module Ten - Protection of LV UG & OH Distributors, Distribution Transformers and HV OH Networks by Fuses.

4.10 Looped Services

Looped services were conceived as an economic and simple way to enable the widespread expansion of distribution networks in the mid twentieth century and have provided satisfactory performance over many years. However, the national transition to a low carbon economy has seen the introduction Low Carbon Technologies (LCTs) such as domestic heat pumps, storage, solar panels and electric vehicles. The demand profile of heat pumps and electric vehicles puts a sustained load on the service. Dependent upon the existing customer load it may be that looped services do not have sufficient capacity to meet the demand characteristics of these devices.

Domestic storage systems generally operate in tandem with solar panels and other domestic generation to minimise power flows across the meter. Also, EREC G100 limitation schemes are often used to manage power flows. Unlooping is therefore not a policy requirement for connection of domestic storage or generation. Unusually large installations above 32A per phase shall be designed on their own merits with unlooping decisions taken accordingly.

Looped services are commonly shown on mains records, but sometimes records are incomplete or otherwise insufficient to show the presence of a looped service. The following approach shall be taken to check for the presence of looped services:

- Check ENWL records (GIS) and customer cut-out photo for confirmation of looped service
- If looped status is indeterminate, check for EVs or heat pumps at two properties either side of the customer of interest
- If there is an EV or heat pump at any of these four properties, there is a possibility that the customer's new LCT would be the second on a loop. Therefore, it is necessary to establish the looped status via a site survey to inform whether interventions are required in accordance with the policy below.

Intervention is required following the connection of a heat pump or electric vehicle onto looped services unless:

- There is only one heat pump or electric vehicle connected to either the main and looped services, and
- The number of cut outs on the complete looped service are limited to:

Cut out rating	**Number of cut outs on loop**
100A	No more than 3 if electrically heated No more than 4 if not electrically head
60A	No more than 2 if not electrically heated

or

- There are no more than two heat pumps or electric vehicles connected to either the main and looped services, and
- The number of cut outs on the complete looped service are limited to:

Cut out rating	Number of cut outs on loop
100A	No more than 3 if not electrically head

If these conditions are met, the risk of failure is considered extremely low because BS 7657 100A cut outs are subject to overload tests. These tests require the cut outs to withstand currents of 135A (4 hours), 150A (30 mins) and 160A (until fuse operation). It is judged the addition of a single heat pump or electric vehicle will result in a maximum demand significantly below significantly below these test values.

The intervention strategy has been determined based on ADMD modelling for electrically heated and non-electrically heated properties assuming EV chargers up to 7.8kW. It can be summarised in the table below:

	1 x EV*			**2 x EV**			**3x EV**		**4 x EV**
Number of properties	2	3	4	2	3	4	3	4	4
100A cut out non-electric heating						SJ or NS	SJ or NS	NS	NS
100A cut out electric heating			SJ or NS	SJ or NS	SJ or NS	NS	NS	NS	NS
60A cut out non-electric heating		SJ or NS	SJ or NS	SJ or NS	SJ or NS	SJ or NS	SJ or NS	NS	NS
60A cut out electric heating	SJ or NS	SJ or NS	SJ or NS	SJ or NS	SJ or NS	NS	NS	NS	NS

(green)	No intervention
SJ or NS	Safety Joint or new service
NS	New service (SJ may be feasible depending on location of EV/HP)

*Heat Pumps vary in size depending on the size and age of the dwelling. The table above may be used for heat pumps 7.8kW or smaller, using the non-electrically heated rows.

Looped services shall be programmed for removal if the above conditions are not met. The busbar at the bottom of the main cut out carries the full load current of all the services (main and looped), and it the most likely part of the cut out to overheat and fail. This failure may lead to fire and is therefore an unacceptable risk.

The preferred methods for removal are:

- First preference – divert the loop underground by a service breech joint (safety joint), refer to Removal of Looped Services - Safety Breech Joint. A single safety breech joint will be sufficient if the electric vehicles and heat pumps have been installed on the main service, multiple joints will be required if they are installed on a looped service.

- Second preference – install a service to reconfigure the service arrangement to reduce the number of heat pumps or electric vehicles on the looped service to align with the minimum requirements described above. There are a number of reconfiguration techniques available, refer to Removal of Looped Services
- Where customers completely refuse permission to remove looped services, issue the customer with a letter stating that Electricity North West has informed the customer that the service needs to be upgraded and has made all reasonable efforts to arrange this, but the customer has refused. This refusal could result in a fire risk and invalidate any insurance cover. The letter must also state that should continued unsafe use of the service result in any damage to Electricity North West assets, Electricity North West would hold the customer liable.

Mural systems have a wide variety of configurations and each installation will need individual assessment. Systems deemed to be inadequate to supply the heat pump or electric vehicle shall proceed to the triage. A risk based approach based on whether the loop is internal or external to the building shall be used, similar to underground service loops. Some mural systems have internal loops at the bottom of the cut out, these systems shall be classes as high priority where intervention is required. Other mural systems use joints such as gel boxes or fuse boxes which are all located externally. These systems may remain in service if it is determined the wiring is adequately rated to supply the demand including the heat pump or electric vehicle. Particular care shall be taken when assessing single phase systems because all the phase currents summate into the neutral.

When performing routine work (e.g. a cut-out change or service alteration), looped arrangements shall normally remain after completion of the work unless an assessment unsuitable for continued use. Typical indications include signs of burning or distress, compound leaks, and insulation shrink back. In such instances the un-looping shall be considered. Besides the visual inspection of damage from overheating suggestive of high loads or loose connections, the assessment of the service arrangement shall also consider factors suggestive of potentially large increases in load, such as a building extension, or the visible presence of loads such as LCTs (see section 4.9) or swimming pools.

Where a looped service is to be retained but it is necessary to replace the cable, for example if the cable is insulated with Vulcanised India Rubber, the following options are available:

- Where the loop is >1 metre in length, replace loop with modern 35mm^2 concentric SNE cable. If the route of the loop is judged to be exposed or vulnerable to damage, the loop shall be made using a barred cut out, fused in accordance with Module Six 4.10. Otherwise a bottom side loop may be used for all other loops. If there is existing conduit which is in adequate condition, this may be reused using 16mm^2 16mm^2 Cu concentric SNE cable.

- Where the loop is <1 metre in length, replace the loop with a modern 35mm^2 concentric SNE cable using bottom side loop, fused in accordance with Module 6. If there is existing conduit which is in adequate condition, this may be reused using 16mm^2 Cu concentric SNE cable.

4.11 Uptake of Low Carbon Technologies in ED2

Feb 24

Electricity North West produces long-term forecasts of LCT uptakes and the associated demand growth (in kW and/or kVA) impact per distribution substation. These forecasts shall be taken into account when planning new connection, diversion and capital schemes by including the anticipated additional demand within a 5 years horizon for need identification and within a 10 years horizon for defining the capacity of the asset solution. This demand is provided per substation and in the absence of more granular demand forecasts across the LV network shall be allocated by feeder according to the ratio of customer numbers on each feeder against the total customer numbers fed from that substation. The latest version of the LCT forecast across the LV network will be stored in the EPD283 folder in the policy library.

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5 Module Two - Low Voltage Design Procedure

Contents

5.1 Low Voltage Design Procedure

5.1.1 General

All new designs for extensions and alterations to the LV Network shall comply with the requirements of EPD279, Module 1 and Module Ten - Protection of LV Underground and Overhead Distributors and HV Protection of Distribution Transformers.

The network design shall be determined using the ADMD method. As a guide, the following tasks will usually be required:

- Assessment of the total load to be supplied, including any premises other than domestic dwellings, e.g. shops, schools.
- Assessment of the supply capacity of the existing network, including the high voltage system.
- Determination of the number of S/Ss required.
- Determination of the most suitable practical sites for the S/Ss.
- Design of the LV distributors and the LV service layouts.
- Determination of the maximum volt drop along an LV distributor
- Determination of the correct fusing to protect all the cables. Changes to the economical design may be required to achieve correct fusing.
- Checking of the design to ensure that customers are not subjected to voltage fluctuations that give rise to voltage flicker

A manual method for calculating the voltage drop for simple networks is included; voltage drop values are shown in Appendix C and worked examples in Appendix D.

Account shall be taken of the possible need for load-related reinforcement. Proposals for other work shall be co-ordinated with any relevant proposal for such reinforcement. The Infrastructure and Service Development Manager shall be consulted, if any proposal for the alteration of loading affects:

- a distribution transformer, which is already overloaded, e.g. sustaining a cyclic loading in excess of 130% of its nameplate rating or a continuous loading in excess of its nameplate rating; or
- an LV distributor, which is already operating in excess of its rating (cyclic rating or continuous rating as appropriate).

5.1.2 Assessment of ADMD

For a group of customers, it is found in practice that the maximum demand after diversity can be adequately calculated from the expression:

Maximum Demand = (a N + P) kW

where a = average ADMD (kW) per customer

N = number of customers in the group

P = load allowance (kW) for loss of diversity

The values to be used for P are obtained from the recommended values in ENA ER P5 (formerly detailed in ACE Report 105):

(a) For single rate users P = 8kW

(b) For Economy 7 users (or similar tariff) P = 4kW

The use of two values is based on analyses of load research studies, which indicated that the likely variation above an average value is greater for the single rate customer than for the Economy 7 customer with space heating.

The design levels of ADMD to be used for the various types of domestic installations are given in the following table:

PROPERTY TYPE	ADMD PER CUSTOMER (KW)	
	Day	**Night**
Small Non-Electric Non-Detached	1.0	0.4
Non-Electric Detached	1.4	0.6
Electric Heating (installed in each of a group of average-sized properties). (This takes account of the large diversity, where electric heating is not subject to a restricted-hour tariff.)	3.4	2.4
Off-peak Tariff, e.g. E7, (where substantial heating load is switched to take advantage of low 'off-peak' rates)	1.5	0.8(aggregate installed water and storage heating capacity kW) + 0.5
Off-peak Tariff with afternoon boost (where substantial storage heating load is switched to take advantage of low or 'off-peak' rates)	3.4	0.8(aggregate installed water and storage heating capacity kW) + 0.5

Two Rate Tariff, e.g. E10 with afternoon, evening and night cheaper rates (where the tariff provides an incentive to concentrate usage in the cheaper periods, notably in the evening)	0.6 (maximum space heating available 07:00 to 24:00 plus water heating kW) + 2 *	0.6 (maximum space heating available 00:00 to 07:00 plus water heating kW) + 0.5 *
Air conditioning (where installed in each of a group of properties)	Taking account of the likely operating regime, it may be appropriate to add a fraction (say 50%) of the installed cooling load to the above daytime ADMD values.	
Heat Pump (HP)	Use LV AFFIRM to determine average ADMD per customer with a HP.	
Electric Vehicle (EV)	Use LV AFFIRM to determine average ADMD per customer with an EV.	

NOTE: In some installations, space heating circuits may be wired in separate banks, with interlocked change-over switches. Thus, at any particular time of day, not all space heating is "available".

Where electric heating, which is not subject to a restricted-hour tariff is to be used in high-density housing (e.g., flats), the ADMD figures given above are to be used for all aspects of the electrical design except for the rating of distribution transformers. The ADMD contribution of such housing to the loading of transformers shall be taken as:

- 0.5[aggregate installed (fixed) space heating (kW) + 3kW water heating].

This is to take account of greatly reduced diversity in the event of a "cold-start" after a prolonged outage.

In this context, a transformer shall be taken to be feeding high-density housing, where 50% or more of its demand arises from electrically heated properties, without restricted-hour tariffs.

NOTE: The ADMD figures for high-density electrically heated housing without restricted-hour tariffs have been arrived at after considering the following:

- A report by EA Technology on a study of a block of such electrically heated flats.
- The likely hot-spot temperature rise in a distribution transformer subject to short-term overload.
- The likely temperature rise in distribution cables subject to a short-term overload.
- The worst overload condition would occur only after distribution equipment had substantially cooled - after a long outage in cold weather.
- The recovery time is expected to be only of the order of 2 hours, even after a very long outage.
- Distribution fuses might be overloaded during the recovery time and it might prove necessary to replace them temporarily with fuses of higher rating and to monitor the temperature of other equipment.

Considerations for assessing HP demand are described in Subsection 5.3.8. Particular attention is required when the HP incorporates an in-line heater and there is a high-density of HPs supplied by the distribution transformer.

Considerations for assessing EV demand are described in Subsection 5.1.9.

ADMDs associated with clusters of Low Carbon Technologies (LCTs) may vary considerably according to customer behaviour and usage patterns, particularly with EVs. Academic research has indicated thresholds that limit the penetration of LCTs before network reinforcement may be required. Network monitoring shall be fitted to record voltage and demand levels when LCTs reach penetration levels in the table below.

LCT TYPE	THRESHOLD*	MONITOR
HPs (3.6kW)	10%	Demand and voltage at LV board using smart fuse
EVs (3.6kW)	10%	Demand and voltage at LV board using smart fuse

*% of customers with LCT on a feeder and/or transformer

Source: University of Manchester report: WP2 Deliverable 2.2: Assessment of LV interconnection benefits for different LCT penetrations

5.1.3 Number of Substations

Most new housing developments will each be catered for by the provision of one or two new S/Ss.

Normally the maximum transformer rating to be used in determining the optimum number of S/Ss for a development is 800kVA. Thus, for large estates the number of S/Ss will normally be decided by dividing the ultimate load to be supplied by 800. However, with low values of ADMD this method may produce excessive feeding distances and, therefore, the feeding area of each S/S should be limited to the appropriate area.

In certain cases where there is a high load density, such as a multi-storey block of electrically heated flats, it may be economic to establish a S/S with a capacity greater than 1000kVA. In such a case, a two-transformer S/S would be permissible.

The LV windings of transformers shall not be run in parallel except during switching operations.

5.1.4 Substation Siting

Substations should be positioned as near as practicable to the load centre. Generally, the easiest method is to cover the development area on a scale plan of the estate with circular discs, whose area corresponds to the feeding area of each S/S. The discs should be adjusted so that there is a minimum of blank spaces and overlap, the centre point of each disc then represents the ideal location of each S/S.

This method assumes a circular feeding area. In many cases the feeding area will be non-circular, and consideration can be given to feeding some loads at a greater distance using more distributors. The additional costs of such a design should be compared with the costs of using a further S/S.

The ideal locations found by this method may not be the most practicable. Account shall be taken of features peculiar to a particular development. For example:

Substantial blocks of load such as schools, shopping parades and blocks of flats will bias the position of a S/S towards such loads.

LV mains shall start distribution as soon as possible after leaving the S/S. This will be achieved by positioning the S/S close to the building line and, e.g., adjacent to a road junction.

Where parallel roads or certain other road configurations arise, it may be economic to site the S/S behind the building line on one road and negotiate an easement for some cables to be installed through private land into other roads (see Subsection 5.3.7 installing cables in private land).

5.1.5 Transformer Loading and Fusing

Transformers shall be sized to cater for the expected finished development in accordance with Module 1, using the loadings as given in Subsection 5.2.1. The installation of a smaller transformer initially in the knowledge that a transformer change will be required as the anticipated development progresses shall be avoided, as it is usually uneconomic.

Fused LBs shall not be used in place of S/S LV fuseboards. Any existing fused LB used as a S/S or transformer LV fuseboard shall be replaced either when more fuseways are required or when the transformer is replaced.

Fuses, protecting distributors fed from a pole-mounted transformer, shall be mounted on the same support as the transformer.

5.1.6 LV Distributor Design

Newly installed LV distributions shall not be tapered and underground distributors shall have a minimum cross-section of $300mm^2$ SAC.

Every effort shall be made to install cables in the footpaths of public roads and streets, and other public footpaths that are subject to NRSWA.

If a cable installation in such public land cannot be achieved, an easement shall be obtained from the developer in order to preserve rights of access, maintenance etc. If an easement cannot be negotiated, then a wayleave shall be agreed. Under no circumstances shall cables (or lines) be installed in land not subject to NRSWA without written rights of access or a wayleave.

5.1.7 Interconnection

It is not intended that alternative connections should be provided from adjacent S/Ss to cater for the failure of a transformer at full load periods.

The facility to connect mobile generation either to the busbar or to an individual distributor shall be provided in all cases, to assist with post-fault restoration. The policy for the use of mobile generators is described in CP605 - System Operations.

However, interconnection shall be installed as follows:

- to provide the required security of supply to teed transformers, where this is the method of connection (see EPD282); or

- for maintenance purposes; interconnection may be provided at each S/S provided that this can be achieved at reasonably low cost; and

- newly installed parts of interconnectors shall not be tapered and shall have a minimum cross-section of 300mm^2 SAC underground or 95mm^2 ABC overhead.

- Two way cable LBs may be used at the point of interconnection to enable limited alternative feeds during maintenance periods.

- Four-way LBs shall not be designed into new networks or extension to existing networks. They shall only be installed where required as a direct replacement for another four-way or three-way LB, or multi-way street pillar

Under the normal running arrangement:

- Distributors shall not be operated in parallel, whether as interconnectors between substations or as rings on the same substation.

- Where there are switch-cores with linking facilities in LBs, they shall be operated with their open points in the same positions as the open points in the phase-cores. This is to ensure that no cable has its phase cores fed in one direction and its switch-core fed in the opposite direction.

- Fuses shall not be installed in LBs, except as described in Subsection 5.1.9.

5.1.8 Phase Shift Link-Boxes

LBs shall not be installed in LV cables whose two sources have different phase angles.

The normally open point between LV sources having different phase angles shall only be on a LV S/S/transformer fuseboard. The fuseway shall be suitably labelled to draw attention to the existence of a phase-angle difference.

5.1.9 Decommissioning of Existing Street Pillars and Link-Boxes

Where the condition of a FP or LB justifies its decommissioning, or where a LB is included in the blast mitigation programme, the relevant part of the LV Network shall be reconfigured accordingly. The procedure described in this subsection takes limited account of the requirements for voltage, loop impedance and fuse protection and, so far as is reasonably practicable and economic, the preservation of existing Network security. This is based on the assumption that the part of the Network being reconfigured is well established and without any outstanding complaints from customers, or other known problems. Where such reconfiguration work is carried out, for the removal of a street-pillar, it shall be borne in mind that:

(a) the existing Network may have been designed with the FP as a secondary distribution point, rather than as the position for an essential open point; and

(b) some form of secondary fusing of the Network may need to be retained.

Accordingly, the following directions shall be applied, where the decommissioning of each FP or LB is being considered. A decision chart, depicting this process is included as Appendix E. It is intended that the procedure described in this subsection shall be followed, without the need for any further analysis of the Network using LV AFFIRM.

The basic essentials of the work shall be designed in a cost-efficient manner. Four-way LBs shall not be installed, except as provided by Subsection 5.1.7.

The existing local Network shall be examined using CRMS. This is able to depict the positions of fuses and links and the presence of small-section cables.

Non-interconnecting, ie radial, cables from an existing pillar, shall be jointed solidly to interconnecting cables, unless fuse protection, downstream of the S/S, is necessary. Fuse protection shall be provided for small-section radial branches already protected by fuses.

Where fuse protection of small section radial cables is required, one LB, fitted with fuse-links (with carriers approved for use in LBs - see CP606) shall be installed, radial cables being jointed together and protected by the one set of fuses. The rating of the fuse-links shall be chosen, so as to be sufficient to carry the expected demand.

NOTE: This simplified assessment is intended to result in the fuse-protection of the LV Network being made not significantly worse than it is.

An assessment shall be made as to the possibility of jointing interconnecting cables solidly together and placing open points in S/Ss or existing LBs. This will often be possible in dense urban networks. This assessment shall be made, without recourse to a LV AFFIRM model. It is accepted that there might be a small risk that the resulting normal running of the interconnector being marginally unsatisfactory.

Where existing open points cannot be moved to S/Ss or other LBs and any S/S would not otherwise have at least one interconnector for each 200, or part thereof, of its customers, one new LB shall be installed. No more than two such LBs, each supporting different S/Ss, shall be installed. Where, not all existing interconnecting cables are to remain as interconnectors, priority shall be given to those of larger rating and those having greater numbers of connected customers between fusing/linking points.

Any other cables, not already considered (5.1.9), shall be jointed together, jointed to other interconnectors or bottle-ended, as appropriate, provided that this does not result in any group of more than 200 customers being at repair-time risk, in the event of a fault, and being without any alternative feed after an initial cable-cut.

Where designs require LBs to be adjacent, their relative positions shall, so far as is reasonably practicable, reflect their electrical functions within the Network, in order to assist operators in identifying and distinguishing the boxes. Particular care shall be taken to ensure that LBs in close proximity are correctly marked with their numbers both on the bell-covers and on the fixed surrounds, in accordance with CP615, subsection 6.8.5.1.

5.1.10 Switch-cores and Switch-wires

As lengths of switch-cores (in 5-core cables) and switch-wires (on LV overhead lines) become redundant, they shall be isolated from all live conductors.

All reasonable opportunities shall be taken to cut off redundant lengths of switch-cores and to remove redundant lengths of switch-wires.

Where switch-cores are cut as above or in accordance with EPD282, subsection 4.5.7, the cut ends shall be insulated on both sides of the cut.

5.1.11 Distributor Cable Size

The cross-sectional area of the distributor has a minimum cross-section of 300mm^2 SAC. The voltage drop along a new distributor or a modified distributor shall be calculated as described in Subsection 5.2 below.

Electrically heated property having a high ADMD or for distributors close to the S/S, the electrical loading on a cable may be the limiting factor. Tables of continuous cable ratings for underground cables are available in CP203 - Current Ratings for Underground Cables and for overhead lines in CP206 - Current Ratings for Overhead Line Conductors.

The maximum fuse size shall be determined for each distributor, in accordance with Module Ten, to ensure that the distributor cables are protected. In cases where the proposed network cannot be adequately fused, increased cable sizes shall be considered, in order to ensure the necessary protection.

As the LV Network develops and checks reveal that existing network cables are not adequately fuse protected as described in Module Ten (but provide adequate voltage regulation), the appropriate Area Operations Manager shall determine whether the cables are replaced or continue to operate as they are.

It is also necessary to ensure that the earth-fault loop impedance at each cut-out is sufficiently small to pass fault current to operate the cut-out fuse within 5s. The earth-fault loop impedance at any cut-out should not normally be designed to exceed 0.35Ω on a CNE distributor and not to exceed 0.8Ω on any distributor. Where the loop impedance exceeds 0.54Ω, the rating of the cut-out fuse shall be limited to 80A.

5.2 Distributor Voltage Design

The voltage drop from a S/S low voltage busbar to any customer's cut out shall not exceed 7% with the additional requirement that the voltage drop in the service connection shall not exceed 2%. A S/S busbar voltage of 415/240V shall be used for all calculations. In order to obtain the most economical design it is important that this maximum voltage drop is achieved wherever practicable.

5.2.1 Services – PME

New connections shall, in accordance with Module Eleven LV Service Connections and Application of PME, be installed as PME. Notable exceptions are connections to caravans, boats, agricultural premises, sports facilities and petrol filling stations, and temporary connections for construction sites.

For new connections to existing street furniture, every effort shall be made to agree a PME connection. Where this is not possible, a SNE connection shall be provided.

For a new EV charging supply installation, which is deemed to be accessible to the public, the design shall be in accordance with Module Three Connection of Low Carbon Technologies and the relevant section of the IET Code of Practice for the Connection of Electric Vehicle Charging Equipment. This specifies that a PME terminal should not be offered unless the specific criteria in BS 7671 Section 722 are satisfied. In general, the earthing system of the EV charging installation should form part of a TT system by installing a separate earth electrode and fitting appropriate protection in accordance with BS 7671 (e.g. an RCD). In addition, extraneous-conductive-parts (e.g. safety barriers, pedestrian guard rails) should not be connected to a PME earth terminal. Care shall be taken to ensure adequate physical separation between earthing systems. Different arrangements may be required for installations in dwellings, as well as commercial/industrial installations. These arrangements are explained in detail in the IET Code of Practice for Electric Vehicle Charging Equipment.

In all cases earthing shall be designed in accordance with the IET Code of Practice for Electric Vehicle Charging Equipment, ENA ER G12, and Module Eleven LV Service Connections and Application of PME.

5.2.2 Services – Arrangements

In order to minimise voltage drops on distributors, successive service connections shall be made to the distributor's phases in the sequence L1, L2, L3, L3, L2, L1, etc. The whole treatment of voltage drop calculation is based on this sequence of service connections being followed and it shall, therefore, be strictly adhered to.

The four way main/service joint is the preferred option. If all services are not available for connection at the time of mains jointing then bottle ended services, adjacent to the mains joint, shall be provided for the future services, so that only service jointing is then required for the future connections. Work shall be in accordance with EPD201 - Recovery and Identification of Idle Services.

The network design shall ensure that the minimum number of main/service joints is used. This may be achieved by the use of 'single visit' services (where the service can be made live before the property is completed) and of four way service joints.

If the customer or builder requires a design different from the optimum design, the extra costs incurred, including costs of additional operation and maintenance, shall be charged in full to the customer or builder.

All domestic services shall utilise the shortest practical route. The preferred option is shown in Figure 1 below.

Figure 1

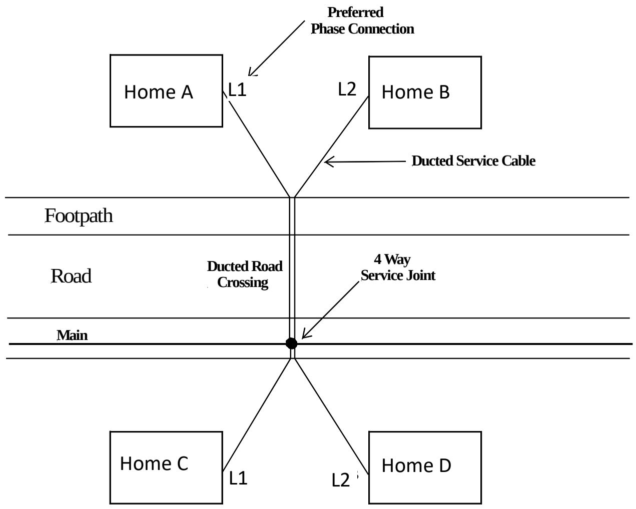


Figure 1

The rating of service cables shall be in accordance with CP203

5.2.3 Estimation of Existing Maximum Demand

Transformer MDI readings shall be recorded, during S/S inspection, as described in CP306, Procedure FM1004, at the frequency prescribed in EPD301.

Transformer MDIs shall be re-set only by Electricity North West nominated staff. Readings shall be forwarded to the Policy and Implementation Manager, or entered in the spreadsheet:

TX Utilisation – Enter New MDI Readings.xls.

Best estimate of peak feeder load readings shall be ascertained as follows:

Measure the LV feeder load readings associated with the transformer (on all feeders simultaneously using a multi channel device).

Sum the feeder load readings to give the transformer demand.

Determine the ratio Annual $\frac{\text{MDI reading}}{\text{Sum of feeders}}$

Scale up the feeder load readings by the above ratio

A typical arrangement for a 5 way LV distribution board is shown in Figure 2 below.

Figure 2

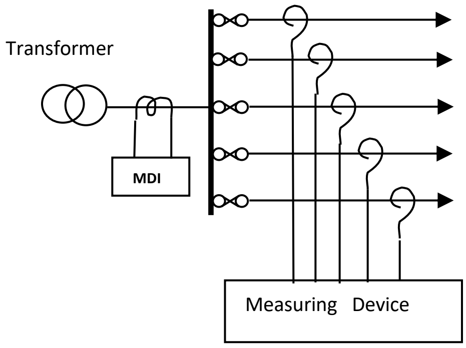


Figure 2

5.2.4 Charging Conditions and Cost Recovery

Guidance on the application of the rules, set out in ENW's Distribution Licence, can be found in CP810 - Charging Conditions for New Connections and CP820 - Charging Conditions for Reinforcement and Replacement. Particular care needs to be taken in the connection of loads with abnormal characteristics (see ENA ER G5/5 and ENA ER P28).

5.3 Low Voltage Network Design Calculations

5.3.1 First Pass Assessment

Appendix A provides details of the "first pass" assessment of new single and three phase demand applications to determine whether a detailed connection study is required.

5.3.2 Connection Studies – Required Results

Calculations shall be carried out for each network design, in order to determine the following:

(a) the maximum voltage drop, as measured at any cut-out, at any end of the network remote from the feeding S/S;

(b) the maximum voltage drop on any service connection;

(c) the greatest earth-fault loop impedance at any cut-out;

(d) the rating of the fuse to comply with Module Ten, ideally such that it will operate within the specified time in the event of an earth fault on any main, discriminate with the HV protection and be sufficient to carry the load.

Where a customer has applied for the connection of a disturbing load, such as a motor or welder, compliance with ENA ER P28 - Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom shall also be checked.

These calculations shall be carried out for all new extensions and alterations to the LV Network and also in order to check the designs of third parties, who design extensions to the Network.

5.3.3 LV AFFIRM – Network Design Workbook

The preferred method of calculation to be used by ENWL staff and Contractors is LV AFFIRM, a Microsoft Excel workbook, as described in detail in Appendix B - LV AFFIRM - Network Design Workbook - Documentation. All users of LV AFFIRM shall be registered as such and shall receive a personalised password-protected copy of the template. Other persons shall not use LV AFFIRM except for training purposes or under the supervision of a registered user.

5.3.4 Manual Calculation of Distributor Voltage Drop

The only approved alternative to the use of LV AFFIRM is a manual calculation, using the data and methods described in Appendices C and D, which may be suitable for the calculation of voltage drops in simple three-phase networks with balanced loads.

5.3.5 General Requirements for Calculations

Whichever method is used, the first step is to assign the ADMD values to the domestic customers using the table in subsection 5.1.2 and to obtain the loads for any non-domestic premises.

Allowance shall be made for lack of diversity in small groups of customers, in accordance with the group demand formula (a N + P) kW of subsection 5.1.2.

Where there is a mix of off-peak and other customers it is necessary to determine when the peak load occurs and to carry out the calculation accordingly.

The S/S(s) should be marked on the plan, an initial layout of the distributor and service cables drawn, and the customers assigned to the distributors. From the connected loads, an initial assessment can be made of the circuit length.

All newly install LV cables shall have a minimum cross-section of 300mm^2 SAC.

5.3.6 Service Voltage Drop

The service cable installation and minimum size shall be as described in Module One.

The calculated voltage drop for the service cable shall not exceed 2% as stated in Module One.

The consideration of the service load follows the same principle as for the distributor loads above, in that the following formulae have been recommended in ENA ER P5 (formerly ACE Report 105), assuming single services to customers.

(a) For Economy 7 or similar off-peak tariff customers with space heating load:

Service load = (X + 4) kW
Where 'X' is the installed space and water heating load

(b) All other customers

Service load = (2aN + 8) kW
Where 'a' is the design ADMD (kW) for the customers.

The greatest value of earth-loop impedance at the termination of any service shall be calculated. On CNE distributors, this is normally not expected to exceed 0.35Ω. See also subsection 5.1.11.

The largest S/S fuse rating, which affords protection to the entire distributor, shall be determined in accordance with CP331. This rating needs to be greater than or equal to the rating required to carry the load of the distributor. The rating of the fuse specified for use might also be restricted by the need to discriminate with the HV protection applied to the transformer and by the rating of the LV cable or line.

5.3.7 Voltage Flicker

The proposed LV network shall be checked to ensure that customers' connections are not subjected to voltage fluctuations that give rise to excessive flicker. For this purpose, reference shall be made to ENA ER P28.

ENA ER P28 uses a three-stage assessment for the acceptance of disturbing loads. Stage 1 recommends approval for the connection of normal domestic appliances and motors of small rating or low-impedance connection (i.e. at a S/S), without the need for calculation. These motors range from 0.37kW, with very frequent starting to 75kW, connected at a S/S with a 1000kVA transformer and started at a minimum of 10 minute intervals.

Equipment outside the Stage 1 limits requires assessment within Stage 2 (or Stage 3). LV AFFIRM provides some assistance with a Stage 2 assessment, in that it considers two significant points at 3% and 1% voltage dip on the curve shown as Figure 4 in ENA ER P28. Provided that a disturbing load gives rise to a voltage dip of 3% or less at intervals of 2 hours or more, it is taken to be acceptable. Similarly, a disturbing load, which gives rise to a voltage dip of 1% or less, is acceptable at intervals down to 20s. Accordingly, LV AFFIRM calculates the step changes in current, which give rise to 3% and 1% voltage dips.

Other disturbing loads, with voltage dips of less than 3% and/or intervals of less than 2 hours may also be acceptable within a Stage 2 assessment. In such cases, reference shall be made directly to ENA ER P28 and to Figure 4 in particular.

Cases where the proposed network does not meet the requirements of ENA ER P28 shall be referred to the Network Planning Policy Manager

5.3.8 Heat Pumps

It is expected that the transition to a low carbon economy will see an increase in applications to connect heat pumps. To facilitate the connection of heat pumps, standardised connection processes have been developed based on compliance of equipment with international standards. The relevant standards are:

- BS EN 61000-3-2 Limits for harmonic current emissions (equipment input current <= 16A per phase)
- BS EN 61000-3-3 Limitations of voltage changes, voltage fluctuations and flicker in public low voltage supply systems – equipment with rated current <16A
- BS EN 61000-3-11 Limitations of voltage changes, voltage fluctuations and flicker in public low voltage supply systems – equipment with rated current <75A and subject to conditional connection
- BS EN 61000-3-12 Limits for harmonic currents produced by equipment connected to public low voltage systems with input current >16A and <75A

Compliance with these standards will ensure compliance with ENA ER P28 and ENA ER G5/4.

The processes describe three categories for connection:

(a) Heat Pumps fully complying with both BS EN 61000-3-2 and BS EN 61000-3-3. These can be connected without detailed assessment. Customers to request connection using the data submission form parts 1 and 3 in Appendix I.

(b) Heat Pumps fully complying with BS EN 61000-3-11 and BS EN 61000-3-12. These can be connected subject to satisfying conditional requirements detailed in Appendices G and H. Customer to request connection using the data submission form parts 1 and 3in Appendix I.

(c) Heat Pumps not compliant with BS EN 61000-3-2, BS EN 61000-3-3, EN 61000-3-11 and BS EN 61000-3-12. These are considered disturbing loads and are assessed accordingly following processes described in ENA ER G5/4 and ENA ER P28. Customer to request connection using Form C – see Appendix I

Heat Pumps fully complying with BS EN 61000-3-2 **and** BS EN 61000-3-3. These heat pumps have an input current <16A per phase and can be connected without further assessment, subject to the limitations of multiple connections described in 5.3.7 above.

Heat Pumps complying with BS EN 61000-3-11 – voltage fluctuations and flicker. These are conditional connections that may require a limit on network impedance at the customer's supply terminals. The assessment compares the maximum permissible source impedance declared by the manufacturer, Z_{max}, against actual source impedance, Z_{act}, calculated using LV Affirm. The connection can be permitted if $Z_{max} > Z_{act}$.

For single phase heat pumps the source impedance Z_{act} is obtained from LV Affirm on the 'Inputs and Results' worksheet, cells J35, J36 and J37 'Total Loop Impedance (inc S/S)'.

Additionally, some heat pumps are intended for use in premises with a service capacity > 100A. It is a requirement of BS EN 61000-3-11 such equipment has a maximum source impedance defined for a service capacity >100A, $Z_{max\ 100A}$.

Source impedances shall comply with the following table:

EQUIPMENT CONNECTION	MAXIMUM SOURCE IMPEDANCE	
	Z_{max}	$Z_{max\ 100A}$
Phase – neutral	As Defined on Application Form B or Database	0.3535Ω
Phase – Phase		0.4243Ω
3- Phase		0.2121Ω

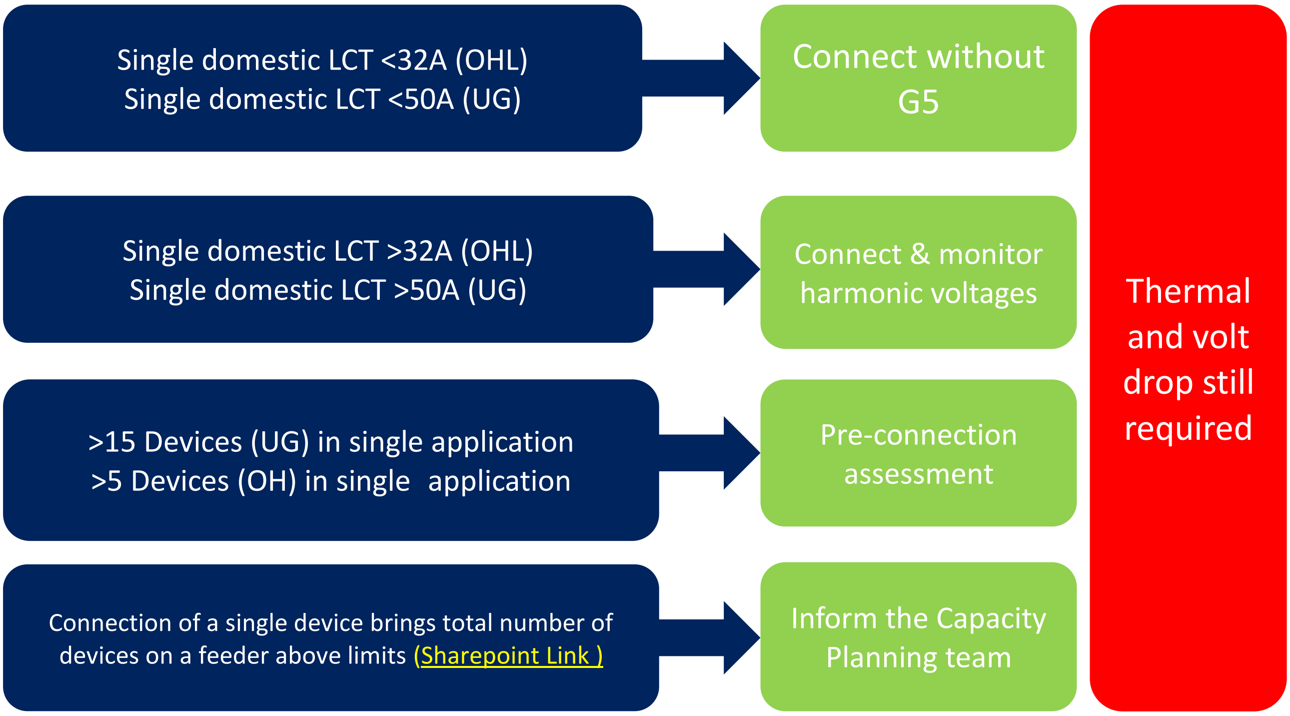
The process for assessing applications against BS EN 61000-3-11 is detailed in Appendix F. This should be followed in conjunction with the completed Form B.

Heat Pumps complying with BS EN 61000-3-12 – limits for harmonic current emissions. These are conditional connections that require a minimum fault current at the point of common coupling. The minimum permissible fault current is derived from the ratio of the three phase short circuit power at the point of connection, S_{sc}, to the heat pump rated power, S_{equ}. BS EN 61000-3-12 defines this ratio as R_{sce} and recommends a minimum value of 33, allowing S_{sc} to be calculated from the heat pump rating S_{equ}. The minimum required fault current, I_{fmin}, can then be calculated from S_{sc}. This can then be compared to the actual fault current I_f, derived from LV Affirm, and the connection can be allowed if $I_f > I_{fmin}$.

For simplicity, values of I_{fmin} can be obtained directly from the heat pump rating using Table G1 in Appendix G. The values within the table have been calculated using $R_{sce} = 33$. The fault current is considered at the point of common coupling, which for domestic services will be the service breech joint onto the main. LV Affirm presents this information for single phase connections in the 'Inputs and Results' worksheet, with values for each section. The value at the end of the section the service is connected to should be chosen.

The process for assessing applications against BS EN 61000-3-12 is detailed in Appendix G. This should be followed in conjunction with the completed Form B.

Multiple applications shall be in accordance with the table below.



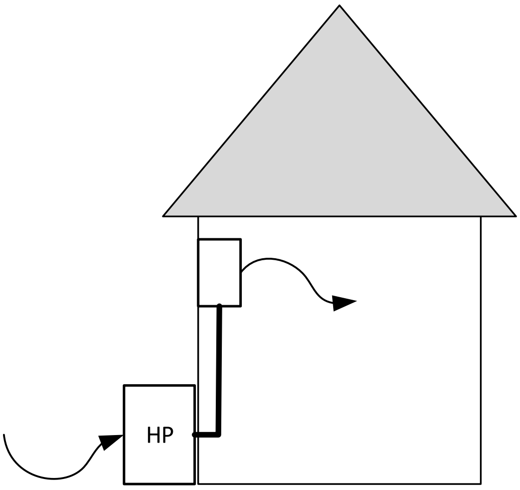
If the multiple application consists of identical heat pumps, the conditional connection assessment required by BS EN 61000-3-11 may be carried out for the installation with the highest source impedance only. Similarly, the BS EN 61000-3-12 assessment may be carried out for the PCC with the lowest fault current only.

Thermal assessments shall be carried out for all multiple applications. No diversity shall be assumed between multiple installations due to the operating regime of heat pumps.

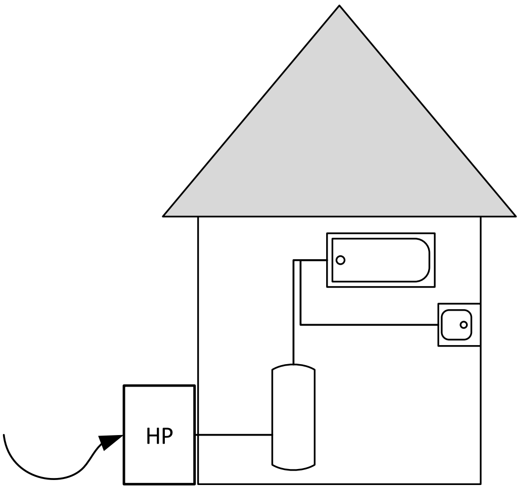
When assessing HP load it is important to understand the configuration of the HP installation. Typically, the HP may be an air-to-air system or an air-to-water system as depicted in Figure 3. If the HP is a standalone type, then the load drawn is wholly dependent on the size of the electrical components in the HP (compressor, pump). However, if the HP system includes an in-line heater which acts as a back-up or boost, as may be the case for water heating, the load drawn will be increased above the HP rating.

NOTE: Some HPs include a heater to raise water temperature above 60°C to remove legionella. Such a heater typically operates 1 hour per week and only when the HP is not running. Hence, this heater does not dramatically increase the load current as would be the case with an in-line heater providing back-up and boost to heating.

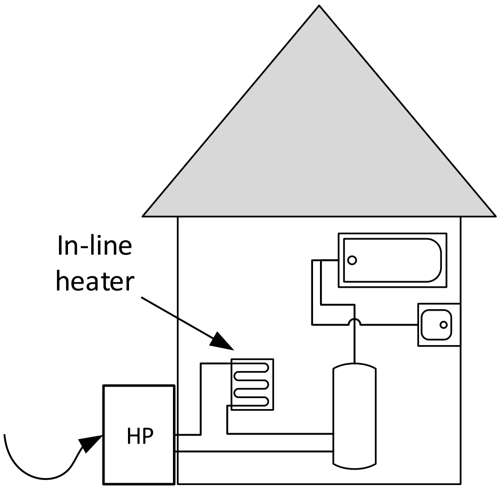
Figure 3



Standalone air-to-air HP unit



Standalone air-to-water HP unit



Air-to-water HP unit with in-line heater

The HP load shall be accounted for by means of an average ADMD value calculated using LV AFFIRM.

The ADMD formulae for HP load are based on the guidance in ENA ER P5.

The ADMD formulae for HP are limited to single-phase LV units.

The average ADMD value is dependent on the electrical rating of the HP and the number of customers with a HP. The rating of the HP may be described in a number of ways:

- Heating capacity – this rating describes the heat output that the HP is capable of delivering and is measured in kW units. Typical values for domestic HPs are 5kW, 8kW and 11kW.

- Electrical rating – this rating describes the electrical power which the HP consumes when operating and is normally measured in amps. It may represent the nominal running current (e.g. HP normal operation), the maximum current consumption (e.g. HP inrush current) or the fused rating (e.g. 16A, 32A).

The relationship between the HP heating capacity and nominal running current is typically captured by an efficiency factor. For example, a 5kW output HP has a nominal running current of 7.4A giving it an efficiency factor of 2.94 (5/1.7).

For the purposes of ADMD calculation, the electrical rating shall be used and preferably the nominal running current. If the nominal running current is unknown, then the maximum running current should be used. Based on the electrical rating, the most appropriate selection on LV AFFIRM shall be used from the 3 available options:

- 16A, 3.68kW

- 25A, 5.75kW

- 32A, 7.36kW

When there is a high-density of HPs, careful consideration is needed to account for in-line heaters, which may be present.

- High-density HPs – when more than 20% of customers fed from a distribution transformer have a HP. In these cases, the in-line heater shall be accounted for in the ADMD calculation. This is necessary to take account of greatly reduced diversity in the event of a “cold-start” after a prolonged outage, as is the case for electrical heating (see subsection 5.1.2).

NOTE: The factor of 20% is a conservative cut-off based on research by Manchester University which indicates that 30% is a capacity threshold between ‘normal’ and ‘dense’ networks. Actual data on the operating characteristics of a group of HPs in the event of a “cold-start” may provide justification to amend the cut-off.

5.3.9 Electric Vehicles

The EV load shall be accounted for by means of an average ADMD value calculated using LV AFFIRM.

The ADMD formulae for EV load are based on the guidance in ENA ER P5.

The ADMD formulae for EV are limited to single-phase 230V units.

The average ADMD value is dependent on the electrical rating of the EV and the number of customers with an EV.

For the purposes of ADMD calculation, the electrical rating shall be used and preferably the nominal running current. If the nominal running current is unknown, then the maximum running current should be used. Based on the electrical rating, the most appropriate selection on LV AFFIRM shall be used from the 3 available options:

- 16A, 3.68kW
- 25A, 5.75kW
- 32A, 7.36kW

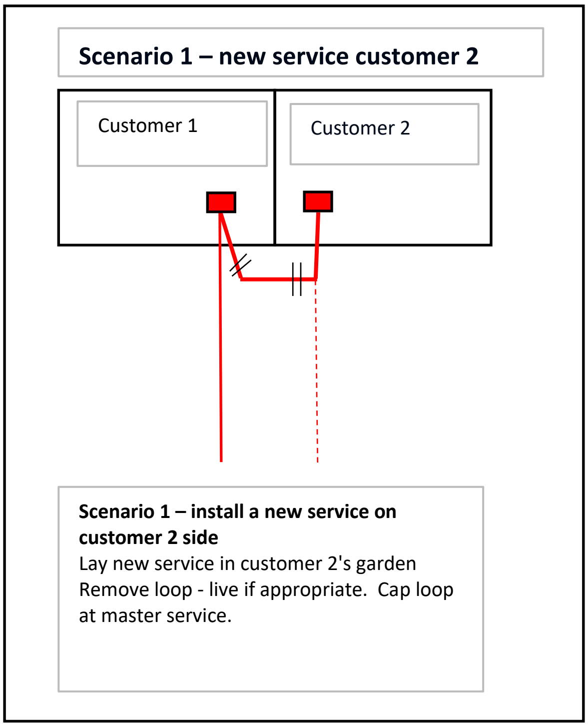
Power quality assessments shall be carried out for larger EV charge points (>32A) using LV AFFIRM.

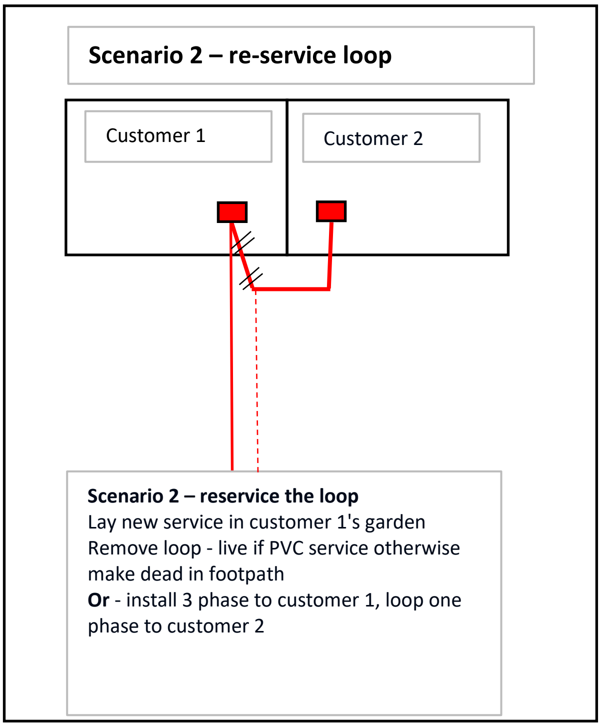
5.4 Removal of Looped Services

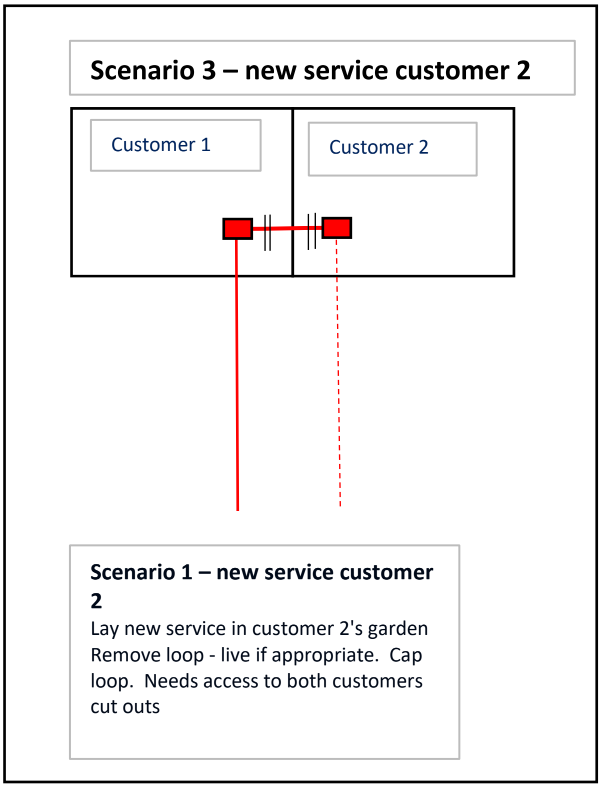
EPD 283 Low Voltage Network Design requires looped services be removed following the connection of an electric vehicle or heat pump to remove the danger of overloading assets at the service position. This work can be disruptive to customers and can be very dependent on their cooperation. Some customers may refuse excavation to install a complete new service, so a range of options are described below to cater for these situations. The options are in order of preference.

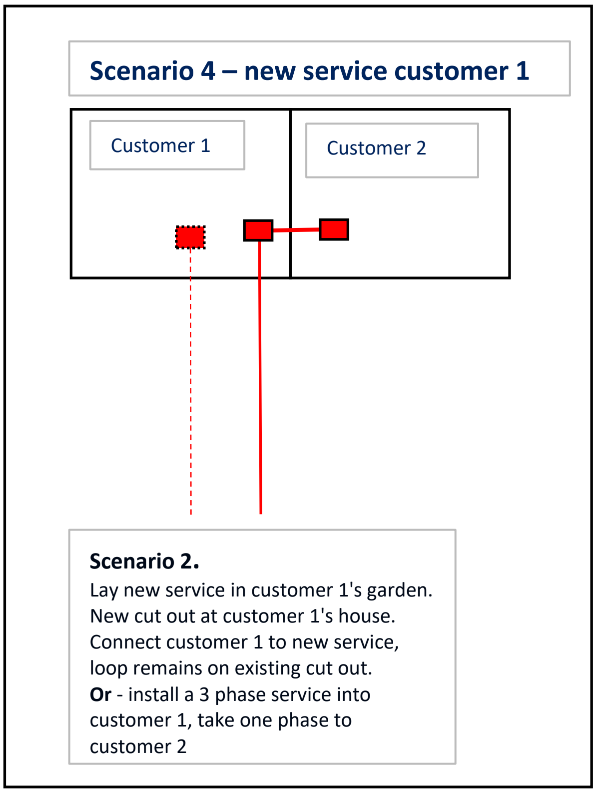
5.4.1 Replacement of Loop with a Dedicated New Service

This is the preferred option and shall be used where practical if agreement can be reached with the customer. The loop is removed as much as reasonably practicable, avoiding live bottle ends where possible. A new 100A service is installed. Existing service cable less than 0.0225 Cu shall be replaced fully, tails of 0.0225 Cu or greater from the cut out may be re-used.



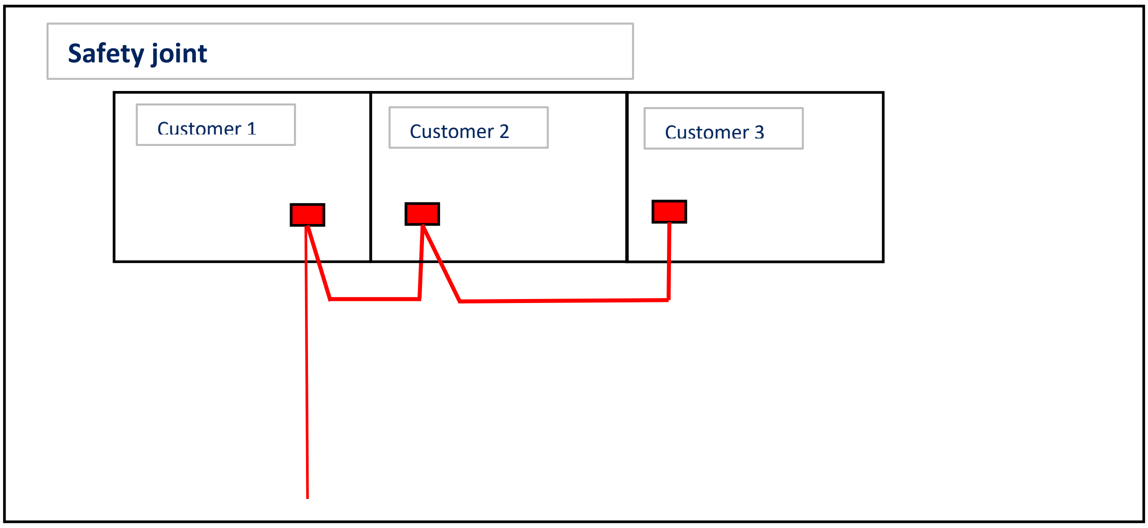


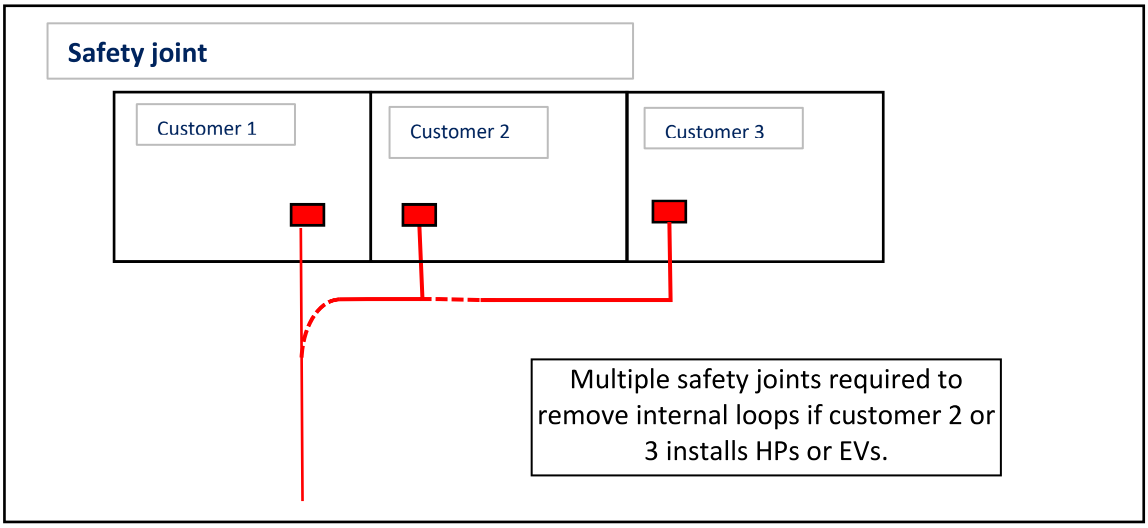




5.4.2 Safety Breech Joint

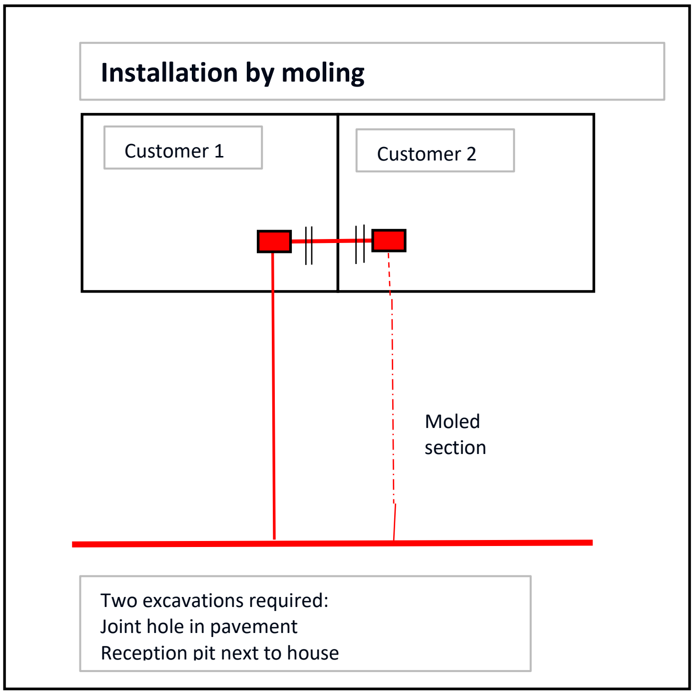
The loop is jointed to the service cable underground, usually requiring only a small joint hole. This removes the above ground danger at the cut out, but the rating restriction of the service cable remains.





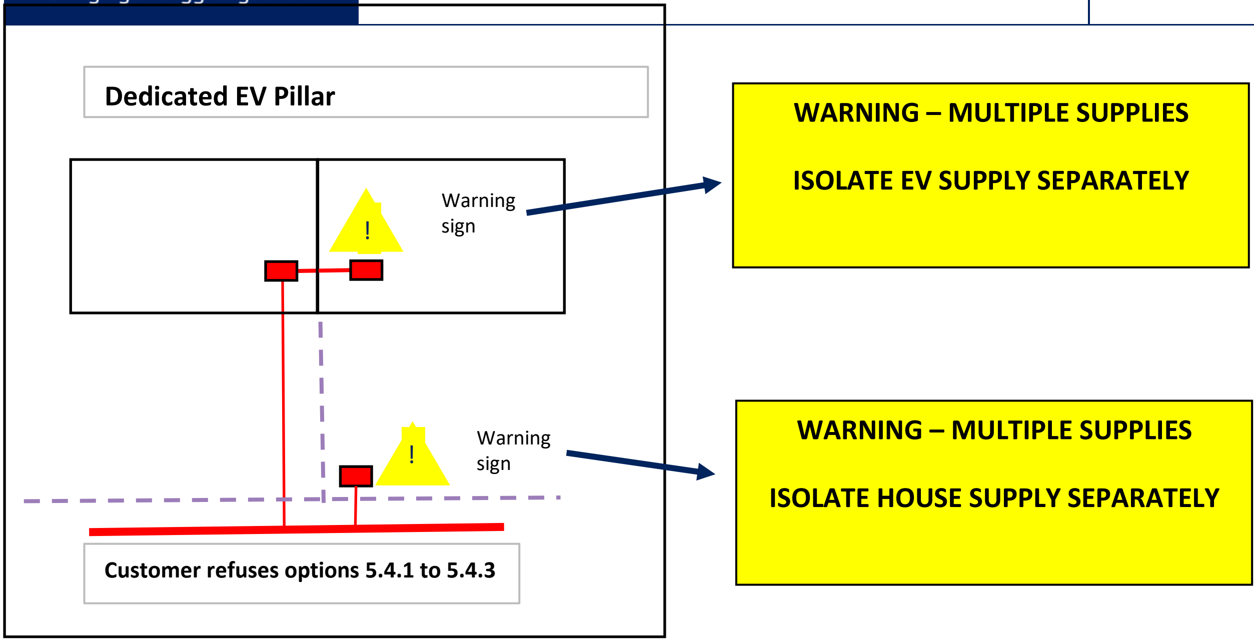
5.4.3 Directional Drilling / Moling

This is well established technology and may be appropriate for some situations. The location of existing services needs to be determined, and there needs to be a suitable area next to the house for a reception pit.



5.4.4 Dedicated EV Charging Pillar

A standalone pillar is installed at the edge of the customer's front garden near the footpath. A new 100A metered service is then installed. The pillar then has an external landing area to accommodate connection of a charging socket. The pillar shall be carefully located to minimise the risk of accidental vehicle strike. Warning labels shall be fitted at both the new and existing service positions to warn of the presence of two exit points.



5.4.5 Above ground Steel Wire Armour (SWA) cable

25mm^2 Cu SWA cable may be run above ground where there is a suitable supporting structure such as a wall. The structure must be permanent, for example a brick or stone wall. A post and panel type wall is unsuitable. Cable guards shall be used where the cable exits the ground. The service should preferably terminate at the existing cut out to provide a new 100A service. If this can't be agreed with the customer, the service may terminate in a wall mounted cabinet on the front of the house to provide a metered supply dedicated to the EV charge point. Service breech joints and cut out termination modules are available for SWA cable. Warning labels shall be fitted at both the new and existing service positions to warn of the presence of two exit points.

A site risk assessment shall be carried out to assess the likelihood of accidental damage to the cable, for example from vehicle strikes. This option is subject to the risk assessment judging the risk of damage to the cable being acceptably low.

5.4.6 Above ground concentric service cable in flexible conduit

This is similar to the option 6.5 above, but ordinary concentric service cable may be used if protected by steel conduit. Where there are multiple bends that would preclude use of rigid conduit, flexible conduit such as the Anaconda system may be used.

A site risk assessment shall be carried out to assess the likelihood of accidental damage to the cable, for example from vehicle strikes. This option is subject to the risk assessment judging the risk of damage to the cable being acceptably low.

6 Module Three – Connection of Low Carbon Technologies

Contents

6.1 Introduction

Increasing numbers of Low Caron Technologies (LCTs) such as Electric Vehicle Charge Points (EVCPs) are being connected to the Electricity North West Limited. The uptake of LCTs is expected to increase in line with the national transition to electrification of heat and transport. Other LCTs include Heat Pumps (HPs) and inverter connected micro-generation. Standard connection arrangements and assessment techniques are required, in order to ensure adequate safety and security for both EVCP users and the public. By applying these standards, Electricity North West Limited expects installations, which it adopts, to comply with the Electricity Safety, Quality and Continuity Regulations 2002 as amended (ESQCR) and to facilitate compliance with the Electricity at Work Regulations 1989.

6.2 Scope

This Electricity Specification (ES) details the requirements for new connections of LCTs directly connected to the Electricity North West Limited electricity distribution network. The connection of the new LCTs may be to either an existing or new exit point. This ES covers connections, which are intended for adoption by Electricity North West Limited, installed both by itself and by Independent Connection Providers.

6.3 General

Any variation to this specification shall be agreed, in writing, with the Planning Policy Manager, Network Strategy directorate, Electricity North West Limited prior to any design being accepted.

The Owner's Works shall comply with the requirements of BS 7671 Requirements for Electrical Installations.

It is a requirement that all work shall be carried out strictly in accordance with the provisions of all relevant legislation and industry best practice.

Design principles in Module One shall apply.

This document shall be read in conjunction with BS 7671 and the IET Code of Practice for Electric Vehicle Charging Equipment Installation.

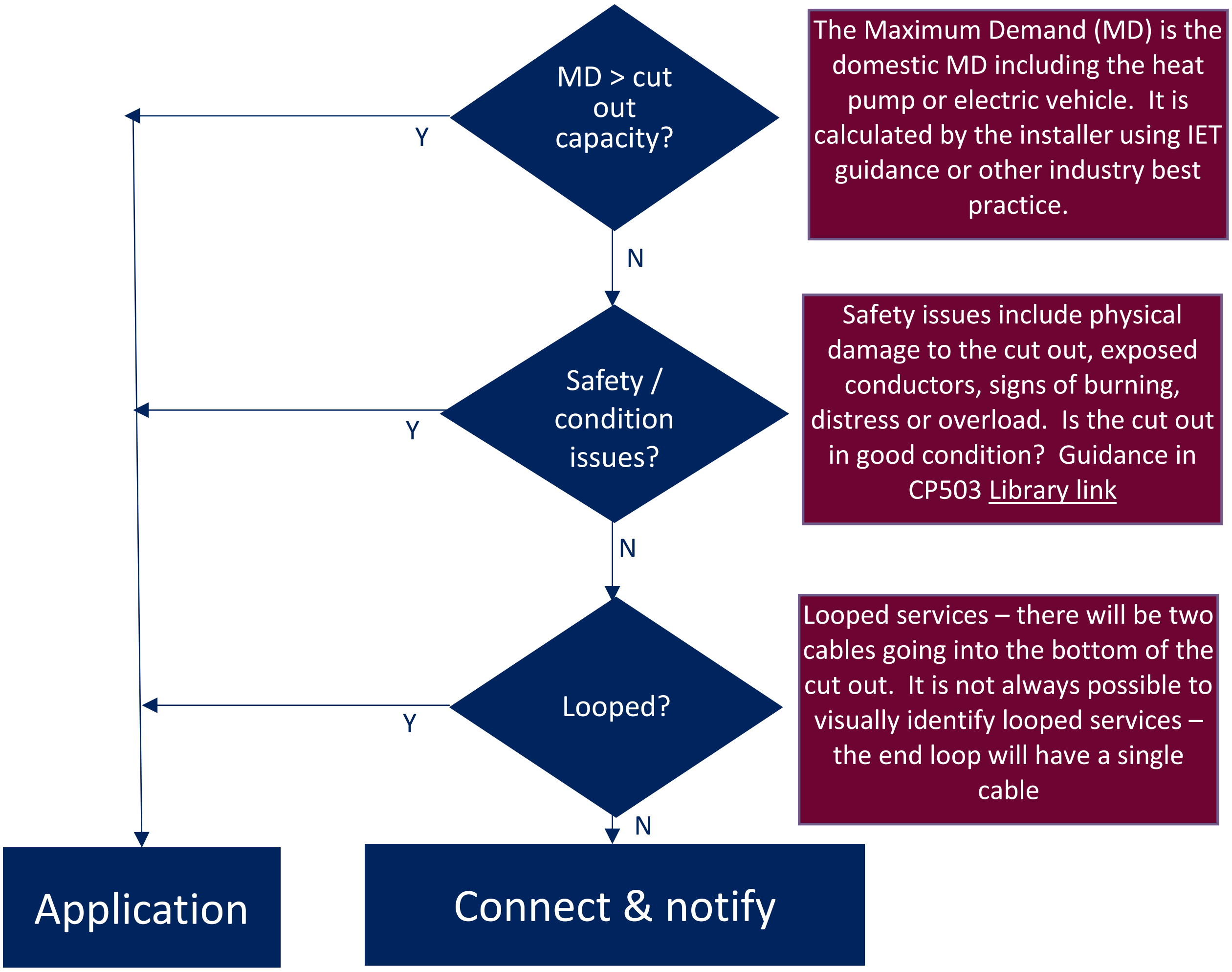
6.4 Domestic Whole Current Metered Heat Pumps and Electric Vehicles Charge Points

Connections have historically been based on the Energy Networks Association (ENA) combined heat pump and EV connection process. This process allows connections to proceed without application if specific conditions are met, otherwise an application is required. The process includes a decision tree to assist installers with this decision, with links to third party websites such as Meter Operation Code of Practice Agreement (MOCOPA) to provide further information.

However, experience gained over several years since the ENA process was introduced demonstrates many of the check points within the process such as power quality are low risk for domestic heat pump and EV charge points. Electricity North West has decided to simplify the connection process and move toward a connect and manage approach. This simplifies the connection of heat pumps and electric vehicles for customers and facilitates the anticipated increase in uptake in ED2 and beyond.

6.4.1 Installer Assessment and Electricity North West Triage

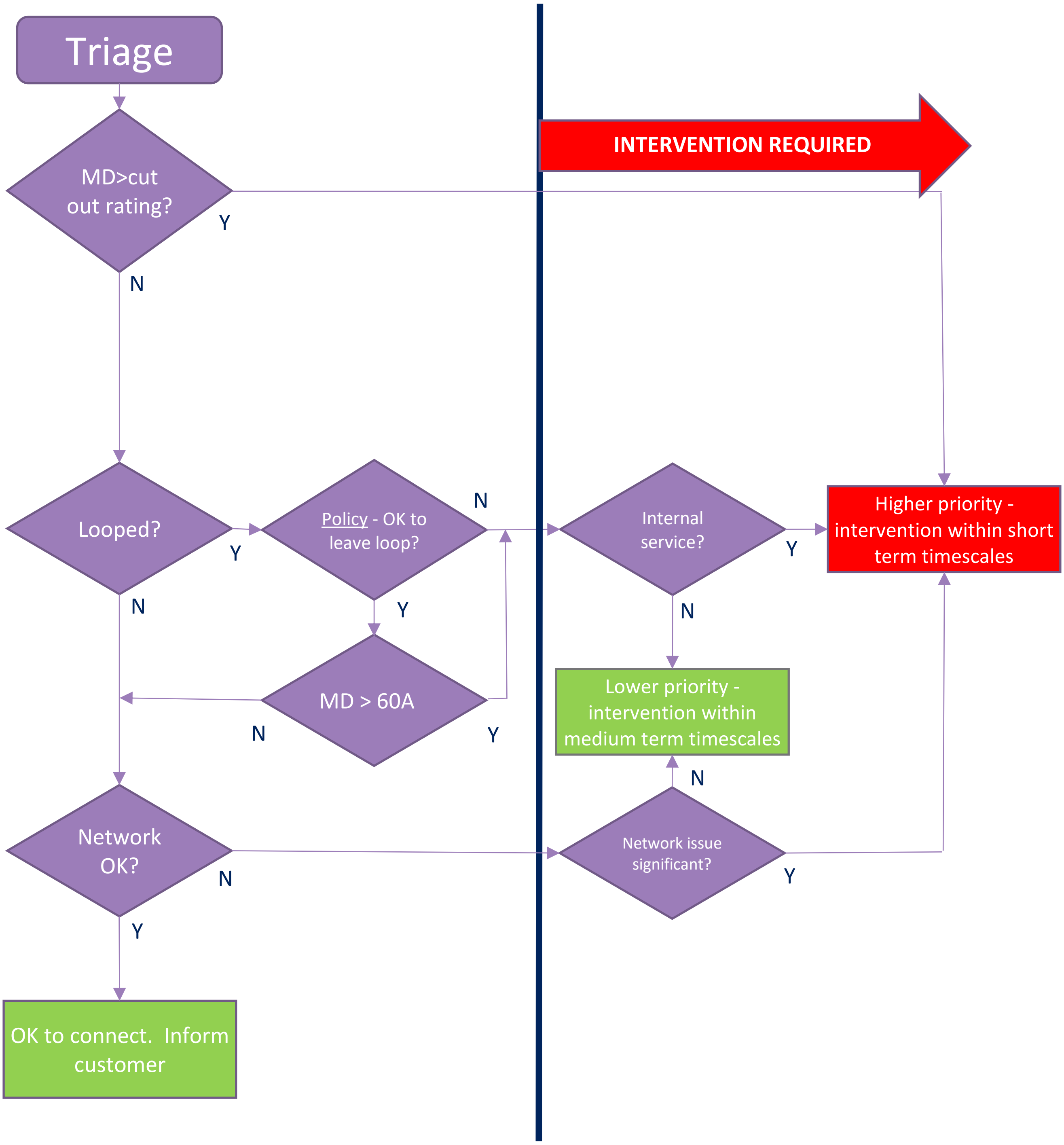
Under the new process, installers carry out an assessment of the suitability of the service to accommodate the heat pump or electric vehicle connection to decide whether an application and subsequent approval is required in advance of the connection. Note this excludes generation and storage.



Process flow – checks required by the installer.

Installers shall be required to submit notifications of connections as soon as a customer commits to the installation, preferably well in advance of installation. Notifications should ideally include photographs of the cut out, meter tails and meter. If of sufficient quality they may allow Electricity North West to identify the type and condition of assets. Installers shall also advise their customers that Electricity North West will assess the adequacy of the service and may need to carry out works including excavation.

On receipt of the notification Electricity North West shall carry out a triage assessment as defined in the process flow chart below.



Notes

- **MD > cut out rating.** Include service cable capacity where there are very small section cables 0.0145 in^2 or 16mm^2. This cable size shall de-rate the service capacity to 60A for the purposes of the unlooping policy assessment. Looped services are fused at 60A.
- **Network OK?** Check using LV AFFIRM worksheet 'VD Estimator'
- **Network issue significant?** Voltages outside statutory limits or earth loop impedance exceeds 0.8Ω
- **Intervention timescales.** These are to be agreed within the business, and are subject to resource and practical considerations

6.4.2 Cut out rating – guidance. Feb 24

Cut outs installed after the year 2000 were specified to BS7657 and are rated at 100A. Prior to 2000, cut outs were manufactured to a number of specifications including ENA ENA TS 12-10 which covered ratings from 60A to 100A. It is therefore necessary to identify the cut out rating as part of the connection assessment process.

Cut outs which are rated at 100A:

- Henley Series 5 and above
- Lucy Mark 4
- BICC UV Series. Fuse carriers marked 60A or 80A may be installed, but this does not affect the rating of the base unit which will be 100A. For a bottom side loop the rating is 100A regardless of the fuse carrier rating.

6.4.3 Multiple Installations

For multiple installations, diversity shall be determined using ENA Engineering Recommendation (EREC) P5.

Each individual connection will need to be assessed in accordance with the process described above. In addition to this, a network assessment may be required depending on the number of devices connecting and the topography of the network. As a guide, a network assessment will probably be required if the number of devices connecting exceed:

- 5 or more for a typical underground cable network
- 2 or more for a typical overhead line network.

These thresholds are only for guidance, and planners should exercise judgement. Thresholds may be lower if the network comprises long lengths of small section conductors.

6.4.4 Installer's responsibilities

EVCP installers shall ensure that their installation comply with BS 7671 and the IET Code of Practice for Electric Vehicle Charging Equipment Installation. In particular, they are responsible for ensuring the safe design and installation of the earth system.

Installers shall email notifications to G98notifications@enwl.co.uk. Details of all installations shall be recorded in the DG Database and marked up on mains records as per CP625.

6.5 Public EVCPs

New connections shall be compliant with the IET Code of Practice for Electric Vehicle Charging Equipment Installation.

Earthing systems shall be TT and in accordance with Module Eleven. Due regard shall be given to the proximity of other earthing systems, including other Class 1 street furniture and earthed steel structures, to avoid hand to hand touch voltages. Current practice requires a minimum 2.5 metre above ground and 10 metre underground separation between TT and TN-C-S (PME) earthing systems. Feb 24

Alternatively, the EVCP may be provided with a PME earthing facility if the installer can demonstrate the device complies fully with BS 7671, in particular section 722.411.4.

The installer shall be responsible for ensuring connections are fully compliant with the requirements of BS 7671.

Installations shall be compliant with the requirements of Module Five and Module Six. Electricity North West Limited's Cut-out may be located in the EVCP providing that it is accessible, and installation, repair, alteration and disconnection of the connection may be carried out without causing a safety hazard or an obstruction. In each case, a risk assessment shall be carried out, taking into account the expected life of the installation.

A diversity factor of 0.8 shall be applied to EVCP located in public locations.

6.6 EVCP connected to unmetered supplies (UMS)

Feb 24

EVCPs may be connected to an UMS if all the conditions below are met:

- The EVCP uses a Measured Central Management System approved by Elexon
- The EVCP is a slow charger no greater than 5kW.
- The combined load of the EVCP and the UMS load does not exceed the rating of any component in the UMS.
- The UMS is not part of a looped system and is single phase.
- The earthing systems of the EVCP and the UMS must be the same. This will generally either be TT or TN-C-S (PME). If TN-C-S (PME) the EVCP must have a protective device which fully complies with BS 7671 section 722.411.4

Connection to an UMS is not suitable if the UMS is part of a fifth core or switched wire system.

The maximum combined load of the EVCP and UMS load will be limited by the service cable size, feeding arrangement and fuse size. Service cable ratings are provided in CP203 Cable Ratings. The total load will be limited by fuse size:

Fuse size	Maximum combined load
6A	1kW
10A	2kW
16A	3.5kW
25A	5kW

Responsibility for the initial selection of street furniture and safe installation of the EVCP lies with the local authority and their installer.

6.7 EVCPs at Multi-Occupancy Buildings

Electricity North West Limited's preferred arrangement is for the EVCP supply to be derived from the building's main supply.

Where the arrangement in 4.3.1 is impractical or significantly uneconomic, a second supply may be provided if all the following conditions can be met.

- There is adequate separation between the earth electrodes of the EVCP and existing earthed structures. This is dependent on local soil resistivity conditions; however it is up to the EVCP installer to determine this distance.
- There is at least 2.5 metres above ground and 10 metre underground separation between metallic / earthed structures between the TT earth and structures connected to the earth of the existing supply. Alternatively, the EVCP may use a PME earth providing the requirements of BS 7671 722.411.4 are met in full. Feb 24
- Likelihood of interconnection is assessed as negligible
- The EVCP is labelled

Danger – Isolate supply to EV Charger separately from main building

Diversity shall be:

- As EREC P5 where every parking bay has an EVCP
- 0.8 where there are fewer EVCPs than parking bays

6.8 EVCPs at Private Locations Managed by Third Parties

EVCPs at private locations used by the public are becoming increasingly common. Examples include EVCPs in pub car parks, hotel car parks, motorway service stations.

The same principles in subsection 6.3 apply.

A second supply may be provided if all of the following conditions can be met.

- There is adequate separation between the earth electrodes of the EVCP and existing earthed structures. This is dependent on local soil resistivity conditions; however it is up to the EVCP installer to determine this distance.
- There is at least 2 metres separation between metallic structures above ground connected to the TT earth and structures connected to the earth of the existing supply.
- Likelihood of interconnection is assessed as negligible

- The EVCP is labelled.

Danger – Isolate supply to EV Charger separately from main building

Diversity shall be 0.8.

6.9 Micro-generation and Domestic Storage

Domestic micro-generation and storage shall be connected in accordance with CP259 and ES259.

Special connection arrangements exist for Installations comprising two fully type tested EREC G98 Micro-generators controlled by an EREC G100 compliant export limitation device. If the export is limited to 16A per phase, customers may apply to connect using a 'fast track' process. The detail and requirements of this process are given in Appendix K.

The fast track process is not appropriate for installations not meeting the requirements of 4.4.2, these shall be assessed under EREC G99.

6.10 Power Quality Assessment

HP connections assessments shall usually be based on equipment compliance with

- BS EN 61000-3-2 Limits for harmonic current emissions (equipment input current <= 16A per phase)
- BS EN 61000-3-3 Limitations of voltage changes, voltage fluctuations and flicker in public low voltage supply systems – equipment with rated current <16A
- BS EN 61000-3-11 Limitations of voltage changes, voltage fluctuations and flicker in public low voltage supply systems – equipment with rated current <75A and subject to conditional connection
- BS EN 61000-3-12 Limits for harmonic currents produced by equipment connected to public low voltage systems with input current >16A and <75A

Manufacturers state compliance against these standards using a Declaration of Conformity. These Declarations are held on an ENA online database, together with any supporting test documentation. The data base is located on the ENA website http://www.energynetworks.org/electricity/futures/electric-vehicles-and-heat-pumps.html

Connections based on stated compliance with BS EN 61000-3-11 are conditional connections, and installers are required to state the maximum allowable source impedance Z_{max}. Installers shall state compliance and Z_{max} using the form in Appendix K.

Connections based on stated compliance with BS EN 61000-3-12 are conditional connections, and installers are required to state the minimum allowable short circuit power S_{sc}.

Equipment not compliant with the standards above may be assessed against EREC G5 and EREC P28. Additional information will be required to enable such assessments. This is also detailed in the form in Appendix K.

The combined emissions from multiple EVCPs connecting to the same local network shall be summated using this formula:

$$V_h = \sqrt[\alpha]{\sum_i (V_{hi}^{\alpha})}$$

α	Harmonic order
1	h < 5
1.4	5 ≤ h ≤ 10
2	H > 10

Source: G5/5 Equation 7

The assessment process for EVCP shall be based on EREC G5/5 using harmonic current emission data supplied by the installer or manufacturer. Initial assessments shall be Stage 1 and assume background harmonic levels. Connections failing the Stage 1 may progress to Stage 2. This is a more detailed assessment and requires a measurement of background levels.

V_h = aggregated harmonic voltage

H = harmonic order

V_{hi} = the ith harmonic voltage

Summation of individual harmonic voltages and pass/fail criteria shall be in accordance with EREC G5/5.

6.11 Equipment Records

The Installer shall provide records of all services installed, using Form C of Module 4 and marked upon the latest available edition of the Ordnance Survey map for the area, at 1/500 scale with any relevant detail shown on 1/250 enlargements. The colour codes and symbols to be used for marking shall comply with CP012.

HP and EVCP installations shall be shown on mains records as per CP012.

6.12 Documentation

Documentation, i.e. Health and Safety File, operating manuals and commissioning test results, shall be as described in Module 4.

7 Module Four – General Specification for Third Party Constructed New Connections, Extensions and Alterations

Contents

7.1 Scope

This specification describes the general requirements for network extensions and temporary connections, designed, installed, commissioned and put into service by others, but intended for adoption by Electricity North West Limited.

This specification and associated specifications are derived from Electricity North West Limited policy and practice.

It specifies:

- **Owner's Works,** which are suitable for the provision of connections within specified power and voltage ratings as stated in the relevant Electricity North West Limited specifications (see clause 2 below).

- **Owner's Works**, which are suitable for adoption by Electricity North West Limited.

This specification and the suite of specifications detailed in clause 2 replace and supersede Module 4.

This specification shall be read in conjunction with one or more of the following Modules:

- Module Five – Design Specification for Third Party Provided New Connections of Street Electrical Fixtures

- Module Six – Design Specification for Third Party Provided New Whole Current Metered Connections up to 60kVA

- Module Seven - Design Specification for Third Party Provided New Multiple Housing Connections

- Module Eight – Design Specification for Third Party Provided New LV Connections up to 300kVA

- Module Nine – Design Specification for Third Party Provided New Connections up to 1500kVA

- ES216 – Design Specification for Third Party Provided New 11kV Connections up to 15MVA

- ES217 – Design Specification for a Third Party Provided New 33kV Connections at 33kV up to 90MVA

- ES218 - Design Specification for Third Party Provided New Connections from either Bulk Supply Point (BSP) Transformers with a Capacity up to 120MVA (33kV) or from the 132kV Network with a Capacity up to 240MVA

7.2 General

Approval by Electricity North West Limited of a network extension for adoption may be obtained by approval of the design and by compliance with one of two design categories, as follows:

A **Registered Design** is a design previously submitted by an **Installer**, which uses specifications, standards and procedures, which have been approved by Electricity North West Limited, and which has been awarded a **Certificate of Registered Design**. Such specifications, standards and procedures are acceptable to Electricity

North West Limited and comply with Electricity North West Limited' general requirements as listed in this Specification. Electricity North West will maintain a **Schedule of Registered Designs** applicable to each **Installer**.

Where no **Registered Design** exists, the **Installer** shall notify Electricity North West Limited of his intentions and the specifications, standards and procedures to be used, by submitting a **Design Proposal**. The requirements for the specifications, standards and procedures that are acceptable to Electricity North West Limited are listed in this and associated Specifications. The **Design Proposa**l shall include comprehensive information, concerning the components to be used, their proven reliability in testing or in service, compliance with relevant performance specifications, including Type and Production testing and where appropriate, procedures for the safe operation of the components and the supply of future spares. A design will be registered only at the request of the Third Party.

7.3 Installer Requirements

7.3.1 Accreditation and Operative Competence

The **Installer** shall be accredited as a Third-Party Installer by Lloyd's Register, before submitting an **Outline Plan of Works**. Accreditation will be limited to particular types of **Owner's Works** for example to LV services, LV mains, 11kV, 33kV or 132kV substations; in these cases the proposed **Owner's Works** shall be within the limits of the **Installer's** accreditation.

If not already accredited as a Third-Party Installer by Lloyd's Register, the proposed **Installer** shall obtain such accreditation. The **Installer** shall be responsible for the costs of accreditation.

In addition to the accreditation of the proposed **Installer**, documentary evidence shall be submitted to Electricity North West Limited confirming the competence, by both training and relevant experience, of the individual trade operatives (who shall be named) engaged by the **Installer** to carry out the proposed **Owner's Works**.

Operative competence will be established by a Electricity North West Limited test of competence or, either a valid certificate issued by INDAS Ltd or documentary evidence of an appropriate NVQ qualification. Where operative competence is limited, for example to cable jointing at specific voltages, such limitation shall be declared and observed throughout the course of the work. All costs relating to the establishment of operator competence (including Electricity North West Limited test of competence), shall be borne by the Third Party.

Approval by Electricity North West Limited to the use of named operatives shall be obtained before site work commences. Where the **Installer** engages, or intends to engage, additional operative(s) during the course of the work, further prior approval by Electricity North West Limited shall be obtained before the operative(s) may work on the **Owner's Works**.

The **Installer** may not sub-contract all or any part of the **Owner's Works** without the prior written approval of Electricity North West Limited. Such approval will not be granted unless the sub-contractor and his operatives fulfil the same quality assurance, competence and safety management criteria specified for the **Installer**, but will not otherwise be unreasonably withheld.

7.3.2 Safety Management

The **Installer** shall provide details of the safety management system in place, to ensure the safe installation, commissioning and operation of the **Owner's Works** until they are adopted by Electricity North West Limited.

The **Installer** shall submit to Electricity North West Limited a copy of his safety procedures relating to work on electricity networks.

7.4 Approval of Proposed Owner's Works

7.5 Point of Connection

The **Installer** shall ask Electricity North West Limited to define the point on Electricity North West Limited' existing network at which the proposed works will be connected. Electricity North West Limited will specify the point of connection and allocate a reference number for the proposed works.

7.6 Outline Plan of Works

The **Installer** shall submit to Electricity North West Limited for approval an **Outline Plan of Works**. This is to comprise the following items:

- 'Form A' as shown in Appendix A.
- A description of the main features of the proposed **Owner's Works**. A site plan shall be provided at 1/500 scale with any relevant detail shown on 1/250 enlargements, based upon the most recently issued Ordnance Survey map of the area, showing the proposed positions of the works.
- Where the proposed **Owner's Works** include a substation enclosure, a drawing showing the elevation, roof, floor and access details of the enclosure, at a scale of not less than 1 to 50.
- An estimate of the electrical loading of the individual parts of the **Owner's Works** (if applicable).
- If connections are to be made at more than one point, or the electrical load is to be connected in stages, appropriate additional details.
- The voltage drop at the maximum electrical loading to the **Exit Point(s) to the User(s)** calculated to include the voltage drop at the point of connection to Electricity North West Limited' existing system with the new load connected.
- The tests to be performed prior to commissioning of the **Owner's Works** and the proposed limiting values of these tests for the works to be deemed to be acceptable. The tests shall demonstrate the following:

(a) That the phase to phase, phase to earth and, where appropriate, phases to neutral values of insulation resistance are satisfactory.

(b) In the case of 11/33/132kV systems that appropriate values of phase to phase and phase to earth voltage withstand have been proven (for both plant and cables).

(c) That the values of the phase to phase, phase to earth and where appropriate phase to neutral loop impedances, or in the case of a substation the value of neutral earth resistance, will allow operation of the protection device or devices selected within a safe time period. These values must also allow effective discrimination with protection devices within Electricity North West Limited' system and within the **User's** installation.

- The date on which it is intended that the connection to the Electricity North West Limited system will be made.

- The **Certificate of Registered Design** reference number or a **Design Proposal**.

- Any requirements for legal agreements and consents necessary for the laying of cables, the erection of overhead lines, leases for the accommodation of substations or other purposes.

    - All cables and lines are to be laid or erected either in or on public land, or in or on land, in which the **Owner** already has, or intends to acquire, the legal right to install the equipment.

    - Electricity North West' preference is for an Easement.

    - The legal framework for all consents and acquisitions negotiated by the **Installer** shall be to the satisfaction of the Electricity North West Limited Connections Liaison Manager.

    - All consents and acquisitions negotiated by the **Installer** shall ultimately be vested in Electricity North West.

    - Electricity North West will apply for consent for overhead lines, to the Secretary of State, pursuant to Section 37 of the Electricity Act 1989.

    - The **Installer** shall be responsible for obtaining all necessary planning permission for the proposed works.

- A statement concerning the means, by which access will be obtained to operate, inspect and maintain the assets.

- In accordance with the Construction (Design and Management) Regulations 1994, a Health and Safety Plan.

7.7 Evaluation of Proposal

Within 28 calendar days of receiving the **Outline Plan of Works** Electricity North West Limited will evaluate the proposal.

For the design to be acceptable, the **Installer** shall certify that all equipment (comprising all components thereof) and their related methods of installation have successfully completed the Type approval processes laid down in the appropriate standards or, where applicable, Electricity Association Engineering Recommendations.

The proposed use of equipment not previously approved shall be subject to the approval of the Electricity Standards Manager.

Using Form B, as shown in Appendix M, Electricity North West Limited will inform the **Installer** that Electricity North West Limited either:

(a) Accepts the **Outline Plan of Works**, or

(b) Rejects the **Outline Plan of Works** or its associated **Design Proposal** (if applicable), stating the reason or reasons why this conclusion has been reached.

The acceptance of the **Outline Plan of Works** is not a guarantee that Electricity North West Limited will be able to achieve the implied timescale, where it is necessary for Electricity North West Limited to negotiate wayleaves or other consents.

7.8 Proposal Amendments

The foregoing does not preclude amendments being made by mutual agreement to either the **Outline Plan of Works** or the associated **Design Proposal,** to avoid rejection.

Costs incurred by Electricity North West Limited in the re-evaluation of any rejected **Outline Plan of Works** or its associated **Design Proposal** (if applicable), shall be met by the **Owner**.

7.9 Commencement of Works

The **Owner** or **Installer** shall complete a 'Joint Construction and Adoption Contract' or other appropriate adoption contract as specified by Electricity North West Limited.

Following acceptance of the **Outline Plan of Works** and, if applicable, the associated **Design Proposal,** the **Installer** shall, subject to Section 7.7 and using the appropriate reference number, notify Electricity North West Limited in writing of the date on which construction of the **Owner's Works** will commence. At least 28 calendar days' notice of commencement of the works shall be given.

The **Installer** shall also submit for approval the names, training and experience of the operatives intended to carry out the work.

Electricity North West Limited will require that means of routine and emergency communication be established between itself and the **Installer** before the **Owner's Works** are commissioned. The specified channels of communication shall be maintained until Electricity North West Limited adopts the **Owner's Works.**

Compliance with the requirements of the New Roads and Street Works Act 1991 to notify the Highway Authority, and all other statutory and non-statutory duties including the procurement of relevant plant records from Electricity North West Limited and other Undertakers is the responsibility of the **Installer**.

Electricity North West reserves the right to inspect the **Owner's Works** without prior notice at all reasonable times during construction, testing, commissioning or operation (prior to adoption) and to check that the operatives on site are those for whom prior approval has been obtained.

7.10 Adoption of the Works

The **Installer** shall, using the appropriate reference number, inform and agree with Electricity North West Limited the date on which it is intended that Electricity North West Limited will adopt the works. Electricity North West Limited reserves the right to carry out all such inspection and testing as it requires prior to adoption and may reject the works, giving the **Installer** the reasons for rejection in writing.

7.11 Information Required for a Design Proposal

7.11.1 Items to be Specified

These notes are provided for **Installers** intending to submit a **Design Proposal** to Electricity North West Limited for approval. The **Design Proposal** shall specify the following:

- The methods or means of compliance with Electricity North West Limited' general requirements (which are listed later in this Specification).
- The specification for each component of the proposed design, addressing the points covered in Electricity North West Limited' general requirements.
- Calculations either actual or specimen for the proposed works, including calculations justifying the selected component ratings, including continuous current, short circuit and earth fault current. Calculations shall also include the maximum permissible value of voltage drop, earth resistance and/or loop / zero sequence impedances.
- The overall reliability of the proposed works, calculated using the aggregated reliability of the individual components and other relevant factors such as third party cable damage rates. The data for this calculation may be based either upon component testing or actual service experience and relevant statistical data shall be provided to Electricity North West Limited.
- The requirements for future maintenance, including the means by which spares may be procured.
- Calculations actual or specimen for the determination of protection settings, including the rating(s) and class(es) of fuses.
- Commissioning details.

7.11.2 Provision of Electricity North West Limited Limited Documentation

Where this and associated specifications and associated specifications require compliance with Electricity North West documents, and extracts of those documents are not contained within the specifications, they may be provided under licence arrangements.

Copyright in Electricity North West documentation is vested in Electricity North West Electricity Limited and this shall be strictly observed.

7.11.3 Provision of Standards

Every component of the proposed **Owner's Works** shall comply with an appropriate standard, which shall be either an Electricity North West Limited standard, IEC, BS, EA Technical Specification (EATS) or EA Engineering Recommendation (ER).

The standard against which each component is to be purchased and/or tested shall be stated and where the standard allows a choice, justification of the selection made shall be provided.

Any differences from the Electricity North West Limited Specification shall be identified.

7.12 General Requirements

The following general requirements are critical to the adoption of **Owner's Works** by Electricity North West Limited and shall be incorporated into any **Design Proposal**.

7.12.1 Compliance with Statute Law

The whole and every part of the proposed **Owner's Works** shall comply with all relevant statutory requirements. The **Installer** shall state which particular statutes have been considered.

- **Electricity Act 1989**

  The proposed Owner's Works shall be suitable for use as part of a distribution system operated by Electricity North West Limited as a Distribution Network Operator (DNO) licensed according to the provisions of the Electricity Act 1989.

- **Type of System – Cables**

  Electricity North West' distribution system is Class A as defined in Appendix A of BS6480: 1988 and is described as a system, in which, when any phase conductor makes contact with earth it is automatically disconnected. Class A systems require a minimum rated voltage of cable U_o/U (U_m) of 0.6/1.0 (1.2) kV for cables used on the LV network, 6.35/11 (12) kV for cables used on the 11/6.6 kV network, 19/33 (36) kV for cables used on the 33 kV network and 76/132 (145) kV for cables used on the 132kV network.

- **The Electricity Safety, Quality and Continuity Regulations 2002**

  The proposed Owner's Works shall be sufficient to enable Electricity North West Limited to comply with the requirements of The Electricity Safety, Quality and Continuity Regulations 2002.

- **Distribution Code**

  The proposed Owner's Works shall comply with the Distribution Code of Licensed Distribution Network Operators of Great Britain (Condition 11 of the Public Electricity Supply Licence).

- **New Roads and Street Works Act 1991**

  The proposed Owner's Works shall comply with the New Roads and Street Works Act 1991 and any reinstatement shall comply with 'Specification for the reinstatement of openings in Highways, a Code of Practice' published by HMSO. Liability for all highway and footpath reinstatement, including Highway Authority inspection charges and the costs of any required remedial works, remain with the Owner, even after the remainder of the works have been adopted by Electricity North West Limited.

- **Construction (Design and Management) Regulations 1994**

  During their design and construction, the proposed Owner's Works shall comply with the Construction (Design and Management) Regulations 1994.

- **Construction (Health, Safety and Welfare) Regulations 1996**

During their construction, the proposed Owner's Works shall comply with the Construction (Health, Safety and Welfare) Regulations 1996.

7.12.2 Sufficiency of Works

The proposed **Owner's Works** shall be designed to be sufficient for the purposes for and the circumstances in which they are used. They shall be so designed, constructed, protected (both electrically and mechanically), commissioned, used, maintained and operated so as to prevent both danger and interruption of supply so far as is reasonably practicable.

7.12.3 Lifespan and Durability

The **Owner's Works** on commissioning shall be generally suitable for an operational life of at least forty years and shall be of durable construction, such that the characteristics specified by Electricity North West Limited in the Electricity North West Limited' Design Specifications (which are listed in Section 7.1) as essential for reliable operation and maintenance are met. In the case of overhead line components, with the exception of wood poles, outdoor insulators, bare conductors and similar items all other components exposed to the weather or to ground water shall be fully enclosed by a corrosion resistant material, either inherently resistant by its material of construction or if constructed of ferrous metal, by means of a zinc coating, either hot dip galvanised or hot sprayed. Aluminium shall not be exposed to, or be in contact with, soil or water underground. The equipment used in the **Owner's Works** shall not be obsolescent. Refurbished equipment shall be used only with the written approval of the Connections Liaison Manager, Electricity North West Limited.

7.12.4 Intrinsic Safety

Every part of the **Owner's Works** shall, so far as is reasonably practicable, be intrinsically safe and the **Installer** shall draw attention to any features that have been considered in this context. Documentary evidence of risk assessment confirming suitability shall be presented in all such cases.

7.12.5 Environmental Compatibility

Every part of the **Owner's Works** shall, so far as is reasonably practicable, be intrinsically environmentally compatible in that:

(a) There is no danger of leakage of toxic or corrosive materials (including insulating, cooling and arc-extinguishing fluids) used in the construction of components, or toxic or corrosive by-products from those components, into the environment.

(b) The materials of the components should be preferably recyclable on final de-commissioning and shall comply with all relevant European Directives.

(c) All materials used in the construction or required for future maintenance of the **Owner's Works** shall allow Electricity North West Limited to comply with the obligations of the Control of Substances Hazardous to Health Regulations 1988.

The **Installer** shall draw attention to any features that have been considered in this context.

7.12.6 Security of Supply

The security of supply shall conform to the requirements of EA Engineering Recommendation P2/7 and comply with any additional requirements of Ofgem.

7.12.7 Voltage of Supply

The supply voltage at the **Exit Point(s) to the User(s) s**hall not vary outside the limits permitted by The Electricity Safety, Quality and Continuity Regulations 2002, which are:

(a) For a low voltage supply, a variation not exceeding ten per cent above or six per cent below the declared voltage of 400/230 V at 50 Hz.

(b) For a high voltage supply operated at or below 132 kV, a variation not exceeding six per cent above or below the declared voltage at 50 Hz.

7.12.8 Capacity of Connection

The capacity of the connection at the **Exit Point(s) to the User(s)** shall be that stated in the Connection Agreement, and shall comprise:

(a) The capacity agreed with the **User(s**) or the limits specified in the attached appendices.

(b) Such increase as may be reasonably foreseeable in the circumstances and agreed between Electricity North West and the **Owner**.

7.12.9 Transient Variations in Voltage and frequency, Limits for Voltage Fluctuations, Harmonics and Fault Level

These will be as specified in BS EN 50160:1995 Voltage Characteristics of Electricity Supplied by Public Distribution Systems. In addition, the requirements of Electricity Association Engineering Recommendation P28 Planning Limits for Voltage Fluctuations caused by Industrial, Commercial and Domestic Equipment in the United Kingdom, and Electricity Association Engineering Recommendation G5/5 Planning Levels for Harmonic Distortion and the Connection of Non-Linear Equipment to Transmission Systems and Distribution Networks in the United Kingdom shall be met.

Fault level calculations shall be in accordance with Electricity Association Engineering Recommendation G74.

7.12.10 Availability of Supply

The supply shall be available to the **User(s)** at such times as may be specified in the Connection Agreement.

7.12.11 Resistance of Interference and Misuse

The proposed **Owner's Works** as constructed shall exhibit a standard of construction which will prevent, so far as is reasonably practicable, all risks considered likely to arise as a result of mischievous or criminal interference by unauthorised persons. It shall not be possible to open any building door, window or component enclosure without the use of a key or other special purpose tool.

The proposed **Owner's Works** shall exhibit a standard of construction which will prevent, so far as is reasonably practicable, all risks considered likely to arise as a result of inadvertent misuse by persons authorised by Electricity North West to work on the component.

7.12.12 Component Installation Records

The **Installer** shall provide details on Form C, as shown in Appendix N, identifying the **Installer** and the date of installation of all parts of the system.

7.12.13 Documentation

Where the proposed **Owner's Works**, during their design and construction, are required to comply with the Construction (Design and Management) Regulations 1994 the **Owner** shall ensure that the health and safety file**,** as required by the regulations, is passed to Electricity North West **before** adoption.

The health and safety file shall contain all information that will enable Electricity North West to manage the health and safety risks associated with maintenance, repair, renovation or demolition. It shall also contain relevant plant and protection operating and maintenance instructions and the project design information.

Where the Construction (Design and Management) Regulations 1994 are not applicable, the **Owner** shall provide a file, to Electricity North West **before** adoption, that contains all relevant information that will enable Electricity North West to manage the health and safety risks associated with maintenance, repair, renovation or demolition. It shall also contain relevant plant and protection operating and maintenance instructions and the project design information.

Where an operation manual is provided by the manufacturer of any component, it shall be handed over to Electricity North West on adoption of the **Owner's Works**.

Commissioning test results shall be provided on Form C, shown in Appendix N.

All documentation shall be provided in electronic format and shall be in one of the following formats:

- Microsoft Word 97 or better (.doc)
- Adobe Acrobat Portable Document Format (.pdf)
- Autocad Version 13 or above (.dwg)

7.13 Reliability Requirements

7.13.1 Reliability Assurance

The **Installer** shall certify that all components and their methods of installation associated with the **Owner's Works** comply with the type approval requirements set out in the relevant clauses of this and associated Specifications.

The **Installer** shall provide reliability data covering all the components to be used in the **Owner's Works**.

All components of the **Owner's Works** shall be new and unused, unless specific approval from Electricity North West has been obtained, for each item, for the use of components that have previously been in service.

7.13.2 Concessions and Variations

All cases shall be identified where the **Installer** proposes to adopt conditions of installation or use that are outside the scope of the manufacturer's design for the installation or use of the component. The **Installer** shall, during the design of the **Owner's Works**, submit such evidence as Electricity North West shall deem necessary, to support such proposals.

7.14 Maintenance Requirements

7.14.1 Objectives

The works as constructed shall be so arranged, so far as is reasonably practicable, to allow preventive maintenance of the system by Electricity North West, without the disconnection of supplies or unnecessary dismantling of enclosures, supporting structures or buildings.

7.14.2 Preventive Maintenance

Prior to commissioning of the proposed **Owner's Works**, all necessary procedures, materials, equipment, documentation, special tools and training necessary for preventive maintenance shall be specified by the **Installer** and where required by Electricity North West, shall be provided by the **Installer**.

7.14.3 Components and Equipment

Equipment and materials necessary to restore the proposed **Owner's Works** to full functionality, following failure or damage, shall be specified by the **Installer** and, where required by Electricity North West, provided by the **Installer.**

7.15 Commissioning Requirements

Prior to commissioning by the **Installer** of the **Owner's Works**, all of the requirements specified in previous sections of this Specification shall have been fulfilled and the installation records specified on Form C (as shown in Appendix N) submitted. In addition, the test procedures submitted by the **Installer** on Form A and agreed by Electricity North West shall have been performed and the actual test values obtained also accepted by Electricity North West. Electricity North West reserves the right to witness these tests.

7.16 Agreements

It will be necessary for the **Owner** or **Installer** to enter into agreements with Electricity North West, as follows:

A Joint Construction and Adoption Contract and Supply Agreements will be required in all cases.

One or more of the following agreements will also be required:

- Connection Agreement
- Top Up and Standby Agreement
- Technical and Operating Agreement
- Responsibility Schedule.
- Licence to use Electricity North West Documentation.
- Installation Contract.

8 Module Five – Third-Party Provided New Connections of Street Electrical Fixtures

Contents

8.1 Scope

This Specification details the requirements of a third-party provided connection of street electrical fixtures directly connected to the electricity distribution network of Electricity North West Limited, hereinafter referred to as Electricity North West Limited, that connection being intended to be adopted by Electricity North West Limited. Where new street electrical fixtures are to replace existing fixtures within a short distance, new connections are often made as extensions to the existing connections. Where, alternatively, existing connections are permanently disconnected, work shall be in accordance with EPD201 - Installation, Removal and Identification of Idle Assets. This document shall be read in conjunction with Module Four.

8.2 General

Any variation to this specification shall be agreed, in writing, with the Head of Safety and Policy prior to any design being accepted by Electricity North West Limited.

The Owner's Works shall comply with the requirements of Module Four.

It is a requirement that all work shall be carried out strictly in accordance with the provisions of all relevant legislation and industry best practice.

The Owner's Works shall comply in all respects with the provisions of Regulations 3(1), 6, 7, 8(1), 8(3), 8(4), 10 and 12 to 14, of the Electricity Safety, Quality and Continuity Regulations 2002 and with the Electricity at Work Regulations 1989.

Users will be supplied at a nominal Low Voltage (LV) of 400/230 volts.

The Electricity North West LV electricity distribution network is solidly earthed and makes use of CNE conductors.

The maximum PSCC, at the Exit point to the User, is not expected to exceed the following values:

Three phase =27kA
Single phase = 16kA

8.3 Access and Safety

A street electrical fixture, into which a connection from Electricity North West Limited's network is to be installed, shall be accessible, such that work of installation, repair, alteration and disconnection of the connection may be carried out without causing a safety hazard or an obstruction. In each case, a risk assessment shall be carried out, taking into account the expected life of the installation.

The majority of such fixtures is expected to stand within the footways or verges of adopted highways. Similar situations, giving rise to similar risks, may also be acceptable, e.g. the footways, verges and service strips of privately managed streets, with unrestricted vehicular access; traffic islands large enough to allow a vehicle to stand, without obstructing the carriageway and on which work may be carried out without undue hazard from passing traffic.

Service terminations shall be accommodated in a secure and weather-proof enclosure, normally within 1.5m of the finished ground surface.

8.4 Connection Arrangements

This specification covers service connections of street electrical fixtures within the following limitations:

- The supplied loads shall be for street lighting or other street furniture purposes only and the load per service connection shall not exceed 20 kVA for single phase connections and 60kVA for three phase connections. However, in most cases of connections to single items of street electrical fixtures, the load per service will not exceed 5kVA.

- All services shall enter the street electrical fixtures underground.

- All single phase services, whose load per service does not exceed 5kVA and whose length does not exceed 15m shall be 4 mm^2 copper (Cu) conductor CNE cable and have a 25A capacity.

- Other single phase services up to a maximum of 30m in length, shall be installed using 35 mm^2 Al core CNE cable. The cable shall, if appropriate, be tapered to 4 mm^2 no more than 2m from the street electrical fixture.

- Service cables may be jointed directly to existing mains cables, or to existing service cables, provided that no service termination in a street electrical fixture is at a greater distance from the main than 15m, measured along 4mm^2 (or equivalent) cable, or 30m, measured along large service cable, where "large" means having an equivalent cross-sectional area in excess of 14mm^2 Cu (i.e. includes 0.0225in^2 Cu, 16mm^2 Cu, 25mm^2 Al etc). Where a new 4mm^2 service cable is to be jointed to an existing large service cable, these limits are to be applied in proportion, e.g. 20m of large service cable plus 5m of 4mm^2, 10m of each size etc.

- Where a street electrical fixture is replaced, and the new fixture is to be connected by extending the existing service, the length(s) or cross-section(s) of which are unknown, the length of the extension shall not exceed 3m.

- The calculated voltage drop from the point of connection to Electricity North West Limited' LV electricity distribution network to the cut-out, at the maximum allowable load, shall not exceed 2% and 7% overall (from the substation LV busbars). A 415/240V substation busbar voltage shall be used in all calculations.

- Where mains cables include street-lighting switch-cores (5th cores), the switch-cores may remain in use, until such time as the main (or part of it) is, for whatever reason, replaced, but switch-cores shall not be used for new connections. Where a street electrical fixture, with a service from a switch-core is replaced, a new connection shall be installed and the existing service disconnected, in accordance with EPD201. Electricity North West Limited will permanently de-energise switch-cores, when they become redundant.

- New services looped from the incoming side of the cut out are not permitted. Where a street electrical fixture, with an Electricity North West Limited outgoing looped service, is replaced, the looped service shall be reconnected via a buried joint.

- PME connections are the preferred option.

8.5 Environmental Conditions

The equipment shall be designed and constructed to allow operation in environments defined in Clause 6 of BS EN 60947-1 as follows:

Equipment that is housed in a controlled environment shall be suitable for operation in Pollution Degree 2.

Equipment that is not housed in a controlled environment shall be suitable for operation in Pollution Degree 3.

All equipment shall be protected from the deposit of excessive levels of dust and from the influx of water or other substances liable to have a harmful effect.

8.6 Service Cable

For PME connections the single phase service cable to be used shall be either 4 mm^2 600/1000V, single core stranded copper phase core with helical concentric copper neutral/earth, or 35 mm^2 600/1000V, single core solid aluminium phase core with helical concentric copper neutral/earth, both complying with the requirements of Electricity North West Limited specification ES400C8.

Where it is not appropriate to provide a PME connection an SNE connection may be provided using split concentric service cables. The cables to be used shall be either 4 mm^2 600/1000V, single core stranded copper phase core with a concentric layer of insulated copper wires (neutral) and bare copper (earth), or 35 mm^2 600/1000V, single core solid aluminium phase core with a concentric layer of insulated copper wires (neutral) and bare copper (earth), both complying with the requirements of Electricity North West specification ES400C8.

For three phase connections, the cable to be used shall be three core plus concentric CNE (combined neutral and earth) 600/1000 volt cable; 25sq mm circular solid aluminium phase conductors (Class 1 in accordance with BS 6360); XLPE insulation; CNE concentric copper wires and PVC oversheath. Cable to be in accordance with Electricity North West Limited specification ES400C8.

Where it is not appropriate to provide a three phase PME connection an SNE connection may be provided using split concentric service cable. The cable to be used shall be three core plus split neutral and earth 600/1000 volt cable; 25sq mm circular solid aluminium phase conductors (Class 1 in accordance with BS 6360); XLPE insulation; concentric layer of insulated copper wires (neutral) and bare copper wires (earth) and PVC oversheath. Cable to be in accordance with Electricity North West Limited specification ES400C8.

No other type or cross section of cable is permitted.

8.7 Earthing Conditions

All street furniture installations are to comply with Electricity North West EPD333, CP332 and EPD332. A label shall be fitted to each cut out indicating that the system is PME, if appropriate. PME facilities shall not be provided for any Class 1 street furniture (as defined in BS 7671) exceeding 5kW. PME facilities shall not be provided to any electric vehicle charge point. Further policy is provided in Module Eleven section 14.1.

8.8 Cable Installation and Jointing

The installation and jointing of the underground service cables shall comply with Electricity North West Limited ES400E4. Jointing systems employed should be compatible with the cable used and Type Test evidence should be available to demonstrate that the performance of the complete system of cable and joints is appropriate for the service duty for which the system is installed.

Street lighting service cables shall generally not be routed across private land. Where cables have to be laid in private land legal consents shall be obtained in accordance with Clause 7.6 of Module Four.

No more than four services shall be connected within any one main to service cable joint.

Street lighting may also be connected to service cables, provided the cable length, load and voltage regulation comply with the requirements set out in clause 8.3.

Every effort shall be made to ensure that all underground equipment is installed in accordance with NJUG No.7.

Red ducts compliant with ES400 D4 shall be used.

8.9 Street Lighting Columns

Base compartments and cable ways for street lighting columns shall be sufficient to contain the cut out and its mounting board and shall conform to part 5 of BS 5649:1982 ‘Lighting Columns - Specification for base compartments and cable ways’.

8.10 Cut Out Mounting Board

Cut outs shall be screwed to boards of minimum 12 mm thickness, cut from standard chipboard conforming to BS 5669 Pt.2. Cut out boards shall be rigidly and permanently fixed to lamp columns or other street furniture.

Cut outs shall be mounted at a height and position within lamp columns or other street furniture such that the fuse carriers can be readily removed and replaced through the normal means of access. The height of mounting of cut outs shall be within the limits of 150 to 1500 mm above finished ground level. If the upper measurement is not considered appropriately high enough because the columns are to be installed in areas where they may be subjected to vandalism, higher mounting heights may be acceptable, but approval shall be sought from the Connections Liaison Manager.

8.11 Service Cable Entry

All street furniture shall be provided with suitable duct access through the foundations to the cable entries. The minimum size of duct is 32 mm and it shall comply with Electricity North West Limited’ specification ES400D4.

8.12 Cut Outs

Service cable shall be terminated within Type 1 or 2 cut outs (as appropriate to the earthing system) conforming to the requirements of BS 7654:1997 ‘Single phase street lighting fuses (cut outs) for low voltage public electricity distribution systems - 25 A rating for highway power supplies and street furniture’ and Electricity North West Limited Engineering Specification ES400C6 – Street Lighting Cut Outs. (Note some street lighting cut-outs are only rated at 16Amp and therefore they are only suitable for the provision of 4kW single lamp connections)

If combined double pole switch fuse isolators are used they shall comply with Electricity North West Engineering Specification ES400I3 – Combined Double Pole Switch Fuse Isolators for use in Street Lighting and Other Street Furniture.

Service cables shall enter cut outs from below and cable sheaths shall remain intact except on those parts of cables, which are wholly contained within cut outs.

8.13 Fusing in 25A Rated Cut-Out

Cut outs shall contain fuses with 38 mm offset tags, conforming to the requirements of BS EN 60269-1 and figures 101, 102, 103 and 104 of BS 7654:1997 'Single phase street lighting fuses (cut outs) for low voltage public electricity distribution systems - 25 A rating for highway power supplies and street furniture'. The rated conditional short circuit current in accordance with Clause 8.4 of the standard shall be 16 kA.

The rating of any fuse shall be no greater than is sufficient to support the continuous application of the User's declared load, subject to a maximum fuse rating of 25 A.

The Installer shall submit for approval, for each type of lamp or street furniture to be serviced, a drawing of the method of access by Electricity North West personnel to the cut out.

8.14 Supplier

Before Local Authority adoption of any highway, a Supplier shall be appointed and shall be registered for street lighting schemes either by the Local Authority or the site developer.

8.15 Equipment Records

The **Installer** shall provide records of all services installed, using Form C of Module Four and marked upon the latest available edition of the Ordnance Survey map for the area, at 1/500 scale with any relevant detail shown on 1/250 enlargements. The symbols and attributes to be used for marking shall comply with Electricity North West Limited CP012.

8.16 Documentation

Documentation shall be as described in Module 4.

9 Module Six – Whole-Current-Metered Connections up to 60kVA

Contents

9.1 Introduction

Electricity services with capacity up to 100A are provided to very many premises, the majority being domestic premises. Standard layouts of service termination equipment and service cables are required, in order to ensure adequate safety and security in the accommodation of service cables, cut-outs and meters. By applying these standards, Electricity North West Limited expects installations, which it adopts, to comply with the Electricity Safety, Quality and Continuity Regulations 2002 as amended (ESQCR) and to facilitate compliance with the Electricity at Work Regulations 1989.

9.2 Scope

This Module details the requirements for new connections and temporary connections with ratings up to 100A and with whole current metering directly connected to the Electricity North West Limited electricity distribution network (The Network). This Module covers connections, which are intended for adoption by Electricity North West Limited, installed both by itself and by Independent Connection Providers. Where services are substantially altered, the alterations shall be made to comply with this Module.

This document shall be read in conjunction with Module Four.

9.3 General

Any variation to this specification shall be agreed, in writing, with the Planning Policy Manager, Network Strategy directorate, Electricity North West Limited prior to any design being accepted.

The Owner's Works shall comply with the requirements of Module Four.

It is a requirement that all work shall be carried out strictly in accordance with the provisions of all relevant legislation and industry best practice.

The Owner's Works shall comply in all respects with the provisions of Regulations 3 (1), 6, 7, 8 (1), 8 (3), 9, 12 to 14, 21 and 22 of the ESQCR and with the Electricity at Work Regulations 1989.

Users will be connected to and metered at low voltage (LV) of 400/230 volts, unless otherwise agreed in writing with Electricity North West Limited.

Any group of services supplied from the same three-phase distribution main shall be so connected that the load is balanced between the three phases. Electricity North West Limited reserves the right to refuse to adopt Owner's Works having excessive phase imbalance.

The Network is solidly earthed and makes use of CNE conductors.

The cores of multicore LV mains shall not be 'bunched' or 'paired' to increase the current rating, improve voltage regulation or to reduce the loop impedance.

The maximum Prospective Short Circuit Current, at the exit point to the User, is not expected to exceed the following values:

Three phase = 27kA
Single phase = 16kA

9.4 Connection Arrangements

9.4.1 General

This document specifies 1- and 3-phase underground service cable connections for domestic and small commercial users within the following limitations:

- The maximum cut-out fuse size shall be 100A.
- The maximum single-phase supply capacity shall be 20kVA.
- The maximum three-phase supply capacity shall be 60kVA.
- No three-phase service shall be installed, unless the demand is to exceed 20kVA or the User has a particular requirement for a three-phase connection.
- The service cable length shall not normally exceed 30m, measured from the cut-out to the point of connection to Electricity North West Limited's LV main. Lengths in excess of 30m shall be installed only with the written agreement of the Compliance and Performance Manager, Connections directorate, Electricity North West Limited, or his delegated representative.
- The calculated voltage drop from the point of connection to Electricity North West Limited's LV distributor to the cut-out, at the maximum allowable load, shall not exceed 2% and 7% overall (from the substation LV busbars). A 415/240V substation busbar voltage shall be used in all calculations.

9.4.2 Environmental Conditions

The equipment shall be designed and constructed to allow operation in environments defined in Clause 6 of BS EN 60947-1 as follows:

Equipment that is housed in a controlled environment shall be suitable for operation in Pollution Degree 2.

Equipment that is not housed in a controlled environment shall be suitable for operation in Pollution Degree 3.

All equipment shall be protected from the deposit of excessive levels of dust and from the influx of water or other substances liable to have a harmful effect.

9.4.3 Service Cable

For a PME connection the service cable to be used shall be 35mm^2 600/1000V, single-core, solid-aluminium phase-core, XLPE-insulated, with helical concentric copper neutral/earth, or 25mm^2 600/1000V, three-core, solid-aluminium phase-core, XLPE-insulated, with helical concentric copper neutral/earth, in either case complying with the requirements of ES400C8.

Where it is not appropriate to provide a PME connection a SNE connection may be provided using a split concentric neutral/earth (SCNE) service cable. The cable to be used shall be either 35mm^2 600/1000V, single-core, solid-aluminium phase-core, XLPE-insulated, with a concentric layer of insulated copper wires (neutral) and bare copper (earth), or 25mm^2 600/1000V, three-core, solid-aluminium phase-core, XLPE-insulated, with a concentric layer of insulated copper wires (neutral) and bare copper (earth), in either case complying with the requirements of ES400C8.

Occasionally, it may be appropriate to install an aerial service cable for a SNE connection. In such a case, the cable to be used shall be 16mm^2 600/1000V, single-core, stranded-copper phase-core, XLPE-insulated, with a concentric layer of insulated copper wires (neutral) and bare copper (earth), complying with the requirements of ES400C8.

No other type or cross section of cable is permitted.

9.4.4 Earthing Conditions

All installations are to comply with EPD333 and EPD332. Where appropriate a label shall be fitted to each cut-out indicating that the system is PME (see 9.4.18).

9.4.5 Cable Installation and Jointing

The installation of underground service cables shall comply with ES400E4. All Low Voltage jointing shall be undertaken in accordance with CP411 Part 1.

Each underground service cable shall be laid within the curtilage of the property to be serviced, from the boundary with the adopted (or to be adopted) road or service strip. Each single phase underground service cable shall be drawn into a continuous duct, laid from the boundary to a point adjacent to the service position. The duct shall be red, have a minimum internal diameter of 32mm, comply with ES400D4 and shall be installed, where appropriate, in accordance with Electrolink No.5.

No more than four single-phase services or two three-phase services shall be connected within any one service-cable-to-main joint.

Service cables shall enter cut-outs or any protective lower enclosures from below and cable sheaths shall remain intact except on those parts of cables, which are wholly contained within cut-outs or protective lower enclosures.

9.4.6 Service Position

The preferred arrangement for a service installation is in an outside viewing cabinet (OSVC). However, due regard shall be paid to the long term security of the installation.

Accordingly, services shall normally be terminated on the external walls of buildings within OSVCs, complying with the requirements of ENA TS 12-3. The size selected will depend upon whether the service is 1- or 3-phase and upon the requirements of the Meter Operator, who shall be consulted. Where an OSVC is used, with the service cable entering via the wall cavity, the cable entry duct (See 9.4.5) shall continue into the wall cavity, to enter the OSVC vertically from below. Alternatively, in the case of a single-phase cable, the duct may enter the OSVC externally. In this case, the final part of the duct, comprising a slow bend and riser to enter the OSVC, may be of the same colour as the OSVC. The radius of any bend shall be not less than the bending radius of the three-phase service cable. (See sub-sections 9.4.3 and 9.4.5.) The duct, at its end adjacent to the service termination, shall be sealed to prevent the flow of gas. The height of the base of the OSVC above ground level shall not be less than 500mm or more than 800mm. The exposed part of the duct between ground level and the OSVC shall be straight, vertical and secured to the wall by a saddle or cleat no more than 200mm below the base of the OSVC, with an additional saddle or cleat, where the total exposed length of the duct exceeds 500mm. Further guidance is available in Electrolink No. 5.

Where an OSVC is to be used, the safety issues associated with the proximity of any nearby sited gas service cabinet and gas service pipe shall be considered and appropriate precautionary measures taken.

In cases where an outdoor position cannot be accommodated (e.g. in small terraced properties), services may be terminated in indoor positions, or inside attached garages. Service positions in garages shall preferably be on side walls, rather than on rear walls, where the risk of direct impact by vehicles is greater. The length of service cable within the building shall be as short as is reasonably practicable. The cable shall be installed through a continuous duct, as described in Section 9.4.5, finishing at least 20mm above the finished floor level and sealed at that end to prevent the flow of gas. Where the total length of cable within the building exceeds 2m, the duct shall have a minimum internal diameter of 100mm and be of adequate strength against impact and crushing or otherwise mechanically protected. The length of cable, between the sealed duct end and the termination, shall not exceed 2m.

Care shall be taken with the installation to minimise the risk of accidental damage. All surface-mounted cables outside buildings or where vehicles have access (e.g. inside garages and barns), below a height of 1.8m, shall be continuously protected either by plastic ducts complying with ES400D4 or by plastic cable guards, complying with ES400G1. Elsewhere, straight lengths of cable exceeding 1m, below a height of 1.8m, shall be similarly protected. Straight runs of cable shall be either vertical or horizontal. No bending radius shall be less than the minimum specified. Ducts shall be fixed to walls with plastic saddles, such that the ducts are adequately supported at intervals not exceeding 300mm.

Indoor service terminations shall be installed such that the meter(s) may be mounted at a height not less than 1.0m and not more than 1.35m, above the floor level, with at least 750mm clear access in front of the meter. Service terminations shall not be positioned in or under bathrooms, toilets, adjacent to sinks or in any other position where they may be subjected to water contact. The location shall provide sufficient access to the meter and adequate space to ensure the safety of any person who needs to work on it. The agreed location shall be such that access to the service termination and meter position, including that required for meter reading, will not be restricted by any future construction work.

In certain cases it will be necessary to make provision for a prepayment meter. The preferred arrangement is that a location is provided within the User's premises directly behind the OSVC. The location of the prepayment meter shall permit the installation of a standard medium size wood chipboard meter board of size 575 mm x 375 mm x 18 mm complying with BS EN 312. Interconnecting leads shall be mechanically protected and the route for the leads shall be approved by Electricity North West Limited before installation.

Each exit point, for an individual User, shall be protected by individual fuse link(s) to allow the de-energisation and isolation of only that exit point. No more than two exit points shall be connected to any one phase of a 100A service.

All equipment, except metering equipment and OSVCs, where installed, from the Network up to the outgoing terminals of the cut-out shall be adopted by and maintained by Electricity North West Limited. Metering equipment is the responsibility of the appropriate Meter Operator and OSVCs form part of the building into which they are installed and become the responsibility of the owner of the building.

9.4.7 Looped Services

Looped services shall not be used.

9.4.8 Cut-out Board

All termination equipment including the metering equipment shall be fixed to a wood chipboard board complying with BS EN 312. Typical dimensions of the board are 505mm × 340mm. Other dimensions of boards may be required, in order to provide adequate accommodation for equipment, to suit building requirements, or to fit the standard sizes of OSVCs. All cut-out boards shall have a minimum thickness of 18mm.

Where an OSVC is installed with an external cable entry duct, an additional angled mounting board (also wood chipboard complying with BS EN 312) for the cut-out, shall be securely fixed to the cut-out board. The additional mounting board shall have typical dimensions of 300mm × 140mm wide and be mounted with its lower end supported away from the cut-out board at an angle of 25° to the vertical.

In general a single-phase termination shall be accommodated on a small cut-out board and a three-phase termination on a medium or large board.

9.4.9 Cut-out

All cut-outs shall have a continuous rating of 100A and shall comply with the requirements of ES332. Live cut-outs shall be sealed. As soon as an installation is complete, permanent seals shall be applied, using approved sealing pliers, seals and sealing wire, in accordance with the Meter Operator Code of Practice Agreement (MOCoPA), or CP576, as appropriate. These permanent seals will normally be applied by the meter operator, after installation of the meter(s).

9.4.10 Fusing

Cut outs shall contain fuses conforming to the requirements of Type IIB of BS HD 60269-3 and ES334. Fuse link ratings of 80A and 60A are to be used where circumstances dictate that the fuse link should be sized below the 100A general standard. In particular, where a busbar extension to a single pole fuse base and carrier is installed, the total rating of the service fuse links shall not exceed 120A. If two services are to be sub-fused from a master fuse link, each service shall be fused at 60A and the master fuse link shall be rated at 100A. Reference shall also be made to Module Ten.

9.4.11 Supplier & Meter Operator

The third party connector shall be responsible for ensuring that a Supplier is appointed on behalf on the User. The metering requirements shall be specified by the appointed Meter Operator.

9.4.12 Connection Between Cut-out and Meter

For single-phase service terminations a pre-formed encapsulated meter security block shall be installed to connect the outgoing terminals of the cut-out to the incoming terminals of the meter. Suitable blocks are either straight or angled (for use with the cut-out mounted on a ramped mounting board). In certain circumstances it is permissible to omit the meter security block, but only with the prior permission of Electricity North West Limited.

At three-phase terminations and otherwise where the preferred security blocks are not used, interconnecting cable between the cut-out and meter shall be stranded copper of 25mm^2 cross-section. Connections to time switch motors and their earthing leads shall be of stranded copper of 10mm^2 cross-section and the connections to the switching coil of a two rate meter shall be of stranded copper of 4mm^2 cross-section.

Under the terms of the MOCoPA, the responsibility for this connection between the cut-out and the meter rests with the Meter Operator. It shall be noted, however, that in addition to the use of colour coding of the insulation (and sheaths) of these cables (See 9.4.15), they will be marked, “L1”, “L2”, “L3” and “N”, as appropriate.

9.4.13 Earth Terminal

The connection of the User's installation to any earthing terminal connected to the Network shall be in accordance with EPD332.

The ESQCR prohibit the use of Protective Multiple Earthing (PME) terminals in caravans and boats. Similarly, in other situations such as for temporary connections to building sites, where the integrity of equipotential bonding of extraneous metalwork cannot be relied on, PME terminals shall not be provided, nor shall any metalwork connected to the supply system neutral remain exposed. The User's attention shall be drawn to his own need to provide earthing and/or RCD protection.

In all other situations, a suitably rated earthing terminal block shall be installed to facilitate the bonding of the User's installation's extraneous metalwork to the incoming earth. This earthing terminal block shall have a minimum of three terminals.

9.4.14 Disconnectors

It is no longer Electricity North West Limited's policy to provide and install disconnectors between the meter and the User's equipment at connections that are within the scope of this document.

Where the electricity supplier, meter operator or User installs a disconnector between the meter and the User's equipment, Electricity North West Limited will neither accept ownership of nor responsibility for that disconnector.

Where disconnectors are shown on the arrangement drawings listed in Appendix O, they are owned by and are the responsibility of the installer (i.e. the electricity supplier, meter operator or User).

9.4.15 Interconnection Between Service Equipment and User's Equipment

All interconnecting wiring and termination equipment shall comply with the current edition of BS 7671.

Interconnecting cables between the service equipment and the User's equipment shall not normally exceed 2m in length. Mechanical protection shall be provided where necessary. Any length in excess of 2m must be approved by Electricity North West Limited before installation.

Interconnecting cables, which shall be provided by the User, shall be XLPE insulated and sheathed stranded copper of 25 mm^2 cross section, complying with BS 7889, except for the earth lead connection which shall be 16mm^2 insulated stranded copper.

In a single-phase installation, interconnecting cable insulation shall be colour coded, brown for phase and blue for neutral. In a three-phase installation, the insulation of the neutral cable shall be blue and the insulation of phase cables may all be brown, or alternatively brown, black and grey. Cable sheaths may be the same colour as their insulation or White, but otherwise may not be brown, black, grey, red, yellow, blue or green/yellow. Earth cable shall be single insulated and colour coded green/yellow.

9.4.16 Labelling of Equipment

The following labels shall be attached to the termination equipment. Labels and their means of fixing shall be of such quality that they remain legible and in place for a minimum of 20 years.

9.4.17 Cut-out

At every service termination to be adopted by Electricity North West Limited as part of its electricity distribution network, a label, with approximate dimensions of 50mm × 30mm and black lettering on a white background, shall be attached to the cut-out. This label shall read:

Electricity Distribution Network provided by Electricity North West Ltd

9.4.18 Cut-out (PME Terminal Available)

Only where the connection is PME, a label, with approximate dimensions of 50mm × 30mm and red lettering on a white background, shall be attached to the cut-out. This label shall read:

PME SYSTEM EARTHING TERMINAL

9.4.19 Cut-out (No Earthing Terminal Provided)

Only where no earth connection is provided, a label, with approximate dimensions of 50mm × 30mm and white lettering on a red background, shall be attached to the cut-out. This label shall read:

WARNING! NO EARTHING TERMINAL HAS BEEN PROVIDED; A SEPARATE CONSUMER EARTHING TERMINAL MUST BE PROVIDED. DO NOT ATTEMPT TO MAKE A PME CONNECTION.

9.4.20 Fuse Link Carrier

A label indicating the rating of the service fuse link and its voltage rating shall be attached to the fuse link carrier. This label shall have white lettering on a black background.

9.4.21 Meter Security Block

A label with approximate dimensions of 65mm × 30 mm, with red lettering on a white background shall be attached to the meter security block, reading:

WARNING! INTERFERENCE WITH THIS INSTALLATION IS ILLEGAL AND COULD CAUSE DEATH OR INJURY.

9.4.22 Earth Terminal (Where Provided)

A label with approximate dimensions of 50mm × 40mm, preferably with black lettering on a silver background, shall be attached adjacent to the earth terminal, reading:

EARTH Connect to common earth on customer's installation only after ensuring satisfactory cross bonding of services. Use 16mm^2 earth cable.

9.4.23 Neutral Block (Where Installed)

A label with approximate dimensions of 35mm × 25mm, preferably with black lettering on a silver background, shall be attached to the neutral block, reading:

NEUTRAL CONNECTIONS Connect to customer's installation using 25mm^2 cable.

NOTE:

The use of Arial font in the illustrations of labels in this subsection does not preclude the use of existing stocks of labels printed in Times New Roman.

9.4.24 Arrangement of Equipment

Typical arrangements of termination equipment are shown in the drawings listed in Appendix O. Optimum use shall be made of space on the cut-out board, giving due regard to the bending radii of cables. The following guidelines shall always be followed.

The service cable shall enter the cut-out from below.

Where installed, any disconnector shall be connected to the outgoing terminals of the metering equipment.

The User's tails shall be connected directly to equipment mounted on the cut-out board.

This equipment shall be:

(a) a meter, and, where separately provided, a timeswitch or teleswitch; or

(b) where fitted, a disconnector; or

(c) where there is a need to connect more than one set of User's tails, insulated connector blocks.

User's equipment mounted on the cut-out board in an OSVC shall be restricted to either a disconnector or a single switchfuse, controlling a cable to a remote consumer unit, e.g. in a first-floor flat. User's equipment shall not be mounted on a cut-out board in any other situation. No other item of User's equipment shall be mounted on any cut-out board.

9.5 Equipment Records

The Installer shall provide records of all services installed, using Form C of Module Four and marked upon the latest available edition of the Ordnance Survey map for the area, at 1/500 scale with any relevant detail shown on 1/250 enlargements. The colour codes and symbols to be used for marking shall comply with CP012.

9.6 Documentation

Documentation, i.e. Health and Safety File, operating manuals and commissioning test results, shall be as described in Module Four.

10 Module Seven – Design of New Connections for Housing Developments

Contents

10.1 Scope

This Specification details the requirements for new connections for housing developments. These connections include associated low voltage (LV) distributing mains and distribution substations, directly connected to Electricity North West Limited's electricity distribution network (Network). The connections under consideration are those mains and substations being designed and installed by a third party and intended to be adopted by Electricity North West Limited. Connections to public lighting from these LV mains are excluded from this Specification, but are covered by Module Five.

This document shall be read in conjunction with Module Four, where the definitions of the terms set in bold type may be found.

10.2 General

Any variation to this specification shall be agreed, in writing, with the Network Design Policy Manager prior to any design being accepted.

The Owner's Works shall comply with the requirements of Module Four.

It is a requirement that all work shall be carried out strictly in accordance with the provisions of all relevant legislation and industry best practice.

The Owner's Works shall comply in all respects with the provisions of Regulations 3 (1), 6, 7, 8 (1), 8 (3), 9 to 14, 21 and 22 of the Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR) and with the Electricity at Work Regulations 1989.

Users will be connected to and metered at LV, 400/230 volts. Any group of services supplied from the same three-phase distributing main shall be so connected that the load is balanced between the three phases. Electricity North West reserves the right to refuse to adopt Owner's Works having excessive phase imbalance.

The LV Network is solidly earthed and makes use of Combined Neutral and Earth (CNE) conductors. Likewise, the LV electricity distribution network forming part of the Owner's Works shall be solidly earthed and, wherever appropriate, make use of CNE conductors.

The cores of multicore LV mains shall not be 'bunched' or 'paired' to increase the current rating, improve voltage regulation or reduce the loop impedance.

The maximum Prospective Short Circuit Current, at the Exit point to the User, is not expected to exceed the following values:

Three phase =27kA
Single phase = 16kA

10.3 Design and Equipment Requirements

10.3.1 Environmental Conditions

The equipment shall be designed and constructed to allow operation in environments defined in Clause 6 of British Standard (BS) EN 60947-1 as follows:

Equipment that is housed in a controlled environment shall be suitable for operation in Pollution Degree 2.

Equipment that is not housed in a controlled environment shall be suitable for operation in Pollution Degree 3.

All equipment shall be protected from the deposit of excessive levels of dust and from the influx of water or other substances liable to have a harmful effect.

10.3.2 Point of Connection

The point of connection may be a point on existing LV Network, an LV fuseway at an existing HV/LV substation or a point or points on the existing HV Network. Where the point of connection is at HV, the Owner's Works shall include the design, construction and commissioning of a suitable substation or substations.

10.3.3 Security of Supply

The Owner's Works shall be designed in accordance with Electricity North West Limited's design policies as set down in Electricity Policy Documents (EPD) 279, 282 and Module One. In particular, due regard shall be taken of the need to provide the appropriate level of security of supply. Groups of customers exceeding 200 in number or connected via a transformer whose rating exceeds 500kVA shall have switched alternative feeding arrangements, such that, in the event of an unplanned disconnection, no such group needs to remain without electricity for longer than the time taken to restore by switching (assumed to be no longer than 3 hours).

10.3.4 Substations

The occupancy of any new substation supplying domestic premises shall be secured through freehold or long-term leasehold held by Electricity North West Limited. Where a new substation is to be constructed on land within the control of the Owner, the Owner shall secure such freehold or long-term leasehold on behalf of EN Electricity North West Limited.

Any substation forming part of the Owner's Works shall be designed and constructed in accordance with Electricity North West Limited's policies and practices and any requirements imposed through planning consents etc.

Adequate provision shall be made for normal access to and emergency egress from any substation, and for the delivery and removal of plant and equipment, without the need for subsequent modifications to the civil works of the building structure or access.

Each HV Network circuit shall be terminated on a fully rated load-breaking, fault-making switch, with circuit earthing switch and testing facility.

Transformers may be controlled and protected by either switch-fuses or circuit breakers. A cable connection between a switch-fuse and a transformer shall not exceed 15m in length.

Substation, circuit and plant identification shall be as directed by the appropriate Design Manager, Electricity Connections, Electricity North West Limited prior to the commissioning of the equipment.

10.3.5 11/6.6 kV Switchgear

HV Switchgear shall be designed, manufactured, and tested in accordance with ES314.

EPD307 contains details of equipment, which is currently approved for use on the Electricity North West Limited network. Approval for the use of any types of switchgear, not included in EPD307, shall be obtained, in writing, from the Plant Policy Manager.

10.3.6 Transformers

Transformers shall be designed, manufactured, and tested in accordance with ES322 and shall be of low-loss design.

The ratings of transformers, to be adopted by Electricity North West Limited, shall be selected from the standard ratings allowed by the current version of the Energy Networks Association Technical Specification (ENA TS) 35-1 and shall be such that the initial utilisation factors are not less than 0.6.

The ratings of transformers to be adopted shall not exceed 1000kVA.

10.3.7 LV Fusegear

LV fuseboards and cabinets shall be designed, manufactured and tested in accordance with ES319.

10.3.8 LV Network Design

After-Diversity Maximum Demands (ADMD) for new domestic dwellings may be assumed to be as follows:

PROPERTY TYPE	ADMD PER CUSTOMER (KW)	
	Day	**Night**
Small Non-Electric Non-Detached	1.0	0.4
Non-Electric Detached	1.4	0.6
Electric Heating (installed in each of a group of average-sized properties). (This takes account of the large diversity, where electric heating is not subject to a restricted-hour tariff.) See below regarding high density housing.	3.4	2.4
Off-peak Tariff, e.g. E7 (where substantial storage heating load is switched to take advantage of low ‘off-peak’ rates)	1.5	0.8 (aggregate installed water and storage heating capacity kW) + 0.5
Off-peak Tariff with afternoon boost (where substantial storage heating load is switched to take advantage of low or ‘off-peak’ rates)	3.4	0.8 (aggregate installed water and storage heating capacity kW) + 0.5
Two Rate Tariff, e.g. E10 with afternoon, evening and night cheaper rates (where the tariff provides an incentive to concentrate usage in the cheaper periods, notably in the evening)	0.6 (maximum space heating available 07:00 to 24:00 plus water heating kW) + 2*	0.6 (maximum space heating available 00:00 to 07:00 plus water heating kW) + 0.5 *

Air conditioning (where installed in each of a group of properties)	Depending on the likely operating regime, add an appropriate fraction (say 50%) of the installed cooling load to the above daytime ADMD values.
Heat Pumps and Electric Vehicles	Calculate ADMD as per EREC P5

NOTE:

In some installations, space heating circuits may be wired in separate banks, with interlocked change-over switches. Thus, at any particular time of day, not all space heating is "available".

Where electric heating, which is not subject to a restricted-hour tariff is to be used in high-density housing (e.g., flats), the ADMD figures given above are to be used for all aspects of the electrical design except for the rating of distribution transformers. The ADMD contribution of such housing to the loading of transformers shall be taken as:

0.5[aggregate installed (fixed) space heating (kW) + 3kW water heating].

This is to take account of greatly reduced diversity in the event of a "cold-start" after a prolonged outage.

In this context, a transformer shall be taken to be feeding high-density housing, where 50% or more of its demand arises from electrically heated properties, without restricted-hour tariffs.

Allowance for loss of diversity in small groups shall be 8kW for single rate Users and 4kW for restricted-hour tariffs.

Service maximum demands shall be calculated as follows:

(a) For Economy 7 or similar off-peak tariff customers with space heating load:

Service load = (X + 4) kW
Where 'X' is the installed space and water heating load

(b) All other customers

Service load = (2 a + 8) kW
Where 'a' is the design ADMD (kW) for the customers

A substation LV busbar voltage of 415/240V shall be used in all calculations.

All mains and service cables, and their associated fuses shall be adequately rated to cater for the maximum demand in the conditions in which they are to be installed.

All connections to new housing shall be by underground services and all new mains in new developments shall be laid underground.

Underground mains shall preferably be installed in areas adopted or to be adopted under NRSWA. Alternatively, where such routes are not available or are impracticable, mains may be laid in permanent easements granted to Electricity North West Limited or its predecessors. Where such an easement is required on land within the control of the Owner, the Owner shall secure the easement on behalf of Electricity North West Limited.

All new LV Networks and extensions to existing LV Networks for the connection of permanent housing shall use Protective Multiple Earthing (PME), in accordance with EPD332 and EPD333. The use of PME terminals at temporary connections (e.g. for building sites), or in caravans or boats is not, however, permitted.

The earth-loop impedance, measured at any service termination, provided as part of the Owner's Works, shall not exceed 0.35Ω.

All LV distributing mains and overhead services forming part of the Owner's Works shall be protected by fuses, in accordance with Section 2 or Section 3 of Module 10 - Protection of LV Underground and Overhead Distributors, Distribution Transformers and HV Overhead Networks by Fuses. This will ensure that a sustained phase to neutral short circuit fault at any point on the distributing main will cause the controlling fuse to operate within 100 second for an underground cable, 30 second for Aerial Bundled Conductor, or 10 second for an overhead line. In determining a fuse rating in this way, a large cross-section cable tail not exceeding 15m in length outgoing from a substation and with no branch or service jointed along its length shall be ignored. Fuse ratings shall be such as to discriminate with the protection applied to the HV side of the transformer, unless agreed otherwise with the appropriate Design Manager, Electricity Connections, Electricity North West Limited.

Where appropriate, in order to comply with the security requirements of EPD282, interconnection with adjacent LV Networks shall be provided via 2-way link boxes. No additional link-boxes, in excess of this requirement, shall be installed, except by agreement with the appropriate Design Manager, Electricity Connections, Electricity North West Limited.

Connections to multi-occupied premises shall be in accordance with ES287.

10.3.9 Mains Cable Installation and Jointing

HV cable to be used (for 11kV or 6.6kV systems) shall be 95 or 300mm² Triplex formation single core 'quasi-dry design' polymeric insulated, with solid aluminium conductors in accordance with ES400C9.

No other type or cross section of HV cable is permitted.

LV mains cables to be used shall be 300mm², 600/1000V three core CNE or four core separate neutral and earth (SNE) conductor cables, polymeric insulated, with solid aluminium phase conductors and concentric copper wire waveform CNE conductor or earth conductor. 95 and 185mm² cables may only be used in situations described in Module One. All three and four core cables shall comply with the requirements of ES400C11.

No other type or cross section of LV mains cable is permitted.

All jointing shall be undertaken in accordance with CP411 - Cable Jointing.

10.3.10 Service Cable

For PME connections, the service cable to be used shall be 35mm² 600/1000V, single solid aluminium phase core with helical concentric copper neutral/earth, or 25mm² 600/1000V, three solid aluminium phase cores with helical concentric copper neutral/earth, in either case complying with the requirements of ES400C8.

Where it is not appropriate to provide a PME connection, an SNE connection may be provided, using split concentric service cables. The cables to be used shall be either 35mm^2 600/1000V, single solid aluminium phase core with a concentric layer of insulated copper wires (neutral) and bare copper (earth), or 25mm^2 600/1000V, three solid aluminium phase cores with a concentric layer of insulated copper wires (neutral) and bare copper (earth), in either case complying with the requirements of ES400C8.

No other type or cross section of service cable is permitted.

The maximum single-phase supply capacity shall be 20kVA. The maximum three-phase supply capacity shall be 60kVA. No three-phase service shall be installed, unless the demand is to exceed 20kVA or the User has a particular requirement for a three-phase connection.

Service cables shall be laid in accordance with ES400E4. Each underground service cable shall be laid within the curtilage of the property to be serviced, from the boundary with the adopted (or to be adopted) road or service strip. Each single phase underground service cable shall be drawn into a continuous duct, laid from the boundary to a point adjacent to the service position. The duct shall be red, have a minimum internal diameter of 32mm, comply with ES400D4 and shall be installed in accordance with Electricity North West Electrolink No.5. Looped services shall not be used.

The service cable length shall not exceed 30m, measured from the cut out to the point of connection to the LV main. Where, exceptionally, this length is to be exceeded, evidence must be available that voltage drop and flicker criteria are met and that the risk arising from unprotected service cable length has been assessed in each individual case. In order to reduce this risk, the maximum practical length of any such long service cable, including a three-phase cable, shall be installed in a continuous duct.

No more than four single-phase services or two three-phase services shall be connected within any one joint on a distributing main.

Service cables shall enter cut outs or any protective lower enclosures from below and cable sheaths shall remain intact except on those parts of cables, which are wholly contained within cut outs or their protective lower enclosures.

10.3.11 Earthing Conditions

All installations shall comply with EPD333 and EPD332. A label shall be fitted to each cut out indicating that the system is PME, where appropriate.

10.3.12 Service Position

Services shall normally be terminated on the external walls of buildings within small, medium or large sized meter cabinets complying with the requirements of ENA TS 12-3 'Outdoor meter cabinets'. The size selected will depend upon whether the service is 1 or 3 phase and upon the requirements of the Meter Operator, who should be consulted. Where an external meter viewing cabinet is used, with the service cable entering via the wall cavity, the cable entry duct (See 10.3.10) shall continue into the wall cavity, to enter the cabinet vertically from below. Alternatively, in the case of a single-phase cable, the duct may enter the cabinet externally. In this case, the final part of the duct, comprising a slow bend and riser to enter the cabinet, may be of the same colour as the cabinet. The radius of any bend shall be not less than the bending radius of the largest three-phase service cable specified in see 10.3.10. The height of the base of the cabinet above ground level shall not be less than 500mm or more than 800mm. The exposed part of the duct between ground level and the cabinet shall be straight, vertical and secured to the wall by a saddle or cleat no more than 200mm below the base of the cabinet. Further guidance is available in Electricity North West Limited Electrolink No. 5.

Where an external meter cabinet is to be used, the safety issues associated with the proximity of any nearby sited gas service cabinet and gas service pipe shall be considered and appropriate precautionary measures taken.

In cases where an outdoor position cannot be accommodated (e.g. in small terraced properties), services may be terminated in indoor positions, or inside attached garages. Service positions in garages shall preferably be positioned on side walls, rather than on rear walls, thereby reducing the risk of direct impact by vehicles. The length of service cable within the building shall be as short as is reasonably practicable. The cable shall be installed through a continuous duct, as described in sub-section 10.3.10, finishing at least 20mm above the finished floor level and sealed at that end against the ingress of gas. Where the total length of cable within the building exceeds 2m, the duct shall have a minimum internal diameter of 100mm. The length of cable, between the sealed duct end and the termination, shall not exceed 2m.

Care shall be taken with the installation to minimise the risk of accidental damage. All surface-mounted cables outside buildings or where vehicles have access (e.g. inside garages and barns), below a height of 1.8m, shall be continuously protected either by plastic ducts complying with ES400D4 or by plastic cable guards, complying with ES400G1. Elsewhere, straight lengths of cable exceeding 1m, below a height of 1.8m, shall be similarly protected. Straight runs of cable shall be either vertical or horizontal. No bending radius shall be less than the minimum specified. Ducts shall be fixed to walls with plastic saddles, such that the ducts are adequately supported at intervals not exceeding 300mm.

For internal service terminations, the meter(s) shall be mounted at a height not less than 1.0m and not more than 1.35m, above the floor level. The meter(s) shall be mounted on a meter board with at least 750mm clear access in front. Service terminations shall not be positioned in or under bathrooms, toilets, adjacent to sinks or in any other position where they may be subjected to water contact.

The installation of meter boards, meters and cut-outs shall comply with ES212.

10.3.13 Cut-outs and the Fusing of Cut-outs

Service cables shall be terminated within 100A cut-outs. The cut-out shall be in accordance with the requirements of ES332.

Where a service is to be made live without having a meter fitted, the cut-out fuse carrier shall be sealed in position with no fuselink fitted. Where a meter is fitted and connected prior to a service being made live, a fuselink shall be fitted and the cut-out sealed. Cut outs shall be sealed in a manner approved by Electricity North West.

Cut outs shall be designed to accept fuses conforming to the requirements of Type IIB of BS1361: 1986 ‘Specification for cartridge fuses for AC circuits in domestic and similar premises’ including amendment 2 of 1985 and ES334. Where a fuselink is to be fitted in accordance with the above, the maximum fuse rating shall be 100A.

10.3.14 Service Termination Equipment and Labels

Equipment and labels shall comply with the requirements of Module Six.

10.3.15 Interconnection Between Service Equipment and Customer’s Equipment

All interconnecting wiring and termination equipment shall comply with the current edition of BS7671 “Requirements for Electrical Installations” also known as the “IET Wiring Regulations”.

Interconnecting cables between the service equipment and the customer's equipment shall not exceed 2 m in length. Mechanical protection shall be provided where necessary.

Interconnecting cables form part of the User's installation and shall be provided by or on behalf of the User at no cost to Electricity North West Limited. Phase and neutral cables shall be PVC insulated and sheathed stranded copper of 25mm² cross section, complying with BS6004: 1991 'Specification for PVC insulated cables (non armoured) for electric power and lighting.' Earthing lead connections shall be 16mm² PVC insulated stranded copper.

Interconnecting cable insulation shall be colour coded, brown for phase and blue for neutral, each with a grey oversheath. Earth cables shall be single insulated and colour coded green/yellow.

10.3.16 Parallel Generation

Where any User's installation is to include a domestic generation appliance (e.g. micro combined heat and power), the Owner shall ensure that the installation complies in all respects with EREC G98 and EREC G99. The labelling required by EREC G98 and EREC G99 shall be fixed in addition to the labelling required by Module Six. (See 10.3.14.)

10.3.17 Supplier & Meter Operator

The Owner shall be responsible for ensuring that a Supplier is appointed on behalf of each User.

10.4 Documentation and Records

Documentation shall be as described in ES210.

The Installer shall provide records of all services installed, using Form C of Module Four and marked upon the latest available edition of the Ordnance Survey map for the area, at 1/500 scale with any relevant detail shown on 1/250 enlargements. The colour codes and symbols to be used for marking shall comply with CP012.

11 Module Eight – New LV Connections of up to 300kVA Capacity

Contents

11.1 Scope

This Electricity Specification (ES) details the requirements for LV connections with metering with capacities up to 300kVA directly connected to the Electricity North West Limited electricity distribution network (Network), that connection being intended to be adopted. This ES applies to new connections, whether installed by Electricity North West Limited, or by Independent Connection Providers (ICP). It is usually appropriate to provide connections of up to 60kVA capacity in accordance with Module Six.

This document shall be read in conjunction with Module Four.

11.2 General

Any variation to this specification shall be agreed, in writing, with the Network Planning Policy Manager, Network Strategy, Electricity North West Limited prior to any design being accepted.

The Owner's Works shall comply with the requirements of Module Four.

It is a requirement that all work shall be carried out strictly in accordance with the provisions of all relevant legislation and industry best practice.

The Owner's Works shall comply in all respects with the provisions of Regulations 3 (1), 6, 7, 8 (1), 8 (3), 9, 10, 12 to 14 and 17 to 22 of the Electricity Safety, Quality and Continuity Regulations 2002 and with the Electricity at Work Regulations 1989.

Users will be connected and metered at 400/230 volts.

The LV electricity distribution Network is solidly earthed and makes use of CNE conductors.

The conductors of LV mains shall not be 'bunched' or 'paired' to increase the current rating, improve voltage regulation or reduce loop impedance.

The maximum three-phase prospective short circuit current, at the Exit point to the User, is not expected to exceed 27kA.

11.3 Connection Arrangements

This document specifies LV connections provided via single 3 phase underground cables for industrial and large commercial users within the following limitation:

- The 3-phase maximum demand supplied shall not exceed 300 kVA.
- The Users connection shall be either to an Electricity North West Limited LV main or directly from the LV distribution board of an Electricity North West Limited substation. The point of connection shall be defined by Electricity North West Limited.
- Typical connection configurations are shown in Appendix P.
- The calculated voltage drop from the point of connection to the Network (as described above) to the Exit point to the User, at the maximum allowable load, shall not exceed 2% on the service cable/line and 7% overall (from the substation LV busbars). A 415/240V-substation busbar voltage shall be used in all calculations.

11.3.1 Environmental Conditions

The equipment shall be designed and constructed to allow operation in environments defined in Clause 6 of BS EN 60947-1 as follows:

Equipment that is housed in a controlled environment shall be suitable for operation in Pollution Degree 2.

Equipment that is not housed in a controlled environment shall be suitable for operation in Pollution Degree 3.

All equipment shall be protected from the deposit of excessive levels of dust and from the influx of water or other substances liable to have a harmful effect.

11.3.2 Cables

Cables to be used shall be 300 mm², 600/1000V three core combined neutral/earth (CNE) or four core separate neutral/ earth (SNE) conductor cables, polymeric insulated, with solid aluminium phase conductors and concentric copper wire waveform CNE conductor or earth conductor. 95 and 185mm² cable may only be used in situations described in EPD283 subsection 4.1. All three and four core cables shall comply with the requirements of ES400C11.

No other type or cross section of cable is permitted.

The conductor cross section selected for any particular installation shall be compatible with the load to be supplied and the permitted voltage drop, which shall be as described in clause 4.

11.3.3 Earthing Conditions

All installations shall comply with Electricity North West Limited Electricity Policy Document 332.

11.3.4 Cable Installation and Jointing

The installation and jointing of underground cables shall comply with the relevant parts of ES400E4. All jointing shall be undertaken in accordance with Electricity North West Limited Code of Practice 411 - Cable Jointing.

Small wiring shall be ferruled in accordance with ENA TS 50-19.

11.3.5 Routeing of Cables in Buildings

In general cables installed in buildings shall comply with the requirements of Appendix 4 of BS 7671 – Requirements for Electrical Installations (IET Wiring Regulations) and with the additional requirements specified below. Access may be required at any time in the future. Hence, direct burial of cables within building materials is not acceptable.

Ducts within buildings shall be a minimum of 150 mm in diameter and shall be in accordance with ES400D4. Where ducted cable routes change direction in buildings, draw pits at least 1.5 m square shall be provided, allowing for future repair or replacement of cables. No single run of duct within a building shall exceed 25 m between draw pits.

Alternatively, covered trenches may be used to route cables. On completion of cable work, cable trenches shall be filled with sand and covered with a 100mm thick screed.

Where LV cables are fixed to racks or cleated to walls, adequate mechanical protection shall be provided.

The vertical part of any cable run, as it rises to the cut out/meter cabinet, shall be secured, such that the weight of the cable is supported independently of the termination.

11.3.6 Cut-outs, Meter Cabinets and Current Transformers

Electricity North West Limited will supply the cut out, cable termination box, metering current transformers and all associated ancillary equipment on a chargeable basis. The installation of these items shall be so arranged that safe access is provided to the fuses and metering equipment, including at least 1m of clear space in front.

11.3.7 Fusing

Electricity North West Limited will check that the source fuses in the LV substation are compatible with the anticipated loading and provide adequate protection for the network extension.

Fuses used in the cut-out shall comply with BS88 Part 5 (1988) and ES334.

Ratings of cut-out fuses and sizes of single-core cable tails are tabulated in Appendix Q.

11.4 Supplier

The Installer shall be responsible for ensuring that a Supplier is appointed on behalf on the User.

11.4.1 Second Connection for Emergency Purposes

The request for a second connection for emergency firefighting lifts and equipment, pressurised escape routes, or any other emergency purpose shall be refused even if the Installer claims to satisfy the requirements of BS7671 “Requirements for Electrical Installations” also known as the “IEE Wiring Regulations”.

The preferred option is for the Installer to install automatically started generation (in accordance with BS 9999) for the following reasons:

There are adverse safety implications (inadvertent re-energisation, stray earth and return currents etc) from having two connections. It is not prudent to introduce a safety risk in order to mitigate another.

It cannot be assumed that the second connection will always be available during LV or 11/6.6kV (or higher voltage) faults. Even if a second connection were to be derived from a separate source, Electricity North West Limited could not guarantee that this separation would be maintained.

It may be necessary to de-energise substations or feeders for fault location or maintenance work. It follows that Electricity North West Limited cannot guarantee 100% availability of the second connection.

To be of practical use, the integrity of the second connection would need to be continuously monitored. Electricity North West Limited cannot undertake this responsibility.

The Installer shall be made aware that, although a second connection might appear to be the cheapest option, it would not produce the desired level of safety and might engender an unwarranted sense of security.

Distributors are absolved from the obligation to provide a quotation on demand for a connection where it would not be reasonable in all the circumstances (s17(1)(c) of the Electricity Act 1989 (as amended)). The issues listed above mean that it is not reasonable to provide a second connection, where a safer and more reliable option is for the Installer to install on-site generation.

11.5 Equipment Records

The installer shall provide records of all equipment installed, using form C of Module Four and marked upon the latest version of the Ordnance Survey MasterMap Topographic map for the area, at 1:500 scale with any complex details shown on 1:250 enlargements. Guidance on the provision of records of underground equipment may be found in ES281, Part 6.

11.6 Documentation

Documentation shall be as described in Module Four.

12 Module Nine – New Connections of up to 1,500kVA Capacity

Contents

12.1 Scope

This Specification details the requirements for new connections and metering of HV (11/6.6kV) or LV connections up to 1,500kVA directly connected to the Electricity North West Limited electricity distribution network (Network), that connection being intended to be adopted by Electricity North West Limited. It is usually appropriate to provide connections of up to 300kVA capacity in accordance with Module Eight.

This document shall be read in conjunction with Module Four.

12.2 General

Any variation to this specification shall be agreed, in writing, with the Network Planning Policy Manager, Central Engineering Services (CES), Electricity North West Limited prior to any design being accepted by Electricity North West Limited.

The Owner's Works shall comply with the requirements of Module Four.

It is a requirement that all work shall be carried out strictly in accordance with the provisions of all relevant legislation and industry best practice.

The design shall ensure that Electricity North West Limited can comply with all relevant Energy Networks Association (ENA) Engineering Recommendations.

The Owner's Works shall comply in all respects with the provisions of Regulations 3 (1), 6, 7, 8 (1), 8 (3), 9, 10, 12 to 14 and 17 to 22 of the Electricity Safety, Quality and Continuity Regulations 2002 and with the Electricity at Work Regulations 1989.

Users will be supplied and metered at 11000/6600 or 400/230 volts. More than one User may be supplied from a single transformer.

With any single circuit arrangement, the agreed supply capacity shall not be considered to be firm.

The design of the connection shall take account of the following system requirements:

Maximum Fault Levels on the Network are:

- 11 or 6.6kV = 250MVA
- LV = 19.4MVA (based on a supply from a maximum transformer size of 1000kVA)

The maximum short circuit ratings shall be:

- 11kV = 13.1kA for 3 seconds
- 6.6kV = 21.9kA for 3 seconds
- LV = 27kA

The maximum earth fault current for both the 11kV and 6.6kV electricity distribution network is 3300A, based on connection to a primary substation, with three transformers operating in parallel.

The minimum impulse withstand level for new equipment connected to the 11kV and 6.6kV distribution network is 75kV.

In particular, the rating of any switchgear and fusegear, forming part of any new connection, must be fully compatible with all the system parameters.

12.3 Connection Arrangements

The connection provided from the Network may be one of the following arrangements:

Distribution Substation Connection with Provision for LV Network – see Figure 1 in Appendix R.

A maximum of three fuseways shall be made available to the User.

The maximum connected load, which is subject to the existing loading on the Network, shall not exceed the following:

- 1 Fused Way (400 or 500A Fuselink) up to 360kVA
- 2 Fused Ways in Parallel (400A Fuselink) up to 575kVA
- 3 Fused Ways in Parallel (400 or 500A Fuselinks) up to 1000kVA

Fuse ratings, metering ct ratios and connection types for the above arrangements are tabulated in Appendix S.

Metering current transformers (ct) shall be positioned as shown in Figure 1 in Appendix R.

Where protection is to be provided by means of HV fuses, such as in a switch-fuse, the maximum length of the11/6.6kV transformer cable connection shall be 15m.

The exit point shall be as shown in Figure 1 in Appendix R.

The User's connection to the exit point shall comply with the current edition of British Standard (BS) 7671 (IET Wiring Regulations).

11/6.6kV connection with NO LV Network Provision – see Figure 2 in Appendix R.

This arrangement is available, where there is to be no provision for LV connections to the Network and the substation is not to be looped into an existing 11/6.6kV ring.

The maximum connected load, which is subject to the existing loading on the Network, shall not exceed 1500kVA at 11kV or 1000kVA at 6.6kV.

Where protection is to be provided by means of HV fuses, such as in a switch-fuse, the maximum length of the11/6.6kV transformer cable connection shall be 15m.

Metering cts and voltage transformer (vt) shall be accommodated in an HV metering unit and be positioned as shown in Figure 2 in Appendix R.

The exit points shall be at the outgoing terminals of the HV metering unit.

Part of the works to be adopted shall be a User-accessible emergency trip facility that, when operated, will trip the 11/6.6kV Electricity North West Limited - owned switch.

The substation shall be fitted with a low voltage electrical installation conforming with ES397, supply being provided, where necessary, by the User.

11/6.6kV RMU connection – see Figure 3 in Appendix R.

This arrangement is available where there is to be no provision for LV connections to the Network and the substation is to be looped into an existing 11/6.6kV ring.

The maximum connected load, which is subject to the existing loading on the Network, shall not exceed 1500kVA at 11kV or 1000kVA at 6.6kV.

The maximum length of the 11/6.6kV transformer cable connection, connected to a switch-fuse, shall be 15m.

3.1.3.4 Metering cts and vt shall be accommodated in an HV metering unit and be positioned as shown in Figure 3 in Appendix R.

The exit points shall be at the outgoing terminals of the HV metering unit.

Part of the works to be adopted shall be a User-accessible emergency trip facility that, when operated, will trip the 11/6.6kV Electricity North West Limited - owned switch.

The substation shall be fitted with a low voltage electrical installation conforming with ES397, supply being provided, where necessary, by the User.

12.3.1 Environmental Conditions

The equipment shall be designed and constructed to allow operation in environments defined in Clause 6 of BS EN 60947-1 as follows:

Equipment that is housed in a controlled environment shall be suitable for operation in Pollution Degree 2.

Equipment that is not housed in a controlled environment shall be suitable for operation in Pollution Degree 3.

All equipment shall be protected from the deposit of excessive levels of dust and from the influx of water or other substances liable to have a harmful effect.

12.3.2 Cables

The 11kV cable to be used shall be 95 or 300 mm² Triplex formation single core 'quasi-dry design' polymeric insulated with solid aluminium conductors in accordance with ES400C9.

No other types or cross section of cable is permitted.

Where the point of connection is to a single transformer or two transformer groups, the single core cable earth screen shall, as a minimum, carry the fault current detailed in BS7870, Section 4.10 without sustaining damage.

Cable of 95mm^2 cross-section may be used for the local connection between switchgear and transformer and for connections to or from overhead lines of equal or less current rating. In all other situations, 300mm^2 cable shall be used.

All multicore and multipair cables shall comply with ES400C13.

12.3.3 Earthing Conditions

All installations are to comply with Electricity North West Limited Electricity Policy Documents 332 and 333.

12.3.4 Cable Installation and Jointing

The installation and jointing of underground cables shall comply with the relevant parts of ES400E4 and Electricity North West Limited Code of Practice 411.

Small wiring shall be ferruled in accordance with ENA TS 50-19.

12.3.5 Substation Housings and Enclosures

Substation housings and enclosures shall comply with ES352.

12.3.6 Cable Entry to Substations

11/6.6 kV cable entries to substations shall be made at the laying depth of the cable, using red plastic duct of at least 150 mm diameter complying with ES400D4. Cable joints are not permitted within entry ducts.

Bends in cable ducts shall be of no smaller radius than that permitted for the cable.

All entry ducts including any spare ducts and any ducts for earth conductors shall be sealed against the ingress of gas and water after installation of the cable. Sealing shall be achieved in an approved manner.

12.3.7 Routeing of Cables in Buildings

The following provisions apply where substations are sited within larger buildings and 11/6.6 kV cables must be routed through those buildings:

Ducts for 11/6.6 kV cables within buildings shall be at least 150 mm in diameter. Where ducted cable routes change direction in buildings, draw pits at least 1.5 m square shall be provided, allowing for future repair or replacement of cables. No single run of duct within a building shall exceed 25 m between draw pits.

Alternatively, covered trenches may be used to route cables. On completion of cable work, cable trenches shall be filled with sand and covered with a 100mm thick screed.

Where 11/6.6 kV cables are fixed to racks or cleated to walls, adequate mechanical protection shall be provided.

All cables shall be securely supported. Particular consideration shall be given to the secure support of cables in vertical runs.

Low Smoke Zero Halogen (LS0H) type cable shall be used.

12.3.8 11/6.6kV Switchgear

Switchgear shall comply with ES314.

Approval for the use of specific types of switchgear shall be obtained, in writing, from the Plant Policy Manager, Electricity North West Limited.

A switch-fuse shall be used to protect only a single ground-mounted transformer, where the transformer loop does not exceed 15m in length.

Substation, circuit and plant identification shall comply with CP615 Substation, Circuit and Plant Identification.

12.3.9 Transformers

Transformers shall be designed, manufactured, and tested in accordance with ES322.

The ratings of transformers, to be adopted by Electricity North West Limited, shall be selected from the standard ratings allowed by current version of ENA TS 35-1 and shall be such that the initial utilisation factors are not less than 0.6.

The maximum transformer size to be adopted shall not exceed 1000kVA.

12.3.10 Metering Current Transformers, Fuse Cabinets and Remote Metering Cabinets

HV metering units shall comply with ES314.

All HV metering cts and vts shall be in accordance with ES501.

LV Transformer flange mounted fused metering chambers, cts and all ancillary equipment including multicore boxes for metering purposes shall be in accordance with ES319.

Remote metering cabinets will be provided by Electricity North West Limited on a chargeable basis.

12.3.11 Metering Current Transformer Burdens

In order to ensure the accuracy of metering, the burden of the cts shall be restricted by using multicore cable of at least 2.5mm^2 copper cross-section and by limiting the length of the cable connecting the cts to the meter. The designer shall ensure that the burden connected to the cts is not excessive. As guide, the length of the cable should not exceed 25m for cts rated at 15VA.

12.3.12 Supplier

Where the connection is installed by an Independent Connection Provider (ICP), it shall be responsible for ensuring that a Supplier is appointed on behalf on the User.

12.3.13 Second Connection for Emergency Purposes

The request for a second connection for emergency fire fighting lifts and equipment, pressurised escape routes, or any other emergency purpose shall be refused even if the **Installer** claims to satisfy the requirements of BS7671 “Requirements for Electrical Installations” also known as the “IET Wiring Regulations”.

The preferred option is for the Installer to install automatically started generation (in accordance with BS 9999) for the following reasons:

There are adverse safety implications (inadvertent re-energisation, stray earth and return currents etc) from having two connections. It is not prudent to introduce a safety risk in order to mitigate another.

It cannot be assumed that the second connection will always be available during 11/6.6kV (or higher voltage) faults. Even if a second connection were to be derived from a separate source, Electricity North West could not guarantee that this separation would be maintained.

It may be necessary to de-energise substations or feeders for fault location or maintenance work. It follows that Electricity North West Limited cannot guarantee 100% availability of the second connection.

To be of practical use, the integrity of the second connection would need to be continuously monitored. Electricity North West Limited cannot undertake this responsibility.

The Installer shall be made aware that, although a second connection might appear to be the cheapest option, it would not produce the desired level of safety and might engender an unwarranted sense of security.

Distributors are absolved from the obligation to provide a quotation on demand for a connection where it would not be reasonable in all the circumstances (s17(1)(c) of the Electricity Act 1989 (as amended)). The issues listed above mean that it is not reasonable to provide a second connection, where a safer and more reliable option is for the Installer to install on-site generation.

12.4 Equipment Records

The installer shall provide records of all equipment installed, using form C of Module Four and marked upon the latest version of the Ordnance Survey MasterMap Topographic map for the area, at 1:500 scale with any complex details shown on 1:250 enlargements. Guidance on the provision of records of underground equipment may be found in ES281, Part 6.

12.5 Documentation

Documentation shall be as described in ES210.

13 Module Ten – Protection of LV Underground and Overhead Distributors and HV Protection of Distribution Transformers

Contents

13.1 Scope

This Code of Practice (CP) has been created to cover the protection of LV underground and overhead distributors and the HV protection of distribution transformers on the electricity distribution network (Network) owned and operated by Electricity North West Limited.

A manual method is presented for checking that a chosen fuse-link will protect the whole distributor (using phase-neutral or earth loop impedance) from the substation to the fault position. An alternative approach is to use the software tool LV AFFIRM as described in Module Two, Appendix B, and Appendix W which also carries out checks on the electrical loading on the cables, compliance with the limits for voltage fluctuations set out in ER P28 and the correct fusing to protect the system in accordance with this CP.

13.2 Protection of Low Voltage Distributors – General

Fuse-links protecting a low voltage cable distributor shall operate for a phase-phase, phase-neutral or a phase-sheath fault at any point on the distributor.

Fuse-links protecting a low voltage overhead line distributor shall operate for a phase-phase, phase-neutral or phase-earthwire fault at any point on the distributor, and at any point on any overhead service line connected to the distributor.

In principle, fuse-links shall be selected so as to comply with each of the following:

(a) Distributors shall be protected such that faults will be cleared within the stated times;

(b) Discrimination with HV protection shall be achieved; and

(c) Fuse-ratings shall be sufficient to cater for loads up to the thermal ratings of the distributors, which they protect.

Wherever a new distributor is designed, satisfying a) above is an absolute requirement.

NOTE:

The fuse reach is dependent on the HV source impedance. Module Ten uses a value of either 50MVA if the HV infeed is a cable or 10MVA for an overhead infeed since a separate table would be required for each impedance value. LV AFFIRM allows the user to enter the actual HV source impedance, if known. Otherwise it uses these same default values: 10MVA for an overhead infeed and 50MVA for a cable infeed. Thus maximum fuse reach obtained using LV AFFIRM will differ from those calculated using Module Ten if the source impedance is different from those used for the tables. However, the effect of source impedance on fuse reach is small eg the difference between maximum fuse reach between using a 10MVA and 50MVA source impedance is typically <10m.

Where an existing distributor is reinforced or otherwise significantly altered, the ratings of fuse-links installed on the network shall be altered as necessary to comply with this CP. In particular, compliance with the above a) is a priority, in such circumstances. Where an existing non-compliant distributor is extended, in order to make a new connection, the minimum requirement is that the branch of the distributor up to and including the new connection shall be made to comply.

In exceptional circumstances, consideration may be given to the use of LV fuse-link ratings, such that discrimination with the HV protection is compromised, e.g. where the transformer connects only one customer and larger LV fuses are necessary in order to carry the load. However, the consequences of the possible maldiscrimination shall be considered before adopting such an expedient. Where such lack of discrimination is accepted, appropriate labels shall be fixed adjacent to both the LV fuses and the HV protective device.

Fuse-link current ratings are not normally expected to be less than the rating of the distributor, which shall normally be taken as that of the predominant section of the distributor. Where a short length with increased conductor section is used immediately from a substation or PMT (and no significant amount of load is connected to it), the rating of the distributor shall be taken as the rating of the principal cross-section of the distributor.

Where it is not practicable to comply with all the above, the fuse-link current rating may be less than the rating of the distributor since fuse-link ratings are significantly dependent on transformer capacity as well as line rating. In these circumstances, particular care shall be taken to ensure that the design Maximum Demand (MD) of the distributor does not exceed the fuse-link current rating. Where appropriate, a label indicating that the rating of the distributor is limited to the fuse-link rating shall be attached to the distribution board.

Distributor fuse-link ratings shall be given on the LV network design data.

The outgoing ways of LV distribution boards shall be clearly labelled with fixed 'Trafolite' or similar labels with the details required by CP615 (sub-section 13.6.1) and which requires that the ratings of fuse-links to be installed are included on the label.

Interconnectors shall normally be protected to the normal open point, in accordance with this CP, by the fuse-links installed at each end of the interconnector. When the interconnection is to be utilised, fuse-links shall be installed at the normally open point to provide suitable protection for the downstream part of the interconnector.

NOTE:

Where it is considered to be useful operationally, interconnectors can be protected over their entire length in accordance with this CP, by the fuse-links installed at each end of the interconnector.

Normally fuse-links used to protect LV distributors shall be in accordance with BS-HD 60269: 2010 / BS 88-2: 2010 and Energy Networks Association Technical Standard (ENA TS) 12-8. Where special types of fuse-links may be required to protect distributors with a predominance of load having unusual characteristics e.g. large motors, details shall be provided to the Policy and Standards section for consideration.

Changes in the Standards, such as the replacement of BS 88-5 (1988) by BS-HD 60269: 2010 / BS 88-2: 2010, “Low-voltage fuses. Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)”, has not necessarily changed the fuse characteristics. The compatibility of the characteristics of fuses purchased in accordance with current standards is checked at the time of contract renewal and on the publication of standards revisions against the BS 88 Part 5 (1988).

Table 2A gives the maximum LV fuse-link rating for which discrimination is maintained across the associated distribution transformer.

Table 2A – Distribution Transformer Maximum LV Fuse-Link

DISTRIBUTION TRANSFORMER RATING (KVA)	PHASE	MAXIMUM ASSOCIATED LV FUSE-LINK RATING (A)
5	1	100 [1]
10	1	100 [1]
15/16	1	100
25	1	160
50	1	200
100	1	200
25	Split	100
50	Split	160
100	Split	200
25	3	100
50	3	160
100	3	200
200	3	200
300/315	3	315
500	3	400
750/800/1000	3	630

NOTE:

100A is the smallest BS 88 fuse size fitted by Electricity North West Limited. This will not provide overload protection for these 2 smallest transformer sizes.

13.3 Low Voltage Cable Distributors

The requirements of section 13.2 shall apply.

The distributor shall be designed such that the fuse-link operating time does not exceed 100s.

Tables 3A and 3B to 3I contain information to permit the selection of fuse-link current ratings for the protection of LV cable distributors.

The data given in Tables 3B to 3I, which give the cable data and maximum distributor loop impedance, are based on the following considerations:-

Cables are protected by HRC fuse-links in accordance with ENA TS 12-8 and BS-HD 60269:2010/BS 88-2:2010 (BS 88). No additional allowance has been made for fuse-link operation outside the BS 88 time/current zones. (Manufacturers are allowed ±10% on their published curves).

The fault is assumed to be a single phase to earth fault. Phase resistance values are derived from CP204 and adjusted to 50°C. Phase reactance values are taken from CP204. Earth-return/neutral resistance and reactance values are derived from CP204, using the formulae Re = (R0 - R1)/3 and Xe = (X0 - X1)/3.

For 4-core cables, separate entries are included for operation as SNE and with neutral and sheath bonded. Neutral-earth bonds have their full effect only on the part of the distributor downstream of the bond. Accordingly, the network shall first be analysed using the SNE values. Only, if loop impedances are found to be high, but only downstream of known bonded sections, may the bonded values be substituted in those sections upstream of the bonds.

A minimum phase to neutral substation voltage of 240V is considered. A factor of 0.85 has been used in deriving the maximum earth-fault loop impedances, to allow for fault impedance.

On PVC sheathed cables the sheath temperature is not to exceed 160°C.

Ferrule temperature is not to exceed the melting point of solder, taken as 185°C.

NOTE:

Where the temperature limit of cable and connector is higher than the above limits then the loop impedance can be re-calculated using the methods outlined in Appendix T. This is only necessary for those cases where the maximum loop impedance in the tables is limited by a thermal limit.

Impedances of transformers are taken from CP204, adjusted to 240V.

A source impedance equivalent to 50MVA (purely inductive) has been assumed, ie the transformer is assumed to have an HV cable infeed. The tables are also applicable where the transformer has an HV overhead line infeed of typical X/R ratio, with the same fault level, the inclusion of the resistive component having an insignificant effect.

13.3.1 Procedure for Selecting a Fuse-link Rating

Refer to Table 2A and note the maximum fuse-link rating for which discrimination is maintained across the associated distribution transformer.

From Table 3A note the preferred fuse-link rating for the largest cable section in the distributor (ignoring any short lengths with increased conductor section used immediately from a substation or PMT with no significant amount of load connected to it, in accordance with 13.2). Establish a fuse-link rating that will maintain discrimination and enable the distributor to be loaded up to its cyclic rating in accordance with 13.2.

Using the appropriate Table 3B to 3I check that the chosen fuse-link will protect the whole distributor (using earth-fault loop impedance) from the substation to a fault position at the remote end of each branch of the distributor (excluding the service connection). For composite distributors, it is necessary to add the given loop impedances to calculate the total loop impedance for the distributor. It is quite permissible to add the loop impedances arithmetically in this case. For each constituent cable type in the distributor check that the maximum value of loop impedance against each, for the chosen fuse-link, is greater than the total loop impedance of the whole distributor.

NOTE:

The allowable fuse size to protect the whole feeder is frequently determined by a cable size that is subject to a thermal limit. This arises because, for a given fuse size, the fault must be cleared in less than 100s to prevent the thermal limit being exceeded. Thus, a higher fault current is required in these cases and if the total loop impedance is too high to give the required fault current then a smaller fuse size is required to ensure that cable sections with a thermal limit are protected. Where such a section occurs in the middle of a distributor be aware that downstream larger cable sizes that are not subject to a thermal limit may appear to be protected by a larger fuse size as the clearance time may be within the 100s requirement. However, use of the larger fuse size is not acceptable since the upstream cable sections with a thermal limit would then not be protected i.e. the thermal limit would be exceeded.

Whilst use of the CP331 tables will allow correct selection of the fuse size to protect the whole distributor, LV AFFIRM provides a more comprehensive solution by, in addition to selecting the correct fuse size, displaying the unprotected lengths of all sections of the distributor for all fuse sizes.

Where, in order to ensure HV/LV discrimination, and the protection of the whole length of the distributor a fuse-link rating less than the preferred rating given in Table 3A is required, a fuse-link to suit the MD of the distributor shall be established in accordance with 13.2. The selected fuse-link shall be re-checked in accordance with the above.

If the HV system fault level is below 50MVA, then the values given in this CP may be inappropriate. In these cases the maximum length of protected LV cable shall be calculated from first principles, using the criteria given in this section and the methods outlined in Appendix T. Guidance may be sought from the Policy and Standards section.

NOTE:

As a guide, the maximum distributor loop impedance is reduced by ~1-2% at a system fault level of 10MVA.

Table 3A – Preferred Fuse-Links Related to Largest Cable Section in a Distributor [1]

CABLE	CONDUCTOR SECTION	PREFERRED FUSE-LINK RATING (A)
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	315 500 500[2] 630
4-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	315 500 500[2] 630
CONSAC	95mm^2 185mm^2 300mm^2	315 400[2] 630
4-core Aluminium (PILC)	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	250 355 400[2] 630 250 355 500 630
4-core Copper (PILC)	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	160 200 200 250 250 315 355 400 500 500 630 630[2] 630[2]

NOTE:

(a) Select cable size in accordance with section 13.2.

(b) The cyclic rating of the distributor is limited to the rating of fuse-link. This shall be stated on a label attached to the distribution board.

Table 3B – Distributor Data and Maximum Distributor Loop Impedance 25kVA (3 phase) Transformers

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 100A (100S OPERATION)
3-core Waveform	95mm² 185mm² 240mm² 300mm²	0.687 0.361 0.318 0.291	0.501 0.486 0.482 0.480
CONSAC	95mm² 185mm² 300mm²	0.659 0.347 0.221	0.503 0.489 0.475
4-core Waveform SNE	95mm² 185mm² 240mm² 300mm²	0.687 0.361 0.318 0.290	0.502 0.486 0.483 0.481
4-core Waveform with N-E bond	95mm² 185mm² 240mm² 300mm²	0.528 0.280 0.228 0.194	0.498 0.480 0.473 0.467
4-core Aluminium (PILC) SNE	70mm² 120mm² 185mm² 300mm² 0.10in² 0.20in² 0.30in² 0.50in²	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.512 0.507 0.500 0.491 0.510 0.503 0.496 0.485
4-core Aluminium (PILC) with N-E bond	70mm² 120mm² 185mm² 300mm² 0.10in² 0.20in² 0.30in² 0.50in²	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.508 0.500 0.489 0.475 0.507 0.496 0.486 0.472
4-core Copper (PILC) SNE	0.0225in² 0.040in² 0.050in² 0.060in² 0.075in² 0.100in² 0.120in² 0.150in² 0.200in² 0.250in² 0.300in² 0.400in² 0.500in²	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.461* 0.514 0.513 0.512 0.511 0.508 0.507 0.504 0.500 0.496 0.493 0.485 0.480

4-core Copper (PILC) with N-E bond	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.266 1.331 1.115 0.899 0.764 0.540 0.479 0.390 0.304 0.255 0.221 0.159 0.137	0.461* 0.512 0.511 0.508 0.506 0.500 0.498 0.493 0.486 0.481 0.476 0.463 0.457

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3C – Distributor Data and Maximum Distributor Loop Impedance 50kVA (3 phase) Transformers

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	**CONDUCTOR SECTION**	**EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)**	**FUSE-LINK RATING 160A (100S OPERATION)**
3-core Waveform	95mm² 185mm² 240mm² 300mm²	0.687 0.361 0.318 0.291	0.339 0.329 0.327 0.325
CONSAC	95mm² 185mm² 300mm²	0.659 0.347 0.221	0.340 0.331 0.322
4-core Waveform SNE	95mm² 185mm² 240mm² 300mm²	0.687 0.361 0.318 0.290	0.339 0.329 0.327 0.326
4-core Waveform with N-E bond	95mm² 185mm² 240mm² 300mm²	0.528 0.280 0.228 0.194	0.337 0.325 0.321 0.317
4-core Aluminium (PILC) SNE	70mm² 120mm² 185mm² 300mm² 0.10in² 0.20in² 0.30in² 0.50in²	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.346 0.342 0.338 0.332 0.344 0.340 0.336 0.328
4-core Aluminium (PILC) with N-E bond	70mm² 120mm² 185mm² 300mm² 0.10in² 0.20in² 0.30in² 0.50in²	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.343 0.338 0.331 0.322 0.343 0.336 0.329 0.320
4-core Copper (PILC) SNE	0.0225in² 0.040in² 0.050in² 0.060in² 0.075in² 0.100in² 0.120in² 0.150in² 0.200in² 0.250in² 0.300in² 0.400in² 0.500in²	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.189* 0.317* 0.346 0.345 0.345 0.343 0.342 0.341 0.338 0.336 0.334 0.329 0.325

4-core Copper (PILC) with N-E bond	0.0225in^2	2.266	0.189*
	0.040in^2	1.331	0.316*
	0.050in^2	1.115	0.345
	0.060in^2	0.899	0.343
	0.075in^2	0.764	0.342
	0.100in^2	0.540	0.338
	0.120in^2	0.479	0.337
	0.150in^2	0.390	0.334
	0.200in^2	0.304	0.329
	0.250in^2	0.255	0.326
	0.300in^2	0.221	0.323
	0.400in^2	0.159	0.314
	0.500in^2	0.137	0.310

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3D – Distributor Data and Maximum Distributor Loop Impedance 100kVA Transformers

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 200A (100S OPERATION)
3-core Waveform	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.687 0.361 0.318 0.291	0.288 0.282 0.280 0.279
CONSAC	$95mm^2$ $185mm^2$ $300mm^2$	0.659 0.347 0.221	0.289 0.283 0.277
4-core Waveform SNE	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.687 0.361 0.318 0.290	0.289 0.282 0.281 0.280
4-core Waveform with N-E bond	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.528 0.280 0.228 0.194	0.287 0.279 0.276 0.273
4-core Aluminium (PILC) SNE	$70mm^2$ $120mm^2$ $185mm^2$ $300mm^2$ $0.10in^2$ $0.20in^2$ $0.30in^2$ $0.50in^2$	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.293 0.291 0.288 0.284 0.292 0.289 0.286 0.282
4-core Aluminium (PILC) with N-E bond	$70mm^2$ $120mm^2$ $185mm^2$ $300mm^2$ $0.10in^2$ $0.20in^2$ $0.30in^2$ $0.50in^2$	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.291 0.288 0.283 0.277 0.291 0.286 0.282 0.276
4-core Copper (PILC) SNE	$0.0225in^2$ $0.040in^2$ $0.050in^2$ $0.060in^2$ $0.075in^2$ $0.100in^2$ $0.120in^2$ $0.150in^2$ $0.200in^2$ $0.250in^2$ $0.300in^2$ $0.400in^2$ $0.500in^2$	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.156* 0.239* 0.271* 0.293 0.292 0.291 0.291 0.290 0.288 0.286 0.285 0.282 0.279

4-core Copper (PILC) with N-E bond	0.0225in²	2.266	0.156*
	0.040in²	1.331	0.239*
	0.050in²	1.115	0.271*
	0.060in²	0.899	0.291
	0.075in²	0.764	0.290
	0.100in²	0.540	0.288
	0.120in²	0.479	0.287
	0.150in²	0.390	0.285
	0.200in²	0.304	0.282
	0.250in²	0.255	0.280
	0.300in²	0.221	0.278
	0.400in²	0.159	0.271
	0.500in²	0.137	0.268

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3E – Distributor Data and Maximum Distributor Loop Impedance 200kVA Transformers

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 200A (100S OPERATION)
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.318 0.315 0.314 0.313
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.319 0.315 0.312
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.319 0.315 0.314 0.313
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.318 0.313 0.311 0.309
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.321 0.320 0.318 0.316 0.320 0.319 0.317 0.314
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.320 0.318 0.315 0.312 0.320 0.317 0.315 0.311
4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.187* 0.268* 0.300* 0.321 0.320 0.320 0.320 0.319 0.318 0.317 0.316 0.315 0.313

4-core Copper (PILC) with N-E bond	0.0225in^2	2.266	0.187*
	0.040in^2	1.331	0.268*
	0.050in^2	1.115	0.299*
	0.060in^2	0.899	0.320
	0.075in^2	0.764	0.319
	0.100in^2	0.540	0.318
	0.120in^2	0.479	0.318
	0.150in^2	0.390	0.316
	0.200in^2	0.304	0.315
	0.250in^2	0.255	0.313
	0.300in^2	0.221	0.312
	0.400in^2	0.159	0.308
	0.500in^2	0.137	0.306

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3F – Distributor Data and Maximum Distributor Loop Impedance 300kVA / 315kVA Transformers

Distributor Data			Maximum Earth-Fault Loop Impedance (Ω) to Ensure Distributor Protection		
Cable Type	Conductor Section	Earth-Fault Loop Impedance per km (Ω)	Fuse-Link Rating (100s operation)		
			200A	250A	315A
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.327 0.324 0.323 0.323	0.255 0.252 0.251 0.251	0.207 0.204 0.203 0.203
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.327 0.324 0.322	0.255 0.253 0.250	0.207 0.204 0.202
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.327 0.324 0.323 0.323	0.255 0.252 0.252 0.251	0.207 0.204 0.203 0.203
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.326 0.323 0.321 0.320	0.254 0.251 0.250 0.248	0.206 0.203 0.202 0.200
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.328 0.328 0.326 0.325 0.328 0.327 0.326 0.324	0.240* 0..256 0.255 0.253 0.235* 0.255 0.254 0.252	0.182* 0.208 0.206 0.205 0.173* 0.207 0.206 0.204
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.328 0.326 0.324 0.322 0.328 0.326 0.324 0.321	0.239* 0.254 0.253 0.250 0.234* 0.254 0.252 0.249	0.181* 0.206 0.205 0.202 0.172* 0.206 0.204 0.201
4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.195* 0.276* 0.307* 0.328 0.328 0.328 0.328 0.327 0.326 0.326 0.325 0.324 0.323	0.110* 0.182* 0.203* 0.235* 0.256 0.256 0.256 0.255 0.255 0.254 0.253 0.252 0.251	0.067* 0.105* 0.135* 0.173* 0.182* 0.208 0.207 0.207 0.206 0.206 0.205 0.204 0.203

4-core Copper (PILC) with N-E bond	0.0225in^2	2.266	0.195*	0.110*	0.067*
	0.040in^2	1.331	0.276*	0.182*	0.105*
	0.050in^2	1.115	0.307*	0.202*	0.135*
	0.060in^2	0.899	0.328	0.235*	0.172*
	0.075in^2	0.764	0.327	0.256	0.181*
	0.100in^2	0.540	0.326	0.255	0.206
	0.120in^2	0.479	0.326	0.254	0.206
	0.150in^2	0.390	0.325	0.253	0.205
	0.200in^2	0.304	0.324	0.252	0.204
	0.250in^2	0.255	0.323	0.251	0.203
	0.300in^2	0.221	0.322	0.250	0.202
	0.400in^2	0.159	0.319	0.247	0.199
	0.500in^2	0.137	0.318	0.246	0.198

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3G – Distributor Data and Maximum Distributor Loop Impedance 500kVA Transformers

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION				
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (100S OPERATION)				
			200A	250A	315A	355A	400A
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.333 0.331 0.330 0.330	0.261 0.259 0.259 0.258	0.213 0.211 0.211 0.210	0.152* 0.172 0.171 0.171	0.119* 0.147 0.147 0.146
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.333 0.331 0.329	0.261 0.259 0.258	0.213 0.211 0.210	0.152* 0.172 0.170	0.120* 0.148 0.146
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.333 0.331 0.330 0.330	0.261 0.259 0.259 0.258	0.213 0.211 0.211 0.210	0.152* 0.172 0.171 0.171	0.119* 0.147 0.147 0.147
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.332 0.330 0.329 0.328	0.261 0.258 0.257 0.257	0.213 0.210 0.209 0.209	0.152* 0.171 0.170 0.169	0.119* 0.147 0.146 0.145
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.334 0.333 0.332 0.331 0.334 0.333 0.332 0.331	0.245* 0.261 0.261 0.260 0.241* 0.261 0.260 0.259	0.188* 0.213 0.213 0.212 0.179* 0.213 0.212 0.211	0.129* 0.174 0.173 0.172 0.120* 0.174 0.173 0.172	0.102* 0.136* 0.149 0.148 0.090* 0.143* 0.148 0.147
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.333 0.332 0.331 0.329 0.333 0.332 0.331 0.329	0.245* 0.261 0.259 0.258 0.240* 0.260 0.259 0.257	0.187* 0.213 0.211 0.210 0.178* 0.212 0.211 0.209	0.129* 0.173 0.172 0.170 0.120* 0.173 0.172 0.170	0.101* 0.135* 0.148 0.146 0.089* 0.143* 0.147 0.145

4-core Copper (PILC) SNE	0.0225in^2	2.525	0.201*	0.117*	0.074*	0.046*	0.039*
	0.040in^2	1.708	0.281*	0.188*	0.111*	0.092*	0.066*
	0.050in^2	1.481	0.313*	0.208*	0.142*	0.106*	0.076*
	0.060in^2	1.254	0.334	0.241*	0.179*	0.120*	0.090*
	0.075in^2	1.109	0.334	0.262	0.188*	0.139*	0.106*
	0.100in^2	0.867	0.333	0.262	0.214	0.166*	0.129*
	0.120in^2	0.787	0.333	0.261	0.213	0.174	0.136*
	0.150in^2	0.667	0.333	0.261	0.213	0.174	0.149
	0.200in^2	0.519	0.332	0.261	0.213	0.173	0.149
	0.250in^2	0.441	0.332	0.260	0.212	0.173	0.148
	0.300in^2	0.383	0.332	0.260	0.212	0.173	0.148
	0.400in^2	0.289	0.331	0.259	0.211	0.172	0.147
	0.500in^2	0.243	0.330	0.258	0.210	0.171	0.146
4-core Copper (PILC) with N-E bond	0.0225in^2	2.266	0.201*	0.117*	0.074*	0.046*	0.039*
	0.040in^2	1.331	0.281*	0.188*	0.111*	0.092*	0.066*
	0.050in^2	1.115	0.312*	0.208*	0.141*	0.106*	0.075*
	0.060in^2	0.899	0.333	0.240*	0.178*	0.120*	0.089*
	0.075in^2	0.764	0.333	0.261	0.187*	0.138*	0.105*
	0.100in^2	0.540	0.332	0.261	0.213	0.166*	0.128*
	0.120in^2	0.479	0.332	0.260	0.212	0.173	0.135*
	0.150in^2	0.390	0.332	0.260	0.212	0.173	0.148
	0.200in^2	0.304	0.331	0.259	0.211	0.172	0.147
	0.250in^2	0.255	0.330	0.258	0.210	0.171	0.147
	0.300in^2	0.221	0.329	0.258	0.210	0.170	0.146
	0.400in^2	0.159	0.328	0.256	0.208	0.169	0.144
	0.500in^2	0.137	0.327	0.255	0.207	0.168	0.143

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3H – Distributor Data and Maximum Distributor Loop Impedance 750kVA / 800kVA Transformers

Distributor Data			Maximum Earth-Fault Loop Impedance (Ω) to Ensure Distributor Protection						
Cable Type	Conductor Section	Earth-Fault Loop Impedance per km (Ω)	Fuse-Link Rating (100s operation)						
			200A	250A	315A	355A	400A	500A	630A
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.335 0.334 0.334 0.333	0.264 0.262 0.262 0.262	0.216 0.214 0.214 0.214	0.155 * 0.175 0.175 0.175	0.122 * 0.151 0.150 0.150	0.080 * 0.114 0.113 0.113	0.045* 0.083* 0.090 0.090
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.335 0.334 0.333	0.264 0.263 0.261	0.216 0.215 0.213	0.155 * 0.175 0.174	0.123 * 0.151 0.150	0.080 * 0.114 0.113	0.045* 0.083* 0.090
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.335 0.334 0.334 0.333	0.264 0.262 0.262 0.262	0.216 0.214 0.214 0.214	0.155 * 0.175 0.175 0.175	0.122 * 0.151 0.150 0.150	0.080 * 0.114 0.113 0.113	0.045* 0.083* 0.090 0.090
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.335 0.333 0.333 0.332	0.263 0.262 0.261 0.260	0.215 0.214 0.213 0.212	0.155 * 0.175 0.174 0.173	0.122 * 0.150 0.149 0.149	0.079 * 0.113 0.112 0.112	0.045* 0.083* 0.089 0.089
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.336 0.336 0.335 0.334 0.336 0.335 0.335 0.334	0.248 * 0.264 0.264 0.263 0.243 * 0.264 0.263 0.262	0.190 * 0.216 0.216 0.215 0.181 * 0.216 0.215 0.214	0.132 * 0.177 0.176 0.176 0.123 * 0.176 0.176 0.175	0.104 * 0.139 * 0.152 0.151 0.092 * 0.146 * 0.151 0.151	0.063 * 0.092 * 0.115 0.114 0.061 * 0.097 * 0.114 0.113	0.035* 0.059* 0.084* 0.091 0.033* 0.062* 0.085* 0.090
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.336 0.335 0.334 0.333 0.336 0.335 0.334 0.333	0.247 * 0.263 0.263 0.261 0.243 * 0.263 0.262 0.261	0.190 * 0.216 0.215 0.213 0.181 * 0.215 0.214 0.213	0.131 * 0.176 0.175 0.174 0.123 * 0.176 0.175 0.174	0.104 * 0.138 * 0.151 0.150 0.092 * 0.146 * 0.151 0.149	0.063 * 0.092 * 0.114 0.113 0.061 * 0.096 * 0.114 0.112	.035* 0.059* 0.083* 0.090 0.032* 0.062* 0.084* 0.089

4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.203 * 0.284 * 0.315 * 0.336 0.336 0.336 0.336 0.335 0.335 0.335 0.335 0.334 0.333	0.119 * 0.190 * 0.211 * 0.243 * 0.264 0.264 0.264 0.264 0.263 0.263 0.263 0.262 0.262	0.077 * 0.114 * 0.144 * 0.181 * 0.190 * 0.216 0.216 0.216 0.216 0.215 0.215 0.214 0.214	0.050 * 0.095 * 0.109 * 0.123 * 0.141 * 0.169 * 0.177 0.177 0.176 0.176 0.176 0.175 0.175	0.043 * 0.070 * 0.079 * 0.093 * 0.109 * 0.131 * 0.139 * 0.152 0.152 0.151 0.151 0.151 0.150	- 0.035 * 0.045 * 0.054 * 0.067 * 0.084 * 0.088 * 0.112 * 0.115 0.114 0.114 0.113 0.113	- 0.015* 0.023* 0.028* 0.043* 0.054* 0.061* 0.069* 0.088* 0.091 0.091 0.091 0.090
4-core Copper (PILC) with N-E bond	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.266 1.331 1.115 0.899 0.764 0.540 0.479 0.390 0.304 0.255 0.221 0.159 0.137	0.203 * 0.283 * 0.315 * 0.336 0.336 0.335 0.335 0.335 0.334 0.333 0.333 0.332 0.331	0.119 * 0.190 * 0.210 * 0.243 * 0.264 0.263 0.263 0.263 0.262 0.262 0.261 0.260 0.259	0.077 * 0.114 * 0.144 * 0.181 * 0.190 * 0.216 0.215 0.215 0.214 0.214 0.213 0.212 0.211	0.049 * 0.095 * 0.109 * 0.122 * 0.141 * 0.169 * 0.176 0.176 0.175 0.175 0.174 0.173 0.172	0.043 * 0.069 * 0.078 * 0.092 * 0.108 * 0.131 * 0.138 * 0.151 0.151 0.150 0.150 0.148 0.148	- 0.035 * 0.045 * 0.054 * 0.066 * 0.083 * 0.087 * 0.111 * 0.114 0.113 0.113 0.111 0.111	- 0.015* 0.023* 0.027* 0.042* 0.053* 0.060* 0.068* 0.087* 0.090 0.080 0.088 0.088

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 3I – Distributor Data and Maximum Distributor Loop Impedance 1000kVA Transformers

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION						
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (100S OPERATION)						
			200A	250A	315A	355A	400A	500A	630A
3-core Waveform	95mm^2	0.687	0.337	0.265	0.217	0.156*	0.124*	0.081*	0.047*
	185mm^2	0.361	0.335	0.264	0.216	0.177	0.152	0.115	0.085*
	240mm^2	0.318	0.335	0.264	0.216	0.176	0.152	0.115	0.092
	300mm^2	0.291	0.335	0.263	0.215	0.176	0.152	0.115	0.092
CONSAC	95mm^2	0.659	0.337	0.265	0.217	0.156*	0.124*	0.081*	0.047*
	185mm^2	0.347	0.336	0.264	0.216	0.177	0.152	0.115	0.085*
	300mm^2	0.221	0.335	0.263	0.215	0.176	0.151	0.114	0.091
4-core Waveform SNE	95mm^2	0.687	0.337	0.265	0.217	0.156*	0.124*	0.081*	0.047*
	185mm^2	0.361	0.335	0.264	0.216	0.177	0.152	0.115	0.085*
	240mm^2	0.318	0.335	0.264	0.216	0.176	0.152	0.115	0.092
	300mm^2	0.290	0.335	0.263	0.216	0.176	0.152	0.115	0.092
4-core Waveform with N-E bond	95mm^2	0.528	0.336	0.265	0.217	0.156*	0.124*	0.081*	0.047*
	185mm^2	0.280	0.335	0.263	0.216	0.176	0.152	0.115	0.084*
	240mm^2	0.228	0.335	0.263	0.215	0.176	0.151	0.114	0.091
	300mm^2	0.194	0.334	0.262	0.214	0.175	0.151	0.114	0.091
4-core Aluminium (PILC) SNE	70mm^2	1.200	0.337	0.249*	0.191*	0.133*	0.106*	0.065*	0.037*
	120mm^2	0.778	0.337	0.265	0.217	0.178	0.140*	0.094*	0.061*
	185mm^2	0.529	0.336	0.265	0.217	0.178	0.153	0.116	0.086*
	300mm^2	0.356	0.336	0.264	0.216	0.177	0.153	0.116	0.093
	0.10in^2	1.118	0.337	0.244*	0.182*	0.124*	0.094*	0.062*	0.034*
	0.20in^2	0.640	0.337	0.265	0.217	0.178	0.148*	0.098*	0.064*
	0.30in^2	0.456	0.336	0.265	0.217	0.177	0.153	0.116	0.086*
	0.50in^2	0.300	0.335	0.264	0.216	0.177	0.152	0.115	0.092
4-core Aluminium (PILC) with N-E bond	70mm^2	0.856	0.337	0.249*	0.191*	0.133*	0.105*	0.064*	0.037*
	120mm^2	0.501	0.336	0.265	0.217	0.178	0.139*	0.093*	0.061*
	185mm^2	0.332	0.336	0.264	0.216	0.177	0.152	0.115	0.085*
	300mm^2	0.213	0.335	0.263	0.215	0.176	0.151	0.114	0.091
	0.10in^2	0.856	0.337	0.244*	0.182*	0.124*	0.094*	0.062*	0.034*
	0.20in^2	0.448	0.336	0.265	0.217	0.177	0.147*	0.098*	0.064*
	0.30in^2	0.301	0.335	0.264	0.216	0.177	0.152	0.115	0.086*
	0.50in^2	0.202	0.334	0.263	0.215	0.176	0.151	0.114	0.091

4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.204 * 0.285 * 0.316 * 0.337 0.337 0.337 0.337 0.337 0.336 0.336 0.336 0.335 0.335	0.120 * 0.191 * 0.212 * 0.244 * 0.265 0.265 0.265 0.265 0.265 0.265 0.264 0.264 0.263	0.079 * 0.115 * 0.145 * 0.182 * 0.191 * 0.217 0.217 0.217 0.217 0.217 0.216 0.216 0.215	0.051 * 0.096 * 0.110 * 0.124 * 0.143 * 0.170 * 0.178 0.178 0.178 0.177 0.177 0.177 0.176	0.045 * 0.071 * 0.080 * 0.094 * 0.110 * 0.133 * 0.140 * 0.153 0.153 0.153 0.153 0.152 0.152	- 0.037 * 0.047 * 0.056 * 0.068 * 0.085 * 0.089 * 0.113 * 0.116 0.116 0.116 0.115 0.115	- 0.018* 0.025* 0.030* 0.044* 0.055* 0.062* 0.070* 0.090* 0.093 0.093 0.092 0.092
4-core Copper (PILC) with N-E bond	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.266 1.331 1.115 0.899 0.764 0.540 0.479 0.390 0.304 0.255 0.221 0.159 0.137	0.204 * 0.284 * 0.316 * 0.337 0.337 0.336 0.336 0.336 0.335 0.335 0.335 0.334 0.333	0.120 * 0.191 * 0.212 * 0.244 * 0.265 0.265 0.265 0.264 0.264 0.263 0.263 0.262 0.261	0.079 * 0.115 * 0.145 * 0.182 * 0.191 * 0.217 0.217 0.216 0.216 0.216 0.215 0.214 0.213	0.051 * 0.096 * 0.110 * 0.124 * 0.142 * 0.170 * 0.177 0.177 0.177 0.176 0.176 0.175 0.174	0.044 * 0.071 * 0.080 * 0.094 * 0.110 * 0.132 * 0.139 * 0.153 0.152 0.152 0.151 0.150 0.150	- 0.036 * 0.047 * 0.055 * 0.068 * 0.085 * 0.089 * 0.112 * 0.115 0.115 0.114 0.113 0.113	- 0.018* 0.025* 0.029* 0.044* 0.055* 0.062* 0.070* 0.089* 0.092 0.092 0.090 0.090

* Maximum value of loop impedance limited due to the thermal limit of the cable

13.4 Low Voltage Overhead Line Distributors

The requirements of Section 13.2 shall apply.

The distributor shall be designed such that the fuse-link operating time does not exceed 10s, except where Aerial Bundled Conductors (ABC) are to be installed as part of the distributor and then the use of 30s fuse-link operating times can be considered for the ABC section only. This increase in operating time has been introduced because of the increased safety afforded by the covering of the ABC. However, a risk assessment shall be undertaken of the nature of the surroundings and on the activities undertaken or likely to be undertaken in the vicinity of the equipment, in accordance with EPD405, before implementing a scheme using this increased operating time.

Tables 4A and 4B to 4V contain information to permit the selection of fuse-link current ratings for the protection of LV overhead distributors.

The data given in Tables 4B to 4V are based on the following considerations: -

Overhead lines are protected by HRC fuse-links in accordance with ENA TS 12-8 and BS 88 Part 5 (1988). No additional allowance has been made for fuse-link operation outside the BS 88 time/current zones. (Manufacturers are allowed ±10% on their published curves)

Immediately prior to fault a conductor temperature of 50°C is assumed.

The maximum conductor temperature is not to exceed 200°C (including ABC).

A minimum phase-neutral substation voltage of 240V is assumed. A factor of 0.85 has been used in deriving the maximum impedance values to allow for fault impedance.

Impedances of transformers are taken from CP204, adjusted to 240V.

Tables are provided for single-phase and split-phase transformers. It is assumed that a 3-wire line from a single-phase transformer has a conductor sequence P-N-E, whereas that from a split-phase transformer it is P-P-N.

The worst condition for fuse reach is considered to be a fault between the neutral and the phase conductor furthest from the neutral. For an open wire line this corresponds to a fault between the topmost phase conductor and the neutral, taken to be the conductor below the lowest phase conductor, i.e. the worst case situation is a fault on a service conductor connected between neutral and the top phase conductor. The loop impedance values in the tables are not taken from CP204 but are calculated using the separation between the top phase and the neutral conductor. For ABC conductors the loop impedance values are calculated between the furthest most phase and neutral conductors in the bundle.

The tables of maximum loop impedance are calculated for a 4-wire distributor, the impedance values being based on the maximum separation between the phase and neutral conductor (the same approach has been adopted in LV AFFIRM). This approach provides a suitable basis for the fusing calculations of all OHL constructions:

Both the 4 and 5-wire open wire constructions are covered since the maximum phase-neutral conductor separations are the same in both cases.

Whilst, the fuse reach for 2-wire and 3-wire constructions are under-estimated, the fuse clearance times will be less than 10s i.e. calculations will fail-safe. The shortfall in maximum fuse reach is small (typically 2-20m) and the likelihood of a 2 or 3-wire distributor length falling in this error range is small. The consequence would be a selection of a smaller fuse size than was actually necessary in these small numbers of cases and this may not be an issue if the fuse size is already limited by volt drop considerations.

For ABC the shortfall in fuse reach is smaller since the reactance of the ABC is much smaller making the difference between the 2, 3 and 4-wire impedances much less significant. Since new construction uses ABC, the accuracy is acceptable. Whilst the error in the open wire case may be an issue in a small number of situations of existing distributors, in practice any changes to the distributor is likely to use ABC and so again the accuracy is acceptable.

NOTE:

Previous versions of Module Ten had separate tables for 2, 3, 4 and 5-wire constructions. The logic being that the worst possible case situation was a fault between the top (furthest) phase conductor and the bottom conductor (neutral or earth dependent on construction) with tables covering reduced cross-section neutral and earth-wires. However, a fault to the earth conductor, being situated below the neutral, is a very unlikely event and restricted the calculated value of maximum fuse reach. Thus faults to the earth conductor have not been considered in this current version.

Whilst reduced cross-section neutral conductors are allowable under the Electricity Supply Regulations such installations have rarely been used on the Network. Thus separate tables have not been included – however, refer to section 13.4.1 for advice in such cases.

A source impedance equivalent to 10MVA (purely inductive) has been assumed i.e. the transformer assumed to have an HV overhead line infeed. The tables are applicable to where the transformer has (i) a cable infeed with the same fault level and (ii) an overhead line infeed of typical X/R ratio, with the same fault level, the inclusion of the resistive component having an insignificant effect.

13.4.1 Procedure for Selecting a Fuse-Link Rating

From Table 2A note the maximum fuse-link rating for which discrimination is maintained across the associated distribution transformer.

From Table 4A note the preferred fuse-link rating for the largest conductor section in the distributor (ignoring any short lengths with increased conductor section used immediately from a substation or PMT with no significant amount of load connected to it, in accordance with 3). Establish a fuse-link rating that will maintain discrimination and enable the distributor to be loaded up to its full rating in accordance with 13.2.

Using the appropriate Table 4B to 4V check that the chosen fuse-link will protect the whole distributor (using earth-fault loop impedance) from the substation to a fault position at the remote end of each branch of the distributor including overhead service connections. For composite distributors it is necessary to add the given loop impedances to calculate the total loop impedance of the distributor. It is quite permissible to add the loop impedances arithmetically for these cases. (See also the note attached to section 13.3.1)

Where there is a need to consider a distributor or section of distributor with a reduced cross-section neutral, use the table entry corresponding to the reduced cross-section. This will underestimate the fuse reach but will fail-safe by ensuring clearance times are always less than 10s and, in particular, will ensure that cases where a reduced cross-section neutral conductor is thermally limited are correctly fused.

For each constituent line type in the distributor, check that the maximum value of loop impedance against each, for the chosen fuse-link, is greater than the loop impedance of the whole distributor.

Where a fuse-link smaller than the preferred rating of Table 4A is required, say in order to protect the whole of a distributor and its services, a fuse-link to suit the MD of the distributor shall be chosen in accordance with 13.2. The selected fuse-link shall be checked in accordance with the above.

If the HV system fault level is below 10MVA, then the values given in this CP may be inappropriate. In these cases the maximum length of protected LV line shall be calculated from first principles, using the criteria given in this section and the methods outlined in Appendix T. Guidance may be sought from the Policy and Standards section.

Table 4A – Preferred Fuse-Links Related to Largest Conductor Section in a Distributor [1]

CONDUCTOR	CROSS-SECTION	PREFERRED FUSE-LINK RATING (A) [2]
Copper open wire	$0.025in^2$ (strand) $0.025in^2$ (solid) $0.040in^2$ (strand) $0.050in^2$ (strand) $0.050in^2$ (solid) $0.060in^2$ (strand) $0.075in^2$ (strand) $0.100in^2$ (strand) $0.150in^2$ (strand)	160 160 200 315 315 315 355 400 500
Aluminium open wire	$0.025in^2$ (Cu Eq) $0.040in^2$ (Cu Eq) $0.050in^2$ (Cu Eq) $0.100in^2$ (Cu Eq) $0.150in^2$ (Cu Eq) $50mm^2$ $100mm^2$	200 250 315 400 500 315 400
ABC	$25mm^2$ $35mm^2$ $50mm^2$ $70mm^2$ $95mm^2$	100 160 160 200 315

NOTE:

(a) Select cable size in accordance with section 13.2.

(b) The preferred fuse-link ratings are based on the conductor rating. The smaller sizes of transformer will need smaller fuse-link ratings than the preferred ratings. In this case the required fuse-link rating shall be stated on a label, or other indelible means, attached to the fuse way.

Table 4B – Distributor Data/Maximum Distributor Loop Impedance 5kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 100A
		10S OPERATION
Copper open wire		
0.025in² (solid)	2.580	0.008
0.050in² (solid)	1.432	0.007
0.025in² (strand)	2.542	0.008
0.040in² (strand)	1.740	0.007
0.050in² (strand)	1.410	0.007
0.060in² (strand)	1.265	0.007
0.075in² (strand)	1.096	0.007
0.100in² (strand)	0.917	0.007
0.150in² (strand)	0.778	0.007
Aluminium open wire		
0.025in² (Cu Eq)	2.547	0.008
0.040in² (Cu Eq)	1.664	0.007
0.050in² (Cu Eq)	1.409	0.007
0.100in² (Cu Eq)	0.895	0.007
0.150in² (Cu Eq)	0.754	0.007
50mm²	1.403	0.007
100mm²	0.894	0.007
ABC		
25mm²	2.699	0.009
35mm²	1.957	0.009
50mm²	1.452	0.008
70mm²	1.013	0.008
95mm²	0.744	0.008
		30s operation
ABC		
25mm²	2.699	0.122
35mm²	1.957	0.120
50mm²	1.452	0.118
70mm²	1.013	0.115
95mm²	0.744	0.111

Table 4C – Distributor Data/Maximum Distributor Loop Impedance 10kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 100A
		10S OPERATION
Copper open wire		
0.025in^2 (solid)	2.580	0.290
0.050in^2 (solid)	1.432	0.276
0.025in^2 (strand)	2.542	0.290
0.040in^2 (strand)	1.740	0.281
0.050in^2 (strand)	1.410	0.276
0.060in^2 (strand)	1.265	0.273
0.075in^2 (strand)	1.096	0.271
0.100in^2 (strand)	0.917	0.269
0.150in^2 (strand)	0.778	0.271
Aluminium open wire		
0.025in^2 (Cu Eq)	2.547	0.291
0.040in^2 (Cu Eq)	1.664	0.281
0.050in^2 (Cu Eq)	1.409	0.277
0.100in^2 (Cu Eq)	0.895	0.269
0.150in^2 (Cu Eq)	0.754	0.271
50mm^2	1.403	0.277
100mm^2	0.894	0.269
ABC		
25mm^2	2.699	0.312
35mm^2	1.957	0.308
50mm^2	1.452	0.305
70mm^2	1.013	0.299
95mm^2	0.744	0.293
		30s operation
ABC		
25mm^2	2.699	0.412
35mm^2	1.957	0.408
50mm^2	1.452	0.404
70mm^2	1.013	0.398
95mm^2	0.744	0.391

Table 4D - Distributor Data/Maximum Distributor Loop Impedance 15kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)
CONDUCTOR SECTION	**FAULT LOOP IMPEDANCE PER KM (Ω)**	**FUSE-LINK RATING 100A**
		10S OPERATION
Copper open wire		
0.025in^2 (solid)	2.580	0.377
0.050in^2 (solid)	1.432	0.362
0.025in^2 (strand)	2.542	0.377
0.040in^2 (strand)	1.740	0.367
0.050in^2 (strand)	1.410	0.362
0.060in^2 (strand)	1.265	0.360
0.075in^2 (strand)	1.096	0.356
0.100in^2 (strand)	0.917	0.354
0.150in^2 (strand)	0.778	0.354
Aluminium open wire		
0.025in^2 (Cu Eq)	2.547	0.378
0.040in^2 (Cu Eq)	1.664	0.367
0.050in^2 (Cu Eq)	1.409	0.363
0.100in^2 (Cu Eq)	0.895	0.354
0.150in^2 (Cu Eq)	0.754	0.354
50mm^2	1.403	0.363
100mm^2	0.894	0.354
ABC		
25mm^2	2.699	0.397
35mm^2	1.957	0.394
50mm^2	1.452	0.391
70mm^2	1.013	0.386
95mm^2	0.744	0.380
		30s operation
ABC		
25mm^2	2.699	0.495
35mm^2	1.957	0.492
50mm^2	1.452	0.488
70mm^2	1.013	0.483
95mm^2	0.744	0.477

Table 4E - Distributor Data/Maximum Distributor Loop Impedance 16kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 100A
		10S OPERATION
Copper open wire		
$0.025in^2$ (solid)	2.580	0.388
$0.050in^2$ (solid)	1.432	0.373
$0.025in^2$ (strand)	2.542	0.388
$0.040in^2$ (strand)	1.740	0.379
$0.050in^2$ (strand)	1.410	0.374
$0.060in^2$ (strand)	1.265	0.371
$0.075in^2$ (strand)	1.096	0.367
$0.100in^2$ (strand)	0.917	0.364
$0.150in^2$ (strand)	0.778	0.364
Aluminium open wire		
$0.025in^2$ (Cu Eq)	2.547	0.389
$0.040in^2$ (Cu Eq)	1.664	0.379
$0.050in^2$ (Cu Eq)	1.409	0.374
$0.100in^2$ (Cu Eq)	0.895	0.365
$0.150in^2$ (Cu Eq)	0.754	0.364
$50mm^2$	1.403	0.374
$100mm^2$	0.894	0.365
ABC		
$25mm^2$	2.699	0.408
$35mm^2$	1.957	0.405
$50mm^2$	1.452	0.402
$70mm^2$	1.013	0.397
$95mm^2$	0.744	0.391
		30s operation
ABC		
$25mm^2$	2.699	0.506
$35mm^2$	1.957	0.503
$50mm^2$	1.452	0.499
$70mm^2$	1.013	0.494
$95mm^2$	0.744	0.488

Table 4F - Distributor Data/Maximum Distributor Loop Impedance 25kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)	
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING	
		100A	160A
		10S OPERATION	
Copper open wire			
$0.025in^2$ (solid)	2.580	0.445	0.199
$0.050in^2$ (solid)	1.432	0.432	0.189
$0.025in^2$ (strand)	2.542	0.445	0.199
$0.040in^2$ (strand)	1.740	0.437	0.192
$0.050in^2$ (strand)	1.410	0.432	0.189
$0.060in^2$ (strand)	1.265	0.429	0.186
$0.075in^2$ (strand)	1.096	0.426	0.184
$0.100in^2$ (strand)	0.917	0.423	0.181
$0.150in^2$ (strand)	0.778	0.421	0.180
Aluminium open wire			
$0.025in^2$ (Cu Eq)	2.547	0.446	0.200
$0.040in^2$ (Cu Eq)	1.664	0.437	0.192
$0.050in^2$ (Cu Eq)	1.409	0.433	0.189
$0.100in^2$ (Cu Eq)	0.895	0.423	0.181
$0.150in^2$ (Cu Eq)	0.754	0.421	0.180
$50mm^2$	1.403	0.433	0.189
$100mm^2$	0.894	0.423	0.181
ABC			
$25mm^2$	2.699	0.462	0.213
$35mm^2$	1.957	0.459	0.211
$50mm^2$	1.452	0.457	0.209
$70mm^2$	1.013	0.452	0.206
$95mm^2$	0.744	0.448	0.201
		30s operation	
ABC			
$25mm^2$	2.699	0.558	0.256*
$35mm^2$	1.957	0.556	0.287
$50mm^2$	1.452	0.553	0.285
$70mm^2$	1.013	0.549	0.281
$95mm^2$	0.744	0.544	0.276

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4G - Distributor Data/Maximum Distributor Loop Impedance 50kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in^2 (solid)	2.580	0.490	0.248	0.164*
0.050in^2 (solid)	1.432	0.482	0.239	0.173
0.025in^2 (strand)	2.542	0.491	0.248	0.164*
0.040in^2 (strand)	1.740	0.485	0.243	0.176
0.050in^2 (strand)	1.410	0.482	0.239	0.173
0.060in^2 (strand)	1.265	0.480	0.238	0.171
0.075in^2 (strand)	1.096	0.477	0.235	0.169
0.100in^2 (strand)	0.917	0.474	0.232	0.166
0.150in^2 (strand)	0.778	0.472	0.231	0.164
Aluminium open wire				
0.025in^2 (Cu Eq)	2.547	0.491	0.248	0.159*
0.040in^2 (Cu Eq)	1.664	0.485	0.243	0.176
0.050in^2 (Cu Eq)	1.409	0.482	0.240	0.173
0.100in^2 (Cu Eq)	0.895	0.474	0.233	0.167
0.150in^2 (Cu Eq)	0.754	0.472	0.231	0.165
50mm^2	1.403	0.482	0.240	0.173
100mm^2	0.894	0.474	0.233	0.167
ABC				
25mm^2	2.699	0.501	0.258	0.168*
35mm^2	1.957	0.500	0.256	0.189
50mm^2	1.452	0.498	0.255	0.187
70mm^2	1.013	0.496	0.252	0.185
95mm^2	0.744	0.492	0.249	0.182
		30s operation		
ABC				
25mm^2	2.699	0.597	0.299*	0.168*
35mm^2	1.957	0.595	0.330	0.219*
50mm^2	1.452	0.594	0.329	0.245
70mm^2	1.013	0.591	0.326	0.242
95mm^2	0.744	0.588	0.323	0.239

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4H - Distributor Data/Maximum Distributor Loop Impedance 100kVA Single Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in^2 (solid)	2.580	0.507	0.265	0.183*
0.050in^2 (solid)	1.432	0.501	0.260	0.194
0.025in^2 (strand)	2.542	0.507	0.265	0.183*
0.040in^2 (strand)	1.740	0.504	0.262	0.196
0.050in^2 (strand)	1.410	0.502	0.260	0.194
0.060in^2 (strand)	1.265	0.500	0.259	0.192
0.075in^2 (strand)	1.096	0.499	0.257	0.191
0.100in^2 (strand)	0.917	0.497	0.255	0.189
0.150in^2 (strand)	0.778	0.495	0.254	0.188
Aluminium open wire				
0.025in^2 (Cu Eq)	2.547	0.508	0.266	0.178*
0.040in^2 (Cu Eq)	1.664	0.504	0.262	0.196
0.050in^2 (Cu Eq)	1.409	0.502	0.260	0.194
0.100in^2 (Cu Eq)	0.895	0.497	0.256	0.189
0.150in^2 (Cu Eq)	0.754	0.495	0.254	0.188
50mm^2	1.403	0.502	0.260	0.194
100mm^2	0.894	0.497	0.256	0.189
ABC				
25mm^2	2.699	0.514	0.272	0.184*
35mm^2	1.957	0.513	0.271	0.204
50mm^2	1.452	0.512	0.270	0.203
70mm^2	1.013	0.510	0.268	0.202
95mm^2	0.744	0.508	0.266	0.200
		30s operation		
ABC				
25mm^2	2.699	0.609	0.312*	0.184*
35mm^2	1.957	0.608	0.344	0.234*
50mm^2	1.452	0.607	0.343	0.260
70mm^2	1.013	0.605	0.342	0.258
95mm^2	0.744	0.603	0.340	0.256

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4I – Distributor Data/Maximum Distributor Loop Impedance 25kVA Split Phase Transformer – 3-wire in 240V System

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)	
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING	
		100A	160A
		10S OPERATION	
Copper open wire			
$0.025in^2$ (solid)	2.580	0.425	0.180
$0.050in^2$ (solid)	1.432	0.414	0.172
$0.025in^2$ (strand)	2.542	0.425	0.180
$0.040in^2$ (strand)	1.740	0.418	0.175
$0.050in^2$ (strand)	1.410	0.415	0.172
$0.060in^2$ (strand)	1.265	0.413	0.170
$0.075in^2$ (strand)	1.096	0.410	0.169
$0.100in^2$ (strand)	0.917	0.409	0.167
$0.150in^2$ (strand)	0.778	0.409	0.168
Aluminium open wire			
$0.025in^2$ (Cu Eq)	2.547	0.426	0.181
$0.040in^2$ (Cu Eq)	1.664	0.418	0.175
$0.050in^2$ (Cu Eq)	1.409	0.415	0.172
$0.100in^2$ (Cu Eq)	0.895	0.409	0.167
$0.150in^2$ (Cu Eq)	0.754	0.409	0.168
$50mm^2$	1.403	0.415	0.172
$100mm^2$	0.894	0.409	0.167
ABC			
$25mm^2$	2.699	0.440	0.192
$35mm^2$	1.957	0.438	0.190
$50mm^2$	1.452	0.435	0.188
$70mm^2$	1.013	0.432	0.185
$95mm^2$	0.744	0.427	0.182
		30s operation	
ABC			
$25mm^2$	2.699	0.536	0.234*
$35mm^2$	1.957	0.534	0.266
$50mm^2$	1.452	0.532	0.264
$70mm^2$	1.013	0.528	0.261
$95mm^2$	0.744	0.523	0.257

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4J - Distributor Data/Maximum Distributor Loop Impedance 50kVA Split Phase Transformer – 3-wire in 240V System

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in² (solid)	2.580	0.479	0.236	0.153*
0.050in² (solid)	1.432	0.471	0.229	0.163
0.025in² (strand)	2.542	0.479	0.236	0.153*
0.040in² (strand)	1.740	0.474	0.232	0.165
0.050in² (strand)	1.410	0.471	0.229	0.163
0.060in² (strand)	1.265	0.470	0.228	0.161
0.075in² (strand)	1.096	0.467	0.226	0.160
0.100in² (strand)	0.917	0.465	0.224	0.158
0.150in² (strand)	0.778	0.465	0.223	0.157
Aluminium open wire				
0.025in² (Cu Eq)	2.547	0.480	0.237	0.148*
0.040in² (Cu Eq)	1.664	0.474	0.232	0.165
0.050in² (Cu Eq)	1.409	0.472	0.230	0.163
0.100in² (Cu Eq)	0.895	0.466	0.224	0.158
0.150in² (Cu Eq)	0.754	0.465	0.223	0.157
50mm²	1.403	0.472	0.230	0.163
100mm²	0.894	0.466	0.224	0.158
ABC				
25mm²	2.699	0.490	0.246	0.156*
35mm²	1.957	0.488	0.245	0.177
50mm²	1.452	0.487	0.243	0.176
70mm²	1.013	0.484	0.241	0.173
95mm²	0.744	0.481	0.238	0.171
		30s operation		
ABC				
25mm²	2.699	0.585	0.287*	0.156*
35mm²	1.957	0.584	0.319	0.208*
50mm²	1.452	0.582	0.317	0.233
70mm²	1.013	0.579	0.315	0.231
95mm²	0.744	0.576	0.312	0.228

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4K - Distributor Data/Maximum Distributor Loop Impedance 100kVA Split Phase Transformer – 3-wire in 240V System

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in² (solid)	2.580	0.507	0.265	0.182*
0.050in² (solid)	1.432	0.501	0.260	0.194
0.025in² (strand)	2.542	0.507	0.265	0.183*
0.040in² (strand)	1.740	0.504	0.262	0.196
0.050in² (strand)	1.410	0.502	0.260	0.194
0.060in² (strand)	1.265	0.500	0.259	0.192
0.075in² (strand)	1.096	0.499	0.257	0.191
0.100in² (strand)	0.917	0.497	0.255	0.189
0.150in² (strand)	0.778	0.495	0.254	0.188
Aluminium open wire				
0.025in² (Cu Eq)	2.547	0.508	0.266	0.178*
0.040in² (Cu Eq)	1.664	0.504	0.262	0.196
0.050in² (Cu Eq)	1.409	0.502	0.260	0.194
0.100in² (Cu Eq)	0.895	0.497	0.256	0.189
0.150in² (Cu Eq)	0.754	0.495	0.254	0.188
50mm²	1.403	0.502	0.260	0.194
100mm²	0.894	0.497	0.256	0.189
ABC				
25mm²	2.699	0.514	0.272	0.184*
35mm²	1.957	0.513	0.271	0.204
50mm²	1.452	0.512	0.270	0.203
70mm²	1.013	0.510	0.268	0.202
95mm²	0.744	0.508	0.266	0.200
		30s operation		
ABC				
25mm²	2.699	0.609	0.312*	0.184*
35mm²	1.957	0.608	0.344	0.234*
50mm²	1.452	0.607	0.343	0.260
70mm²	1.013	0.605	0.342	0.258
95mm²	0.744	0.603	0.340	0.256

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4L - Distributor Data/Maximum Distributor Loop Impedance 25kVA Split Phase Transformer – 3-wire in 480V System

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)
CONDUCTOR SECTION	**FAULT LOOP IMPEDANCE PER KM (Ω)**	**FUSE-LINK RATING 100A**
		10S OPERATION
Copper open wire		
$0.025in^2$ (solid)	2.580	0.158
$0.050in^2$ (solid)	1.432	0.142
$0.025in^2$ (strand)	2.542	0.158
$0.040in^2$ (strand)	1.740	0.148
$0.050in^2$ (strand)	1.410	0.142
$0.060in^2$ (strand)	1.265	0.139
$0.075in^2$ (strand)	1.096	0.135
$0.100in^2$ (strand)	0.917	0.132
$0.150in^2$ (strand)	0.778	0.130
Aluminium open wire		
$0.025in^2$ (Cu Eq)	2.547	0.160
$0.040in^2$ (Cu Eq)	1.664	0.148
$0.050in^2$ (Cu Eq)	1.409	0.143
$0.100in^2$ (Cu Eq)	0.895	0.132
$0.150in^2$ (Cu Eq)	0.754	0.130
$50mm^2$	1.403	0.143
$100mm^2$	0.894	0.132
ABC		
$25mm^2$	2.699	0.184
$35mm^2$	1.957	0.181
$50mm^2$	1.452	0.176
$70mm^2$	1.013	0.169
$95mm^2$	0.744	0.162
		30s operation
ABC		
$25mm^2$	2.699	0.299
$35mm^2$	1.957	0.295
$50mm^2$	1.452	0.289
$70mm^2$	1.013	0.280
$95mm^2$	0.744	0.270

Table 4M - Distributor Data/Maximum Distributor Loop Impedance 50kVA Split Phase Transformer – 3-wire in 480V System

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)	
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING	
		100A	160A
		10S OPERATION	
Copper open wire			
0.025in² (solid)	2.580	0.360	0.099
0.050in² (solid)	1.432	0.339	0.088
0.025in² (strand)	2.542	0.360	0.099
0.040in² (strand)	1.740	0.347	0.092
0.050in² (strand)	1.410	0.339	0.088
0.060in² (strand)	1.265	0.335	0.086
0.075in² (strand)	1.096	0.329	0.083
0.100in² (strand)	0.917	0.324	0.080
0.150in² (strand)	0.778	0.320	0.079
Aluminium open wire			
0.025in² (Cu Eq)	2.547	0.362	0.100
0.040in² (Cu Eq)	1.664	0.347	0.092
0.050in² (Cu Eq)	1.409	0.341	0.089
0.100in² (Cu Eq)	0.895	0.324	0.081
0.150in² (Cu Eq)	0.754	0.320	0.079
50mm²	1.403	0.341	0.088
100mm²	0.894	0.324	0.081
ABC			
25mm²	2.699	0.388	0.116
35mm²	1.957	0.384	0.113
50mm²	1.452	0.379	0.110
70mm²	1.013	0.373	0.106
95mm²	0.744	0.364	0.101
		30s operation	
ABC			
25mm²	2.699	0.488	0.165*
35mm²	1.957	0.484	0.200
50mm²	1.452	0.479	0.196
70mm²	1.013	0.472	0.191
95mm²	0.744	0.463	0.184

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4N - Distributor Data/Maximum Distributor Loop Impedance 100kVA Split Phase Transformer – 3-wire in 480V System

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in^2 (solid)	2.580	0.455	0.208	0.120*
0.050in^2 (solid)	1.432	0.440	0.195	0.127
0.025in^2 (strand)	2.542	0.456	0.208	0.120*
0.040in^2 (strand)	1.740	0.446	0.200	0.131
0.050in^2 (strand)	1.410	0.440	0.195	0.127
0.060in^2 (strand)	1.265	0.436	0.192	0.124
0.075in^2 (strand)	1.096	0.432	0.188	0.121
0.100in^2 (strand)	0.917	0.427	0.184	0.117
0.150in^2 (strand)	0.778	0.422	0.181	0.115
Aluminium open wire				
0.025in^2 (Cu Eq)	2.547	0.457	0.209	0.115*
0.040in^2 (Cu Eq)	1.664	0.446	0.200	0.131
0.050in^2 (Cu Eq)	1.409	0.441	0.196	0.127
0.100in^2 (Cu Eq)	0.895	0.427	0.185	0.118
0.150in^2 (Cu Eq)	0.754	0.423	0.181	0.115
50mm^2	1.403	0.441	0.196	0.127
100mm^2	0.894	0.427	0.185	0.118
ABC				
25mm^2	2.699	0.475	0.225	0.129*
35mm^2	1.957	0.472	0.223	0.151
50mm^2	1.452	0.469	0.220	0.149
70mm^2	1.013	0.464	0.216	0.145
95mm^2	0.744	0.459	0.211	0.140
		30s operation		
ABC				
25mm^2	2.699	0.571	0.268*	0.129*
35mm^2	1.957	0.569	0.299	0.184*
50mm^2	1.452	0.565	0.296	0.209
70mm^2	1.013	0.561	0.292	0.205
95mm^2	0.744	0.555	0.287	0.200

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4O - Distributor Data/Maximum Distributor Loop Impedance 25kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 100A
		10S OPERATION
Copper open wire		
$0.025in^2$ (solid)	2.580	0.239
$0.050in^2$ (solid)	1.432	0.223
$0.025in^2$ (strand)	2.542	0.240
$0.040in^2$ (strand)	1.740	0.229
$0.050in^2$ (strand)	1.410	0.223
$0.060in^2$ (strand)	1.265	0.220
$0.075in^2$ (strand)	1.096	0.217
$0.100in^2$ (strand)	0.917	0.214
$0.150in^2$ (strand)	0.778	0.214
Aluminium open wire		
$0.025in^2$ (Cu Eq)	2.547	0.241
$0.040in^2$ (Cu Eq)	1.664	0.229
$0.050in^2$ (Cu Eq)	1.409	0.224
$0.100in^2$ (Cu Eq)	0.895	0.214
$0.150in^2$ (Cu Eq)	0.754	0.214
$50mm^2$	1.403	0.224
$100mm^2$	0.894	0.214
ABC		
$25mm^2$	2.699	0.265
$35mm^2$	1.957	0.261
$50mm^2$	1.452	0.257
$70mm^2$	1.013	0.251
$95mm^2$	0.744	0.243
		30s operation
ABC		
$25mm^2$	2.699	0.369
$35mm^2$	1.957	0.365
$50mm^2$	1.452	0.360
$70mm^2$	1.013	0.353
$95mm^2$	0.744	0.344

Table 4P - Distributor Data/Maximum Distributor Loop Impedance 50kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)	
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING	
		100A	160A
		10S OPERATION	
Copper open wire			
0.025in² (solid)	2.580	0.400	0.148
0.050in² (solid)	1.432	0.383	0.137
0.025in² (strand)	2.542	0.400	0.149
0.040in² (strand)	1.740	0.390	0.141
0.050in² (strand)	1.410	0.383	0.137
0.060in² (strand)	1.265	0.380	0.134
0.075in² (strand)	1.096	0.375	0.131
0.100in² (strand)	0.917	0.370	0.128
0.150in² (strand)	0.778	0.368	0.127
Aluminium open wire			
0.025in² (Cu Eq)	2.547	0.402	0.150
0.040in² (Cu Eq)	1.664	0.390	0.141
0.050in² (Cu Eq)	1.409	0.384	0.137
0.100in² (Cu Eq)	0.895	0.371	0.129
0.150in² (Cu Eq)	0.754	0.368	0.127
50mm²	1.403	0.384	0.137
100mm²	0.894	0.371	0.129
ABC			
25mm²	2.699	0.423	0.166
35mm²	1.957	0.420	0.163
50mm²	1.452	0.416	0.160
70mm²	1.013	0.411	0.156
95mm²	0.744	0.404	0.151
		30s operation	
ABC			
25mm²	2.699	0.521	0.211*
35mm²	1.957	0.518	0.243
50mm²	1.452	0.514	0.240
70mm²	1.013	0.508	0.235
95mm²	0.744	0.501	0.229

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4Q - Distributor Data/Maximum Distributor Loop Impedance 100kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in² (solid)	2.580	0.469	0.224	0.138*
0.050in² (solid)	1.432	0.456	0.212	0.145
0.025in² (strand)	2.542	0.469	0.224	0.138*
0.040in² (strand)	1.740	0.461	0.217	0.149
0.050in² (strand)	1.410	0.456	0.213	0.145
0.060in² (strand)	1.265	0.453	0.210	0.143
0.075in² (strand)	1.096	0.449	0.207	0.140
0.100in² (strand)	0.917	0.445	0.203	0.136
0.150in² (strand)	0.778	0.441	0.200	0.134
Aluminium open wire				
0.025in² (Cu Eq)	2.547	0.470	0.225	0.133*
0.040in² (Cu Eq)	1.664	0.461	0.217	0.149
0.050in² (Cu Eq)	1.409	0.457	0.213	0.146
0.100in² (Cu Eq)	0.895	0.445	0.203	0.137
0.150in² (Cu Eq)	0.754	0.442	0.200	0.134
50mm²	1.403	0.457	0.213	0.146
100mm²	0.894	0.445	0.203	0.137
ABC				
25mm²	2.699	0.485	0.239	0.146*
35mm²	1.957	0.483	0.237	0.167
50mm²	1.452	0.481	0.234	0.165
70mm²	1.013	0.477	0.231	0.161
95mm²	0.744	0.472	0.226	0.157
		30s operation		
ABC				
25mm²	2.699	0.581	0.280*	0.146*
35mm²	1.957	0.579	0.312	0.199*
50mm²	1.452	0.577	0.309	0.224
70mm²	1.013	0.573	0.306	0.220
95mm²	0.744	0.568	0.301	0.216

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4R - Distributor Data/Maximum Distributor Loop Impedance 200kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)		
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING		
		100A	160A	200A
		10S OPERATION		
Copper open wire				
0.025in^2 (solid)	2.580	0.502	0.260	0.176*
0.050in^2 (solid)	1.432	0.494	0.252	0.185
0.025in^2 (strand)	2.542	0.502	0.260	0.176*
0.040in^2 (strand)	1.740	0.497	0.255	0.188
0.050in^2 (strand)	1.410	0.494	0.252	0.185
0.060in^2 (strand)	1.265	0.492	0.250	0.183
0.075in^2 (strand)	1.096	0.489	0.247	0.181
0.100in^2 (strand)	0.917	0.486	0.244	0.178
0.150in^2 (strand)	0.778	0.483	0.242	0.176
Aluminium open wire				
0.025in^2 (Cu Eq)	2.547	0.503	0.260	0.172*
0.040in^2 (Cu Eq)	1.664	0.497	0.255	0.188
0.050in^2 (Cu Eq)	1.409	0.495	0.252	0.186
0.100in^2 (Cu Eq)	0.895	0.486	0.245	0.179
0.150in^2 (Cu Eq)	0.754	0.484	0.242	0.176
50mm^2	1.403	0.495	0.252	0.186
100mm^2	0.894	0.486	0.245	0.179
ABC				
25mm^2	2.699	0.512	0.269	0.180*
35mm^2	1.957	0.511	0.268	0.201
50mm^2	1.452	0.509	0.266	0.199
70mm^2	1.013	0.507	0.264	0.197
95mm^2	0.744	0.504	0.261	0.194
		30s operation		
ABC				
25mm^2	2.699	0.608	0.310*	0.180*
35mm^2	1.957	0.606	0.342	0.231*
50mm^2	1.452	0.605	0.340	0.256
70mm^2	1.013	0.602	0.338	0.254
95mm^2	0.744	0.599	0.335	0.251

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4S – Distributor Data/Maximum Distributor Loop Impedance 300/315kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)				
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING				
		100A	160A	200A	250A	315A
		10S OPERATION				
Copper open wire						
0.025in^2 (solid)	2.580	0.512	0.270	0.187*	0.110*	0.072*
0.050in^2 (solid)	1.432	0.505	0.263	0.197	0.145	0.098
0.025in^2 (strand)	2.542	0.512	0.270	0.187*	0.110*	0.072*
0.040in^2 (strand)	1.740	0.508	0.266	0.200	0.147	0.091*
0.050in^2 (strand)	1.410	0.505	0.264	0.197	0.145	0.098
0.060in^2 (strand)	1.265	0.504	0.262	0.196	0.143	0.096
0.075in^2 (strand)	1.096	0.501	0.260	0.193	0.141	0.095
0.100in^2 (strand)	0.917	0.499	0.257	0.191	0.139	0.092
0.150in^2 (strand)	0.778	0.496	0.255	0.189	0.137	0.091
Aluminium open wire						
0.025in^2 (Cu Eq)	2.547	0.513	0.270	0.182*	0.108*	0.071*
0.040in^2 (Cu Eq)	1.664	0.508	0.266	0.200	0.147	0.091*
0.050in^2 (Cu Eq)	1.409	0.506	0.264	0.198	0.145	0.092*
0.100in^2 (Cu Eq)	0.895	0.499	0.258	0.191	0.139	0.093
0.150in^2 (Cu Eq)	0.754	0.496	0.255	0.189	0.137	0.091
50mm^2	1.403	0.506	0.264	0.197	0.145	0.092*
100mm^2	0.894	0.499	0.257	0.191	0.139	0.093
ABC						
25mm^2	2.699	0.520	0.278	0.189*	0.115*	0.077*
35mm^2	1.957	0.519	0.277	0.210	0.153*	0.098*
50mm^2	1.452	0.518	0.275	0.209	0.156	0.103*
70mm^2	1.013	0.516	0.274	0.207	0.154	0.107
95mm^2	0.744	0.513	0.271	0.205	0.152	0.105
		30s operation				
ABC						
25mm^2	2.699	0.615	0.318*	0.189*	0.115*	0.077*
35mm^2	1.957	0.614	0.350	0.240*	0.153*	0.098*
50mm^2	1.452	0.613	0.349	0.265	0.192*	0.103*
70mm^2	1.013	0.611	0.347	0.263	0.196	0.144
95mm^2	0.744	0.609	0.344	0.261	0.194	0.142

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4T – Distributor Data/Maximum Distributor Loop Impedance 500kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)						
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING						
		100A	160A	200A	250A	315A	355A	400A
		10S OPERATION						
Copper open wire								
0.025in² (solid)	2.580	0.519	0.278	0.195*	0.119*	0.081*	0.045*	0.033*
0.050in² (solid)	1.432	0.514	0.273	0.206	0.154	0.108	0.093*	0.063*
0.025in² (strand)	2.542	0.519	0.278	0.195*	0.119*	0.081*	0.045*	0.033*
0.040in² (strand)	1.740	0.516	0.275	0.208	0.156	0.100*	0.081*	0.055*
0.050in² (strand)	1.410	0.514	0.273	0.206	0.154	0.108	0.093*	0.063*
0.060in² (strand)	1.265	0.513	0.271	0.205	0.153	0.107	0.096	0.076*
0.075in² (strand)	1.096	0.511	0.270	0.204	0.152	0.105	0.094	0.077
0.100in² (strand)	0.917	0.509	0.268	0.201	0.150	0.103	0.092	0.075
0.150in² (strand)	0.778	0.507	0.266	0.200	0.148	0.101	0.090	0.073
Aluminium open wire								
0.025in² (Cu Eq)	2.547	0.520	0.278	0.190*	0.117*	0.080*	0.041*	0.032*
0.040in² (Cu Eq)	1.664	0.516	0.275	0.208	0.156	0.100*	0.081*	0.055*
0.050in² (Cu Eq)	1.409	0.515	0.273	0.207	0.155	0.102*	0.085*	0.061*
0.100in² (Cu Eq)	0.895	0.509	0.268	0.202	0.150	0.103	0.092	0.075
0.150in² (Cu Eq)	0.754	0.507	0.266	0.200	0.148	0.102	0.091	0.074
50mm²	1.403	0.515	0.273	0.207	0.155	0.102*	0.085*	0.061*
100mm²	0.894	0.509	0.268	0.202	0.150	0.103	0.092	0.075
ABC								
25mm²	2.699	0.525	0.283	0.195*	0.122*	0.085*	0.046*	0.036*
35mm²	1.957	0.524	0.283	0.216	0.160*	0.106*	0.070*	0.054*
50mm²	1.452	0.524	0.282	0.215	0.163	0.110*	0.093*	0.069*
70mm²	1.013	0.522	0.280	0.214	0.162	0.115	0.104	0.086
95mm²	0.744	0.520	0.279	0.212	0.160	0.113	0.102	0.085
		30s operation						
ABC								
25mm²	2.699	0.620	0.324*	0.195*	0.122*	0.086*	0.046*	0.036*
35mm²	1.957	0.620	0.356	0.246*	0.160*	0.106*	0.070*	0.054*
50mm²	1.452	0.619	0.355	0.272	0.199*	0.110*	0.093*	0.069*
70mm²	1.013	0.617	0.353	0.270	0.203	0.152	0.113*	0.087*
95mm²	0.744	0.616	0.352	0.269	0.202	0.150	0.126	0.108

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4U – Distributor Data/Maximum Distributor Loop Impedance 750/800kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)							
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING							
		100A	160A	200A	250A	315A	355A	400A	500A
		10S OPERATION							
Copper open wire									
0.025in² (solid)									
0.050in² (solid)	2.580	0.523	0.281	0.199*	0.123*	0.086*	0.050*	0.038*	-
0.025in² (strand)	1.432	0.518	0.277	0.211	0.159	0.112	0.098*	0.068*	0.033*
0.040in² (strand)	2.542	0.523	0.281	0.199*	0.123*	0.086*	0.050*	0.038*	-
0.050in² (strand)	1.740	0.520	0.279	0.213	0.161	0.105*	0.086*	0.060*	0.024*
0.060in² (strand)	1.410	0.519	0.277	0.211	0.159	0.113	0.098*	0.068*	0.033*
0.075in² (strand)	1.265	0.517	0.276	0.210	0.158	0.111	0.100	0.081*	0.042*
0.100in² (strand)	1.096	0.516	0.275	0.208	0.157	0.110	0.099	0.082	0.054*
0.150in² (strand)	0.917	0.514	0.273	0.207	0.155	0.108	0.097	0.080	0.058
	0.778	0.512	0.271	0.205	0.153	0.107	0.096	0.079	0.056
Aluminium open wire									
0.025in² (Cu Eq)	2.547	0.523	0.282	0.194*	0.121*	0.085*	0.046*	0.037*	-
0.040in² (Cu Eq)	1.664	0.520	0.279	0.213	0.161	0.105*	0.086*	0.060*	0.024*
0.050in² (Cu Eq)	1.409	0.519	0.277	0.211	0.159	0.107*	0.090*	0.066*	0.034*
0.100in² (Cu Eq)	0.895	0.514	0.273	0.207	0.155	0.109	0.098	0.081	0.058
0.150in² (Cu Eq)	0.754	0.512	0.271	0.205	0.153	0.107	0.096	0.079	0.056
50mm²	1.403	0.519	0.277	0.211	0.159	0.107*	0.090*	0.066*	0.034*
100mm²	0.894	0.514	0.273	0.207	0.155	0.109	0.098	0.081	0.058
ABC									
25mm²	2.699	0.528	0.286	0.198*	0.125*	0.089*	0.050*	0.041*	0.001*
35mm²	1.957	0.527	0.285	0.219	0.163*	0.109*	0.074*	0.058*	0.017*
50mm²	1.452	0.526	0.285	0.218	0.166	0.114*	0.096*	0.073*	0.040*
70mm²	1.013	0.525	0.284	0.217	0.165	0.119	0.108	0.090	0.058*
95mm²	0.744	0.524	0.282	0.216	0.164	0.117	0.106	0.089	0.066
		30s operation							
ABC									
25mm²	2.699	0.623	0.326*	0.198*	0.125*	0.089*	0.050*	0.041*	0.001*
35mm²	1.957	0.622	0.358	0.249*	0.163*	0.109*	0.074*	0.058*	0.017*
50mm²	1.452	0.621	0.358	0.275	0.202*	0.114*	0.096*	0.073*	0.040*
70mm²	1.013	0.620	0.357	0.273	0.207	0.155	0.117*	0.091*	0.058*
95mm²	0.744	0.619	0.355	0.272	0.205	0.154	0.130	0.112	0.070*

* Maximum value of loop impedance limited due to the thermal limit of the conductor

Table 4V – Distributor Data/Maximum Distributor Loop Impedance 100kVA Three Phase Transformer

DISTRIBUTOR DATA		MAXIMUM FAULT LOOP IMPEDANCE TO ENSURE LINE PROTECTION (Ω)							
CONDUCTOR SECTION	FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING							
		100A	160A	200A	250A	315A	355A	400A	500A
		10S OPERATION							
Copper open wire									
0.025in² (solid)	2.580	0.525	0.283	0.201*	0.125*	0.088*	0.052*	0.041*	0.006*
0.050in² (solid)	1.432	0.521	0.279	0.213	0.161	0.115	0.101*	0.070*	0.036*
0.025in² (strand)	2.542	0.525	0.283	0.201*	0.125*	0.088*	0.052*	0.041*	0.006*
0.040in² (strand)	1.740	0.522	0.281	0.215	0.163	0.107*	0.088*	0.062*	0.027*
0.050in² (strand)	1.410	0.521	0.279	0.213	0.161	0.115	0.101*	0.070*	0.036*
0.060in² (strand)	1.265	0.520	0.278	0.212	0.160	0.114	0.103	0.083*	0.045*
0.075in² (strand)	1.096	0.518	0.277	0.211	0.159	0.113	0.102	0.085	0.056*
0.100in² (strand)	0.917	0.517	0.275	0.209	0.157	0.111	0.100	0.083	0.060
0.150in² (strand)	0.778	0.515	0.274	0.208	0.156	0.110	0.099	0.082	0.059
Aluminium open wire									
0.025in² (Cu Eq)	2.547	0.525	0.283	0.196*	0.123*	0.087*	0.049*	0.040*	0.006*
0.040in² (Cu Eq)	1.664	0.522	0.281	0.215	0.163	0.107*	0.088*	0.062*	0.027*
0.050in² (Cu Eq)	1.409	0.521	0.280	0.213	0.161	0.109*	0.092*	0.069*	0.037*
0.100in² (Cu Eq)	0.895	0.517	0.276	0.209	0.158	0.111	0.100	0.083	0.060
0.150in² (Cu Eq)	0.754	0.515	0.274	0.208	0.156	0.110	0.099	0.082	0.059
50mm²	1.403	0.521	0.280	0.213	0.161	0.109*	0.092*	0.069*	0.037*
100mm²	0.894	0.517	0.276	0.209	0.158	0.111	0.100	0.083	0.060
ABC									
25mm²	2.699	0.529	0.287	0.200*	0.127*	0.091*	0.052*	0.043*	0.008*
35mm²	1.957	0.528	0.287	0.221	0.165*	0.111*	0.076*	0.060*	0.021*
50mm²	1.452	0.528	0.286	0.220	0.168	0.116*	0.098*	0.075*	0.043*
70mm²	1.013	0.527	0.285	0.219	0.167	0.120	0.109	0.092	0.060*
95mm²	0.744	0.525	0.284	0.218	0.166	0.119	0.108	0.091	0.068
		30s operation							
ABC									
25mm²	2.699	0.624	0.328*	0.200*	0.127*	0.091*	0.052*	0.043*	0.008*
35mm²	1.957	0.623	0.360	0.250*	0.165*	0.111*	0.076*	0.060*	0.021*
50mm²	1.452	0.623	0.359	0.276	0.204*	0.116*	0.098*	0.075*	0.043*
70mm²	1.013	0.622	0.358	0.275	0.208	0.157	0.119*	0.093*	0.060*
95mm²	0.744	0.620	0.357	0.274	0.207	0.156	0.132	0.114	0.072*

* Maximum value of loop impedance limited due to the thermal limit of the conductor

13.5 Low Voltage Mixed Cable & Overhead Line Distributors

The requirements of sections 13.2 shall apply as appropriate to the cable and overhead sections of the distributor.

The distributor shall normally be designed such that the fuse-link operating time is not to exceed 10s, in order to ensure that the overhead conductors are adequately protected.

The data given in section 13.4 of maximum allowable loop impedances for the overhead sections (Tables 4B to 4V) are applicable, being based on a 10s operating time.

A set of tables are provided below (Tables 5A to 5H) of maximum allowable loop impedances for the cable sections to give an operating time of 10s based on a source impedance equivalent to 50MVA (purely inductive), except for the 25kVA and 50kVA transformer sizes which are assumed to be overhead fed with a source impedance equivalent to 10MVA.

Tables 2A, 3A and 4A contain the information to permit the selection of fuse-link current ratings dependent on transformer size and whether the main section of the distributor is a cable or an overhead conductor.

Where an operating time of 10s introduces an unacceptable limit on the length of the cable section(s) then consideration can be given to increasing the operating time up to a maximum of 100s. In these cases the maximum length of protected LV cable shall be calculated from first principles, using the criteria given in this section and the methods outlined in Appendix T, taking care to confirm that the thermal limit of the other cables and/or conductors on the distributor will not be reached with the proposed values of fuse-link current and duration. Appendix T includes methods for establishing the thermal limit.

NOTE:

LV AFFIRM provides a more elegant solution for mixed distributors by calculating each section of the distributor separately, thus allowing 100s clearance for cable sections, but limiting overhead sections to 10 (or 30)s.

Refer to section 13.3 for guidance on earth loop impedances values for 4-core cables.

13.5.1 Procedure for Selecting a Fuse-link Rating

Refer to Table 2A and note the maximum fuse-link rating for which discrimination is maintained across the associated distribution transformer.

From Table 3A or 4A note the rating of the distributor and the preferred fuse-link rating. Establish a fuse-link rating that will maintain discrimination and enable the distributor to be loaded up to its rating in accordance with 2.6.

Using the appropriate Table 5A to 5H and 4B to 4V, check that the chosen fuse-link will protect the whole distributor from the substation to the fault position at the remote end of each branch of the distributor including overhead service connections as relevant to give 10s fuse-link operating time. Being a composite distributor, it is necessary to add the given loop impedances to calculate the total loop impedance for the distributor. It is quite permissible to add the loop impedances arithmetically in this case. For each constituent cable or conductor type in the distributor check that the maximum value of loop impedance against each, for the chosen fuse-link, is greater than the total loop impedance of the whole distributor. (See also the note attached to section 13.2).

Where an operating time in excess of 10s is to be considered, in order to provide an acceptable design for the distributor, refer to section 13.5 .

For each constituent line type in the distributor check that the maximum value of loop impedance against each, for the chosen fuse-link, is greater than the loop impedance of the whole distributor.

Where a fuse-link smaller than the preferred rating of Table 3A or 4A is required, say in order to protect the whole of a distributor and its services, a fuse-link to suit the MD of the distributor shall be chosen in accordance with 3. The selected fuse-link shall be checked in accordance with 13.5.

Table 5A – Distributor Data and Maximum Distributor Loop Impedance 25kVA Three Phase Transformers (OHL fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING 100A (10S OPERATION)
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.259 0.247 0.244 0.242
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.260 0.249 0.238
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.259 0.247 0.244 0.243
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.256 0.240 0.235 0.230
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.267 0.263 0.258 0.251 0.266 0.260 0.255 0.246
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	.264 0.257 0.249 0.239 0.264 0.255 0.247 0.236

4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.271 0.269 0.268 0.267 0.266 0.264 0.263 0.261 0.258 0.255 0.253 0.247 0.242
4-core Copper (PILC) with N-E bond	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.266 1.331 1.115 0.899 0.764 0.540 0.479 0.390 0.304 0.255 0.221 0.159 0.137	0.270 0.267 0.266 0.264 0.262 0.258 0.256 0.252 0.247 0.243 0.239 0.230 0.226

Table 5B – Distributor Data and Maximum Distributor Loop Impedance 50kVA (3 phase) Transformer (OHL Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION	
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (10S OPERATION)	
			100A	160A
3-core Waveform	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.687 0.361 0.318 0.291	0.418 0.408 0.406 0.404	0.162 0.154 0.152 0.151
CONSAC	$95mm^2$ $185mm^2$ $300mm^2$	0.659 0.347 0.221	0.420 0.410 0.400	0.163 0.156 0.148
4-core Waveform SNE	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.687 0.361 0.318 0.290	0.419 0.408 0.406 0.404	0.162 0.154 0.153 0.151
4-core Waveform with N-E bond	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.528 0.280 0.228 0.194	0.416 0.404 0.399 0.395	0.157 0.148 0.145 0.142
4-core Aluminium (PILC) SNE	$70mm^2$ $120mm^2$ $185mm^2$ $300mm^2$ $0.10in^2$ $0.20in^2$ $0.30in^2$ $0.50in^2$	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.425 0.422 0.418 0.411 0.424 0.419 0.415 0.407	0.167 0.165 0.161 0.157 0.166 0.163 0.159 0.154
4-core Aluminium (PILC) with N-E bond	$70mm^2$ $120mm^2$ $185mm^2$ $300mm^2$ $0.10in^2$ $0.20in^2$ $0.30in^2$ $0.50in^2$	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.423 0.417 0.410 0.400 0.422 0.415 0.408 0.398	0.165 0.161 0.156 0.148 0.165 0.159 0.154 0.147

4-core Copper (PILC) SNE	$0.0225in^2$	2.525	0.428	0.166
	$0.040in^2$	1.708	0.427	0.165
	$0.050in^2$	1.481	0.426	0.165
	$0.060in^2$	1.254	0.425	0.164
	$0.075in^2$	1.109	0.424	0.163
	$0.100in^2$	0.867	0.423	0.162
	$0.120in^2$	0.787	0.422	0.161
	$0.150in^2$	0.667	0.420	0.160
	$0.200in^2$	0.519	0.417	0.158
	$0.250in^2$	0.441	0.415	0.156
	$0.300in^2$	0.383	0.413	0.155
	$0.400in^2$	0.289	0.408	0.151
	$0.500in^2$	0.243	0.404	0.148
4-core Copper (PILC) with N-E bond	$0.0225in^2$	2.266	0.428	0.169
	$0.040in^2$	1.331	0.425	0.167
	$0.050in^2$	1.115	0.424	0.167
	$0.060in^2$	0.899	0.423	0.165
	$0.075in^2$	0.764	0.421	0.164
	$0.100in^2$	0.540	0.418	0.161
	$0.120in^2$	0.479	0.416	0.160
	$0.150in^2$	0.390	0.413	0.158
	$0.200in^2$	0.304	0.408	0.154
	$0.250in^2$	0.255	0.404	0.151
	$0.300in^2$	0.221	0.401	0.149
	$0.400in^2$	0.159	0.392	0.142
	$0.500in^2$	0.137	0.387	0.139

Table 5C – Distributor Data and Maximum Distributor Loop Impedance 100kVA Transformers (Cable Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	**CONDUCTOR SECTION**	**EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)**	**FUSE-LINK RATING 200A (10S OPERATION)**
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.170 0.164 0.163 0.162
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.171 0.165 0.159
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.170 0.164 0.163 0.162
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.169 0.162 0.159 0.156
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.174 0.172 0.169 0.166 0.173 0.171 0.168 0.164
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.172 0.169 0.165 0.159 0.172 0.168 0.164 0.158

4-core Copper (PILC) SNE	$0.0225in^2$	2.525	0.156*
	$0.040in^2$	1.708	0.175
	$0.050in^2$	1.481	0.174
	$0.060in^2$	1.254	0.174
	$0.075in^2$	1.109	0.173
	$0.100in^2$	0.867	0.172
	$0.120in^2$	0.787	0.172
	$0.150in^2$	0.667	0.171
	$0.200in^2$	0.519	0.169
	$0.250in^2$	0.441	0.168
	$0.300in^2$	0.383	0.167
	$0.400in^2$	0.289	0.164
	$0.500in^2$	0.243	0.162
4-core Copper (PILC) with N-E bond	$0.0225in^2$	2.266	0.156*
	$0.040in^2$	1.331	0.174
	$0.050in^2$	1.115	0.173
	$0.060in^2$	0.899	0.172
	$0.075in^2$	0.764	0.172
	$0.100in^2$	0.540	0.169
	$0.120in^2$	0.479	0.169
	$0.150in^2$	0.390	0.167
	$0.200in^2$	0.304	0.164
	$0.250in^2$	0.255	0.162
	$0.300in^2$	0.221	0.160
	$0.400in^2$	0.159	0.154
	$0.500in^2$	0.137	0.152

*Maximum value of loop impedance limited due to the thermal limit of the cable

Table 5D – Distributor Data and Maximum Distributor Loop Impedance 200kVA Transformers (Cable Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION
CABLE TYPE	**CONDUCTOR SECTION**	**EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)**	**FUSE-LINK RATING 200A (10S OPERATION)**
3-core Waveform	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.687 0.361 0.318 0.291	0.203 0.199 0.198 0.198
CONSAC	$95mm^2$ $185mm^2$ $300mm^2$	0.659 0.347 0.221	0.203 0.200 0.196
4-core Waveform SNE	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.687 0.361 0.318 0.290	0.203 0.199 0.198 0.198
4-core Waveform with N-E bond	$95mm^2$ $185mm^2$ $240mm^2$ $300mm^2$	0.528 0.280 0.228 0.194	0.202 0.198 0.196 0.194
4-core Aluminium (PILC) SNE	$70mm^2$ $120mm^2$ $185mm^2$ $300mm^2$ $0.10in^2$ $0.20in^2$ $0.30in^2$ $0.50in^2$	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.205 0.204 0.202 0.200 0.205 0.203 0.202 0.199
4-core Aluminium (PILC) with N-E bond	$70mm^2$ $120mm^2$ $185mm^2$ $300mm^2$ $0.10in^2$ $0.20in^2$ $0.30in^2$ $0.50in^2$	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.204 0.202 0.200 0.196 0.204 0.202 0.199 0.195

4-core Copper (PILC) SNE	$0.0225in^2$	2.525	0.187*
	$0.040in^2$	1.708	0.206
	$0.050in^2$	1.481	0.205
	$0.060in^2$	1.254	0.205
	$0.075in^2$	1.109	0.205
	$0.100in^2$	0.867	0.204
	$0.120in^2$	0.787	0.204
	$0.150in^2$	0.667	0.203
	$0.200in^2$	0.519	0.202
	$0.250in^2$	0.441	0.202
	$0.300in^2$	0.383	0.201
	$0.400in^2$	0.289	0.199
	$0.500in^2$	0.243	0.198
4-core Copper (PILC) with N-E bond	$0.0225in^2$	2.266	0.187*
	$0.040in^2$	1.331	0.205
	$0.050in^2$	1.115	0.205
	$0.060in^2$	0.899	0.204
	$0.075in^2$	0.764	0.204
	$0.100in^2$	0.540	0.202
	$0.120in^2$	0.479	0.202
	$0.150in^2$	0.390	0.201
	$0.200in^2$	0.304	0.199
	$0.250in^2$	0.255	0.198
	$0.300in^2$	0.221	0.197
	$0.400in^2$	0.159	0.193
	$0.500in^2$	0.137	0.191

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 5E – Distributor Data and Maximum Distributor Loop Impedance 300kVA / 315kVA Transformers (Cable Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION		
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (10S OPERATION)		
			200A	250A	315A
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.211 0.209 0.208 0.208	0.159 0.157 0.156 0.155	0.112 0.110 0.109 0.109
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.212 0.209 0.207	0.160 0.157 0.154	0.113 0.110 0.108
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.212 0.209 0.208 0.208	0.159 0.157 0.156 0.156	0.112 0.110 0.109 0.109
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.211 0.208 0.206 0.205	0.159 0.155 0.154 0.153	0.112 0.109 0.108 0.106
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.213 0.212 0.211 0.210 0.213 0.212 0.211 0.209	0.161 0.160 0.159 0.157 0.161 0.159 0.158 0.156	0.114 0.113 0.112 0.111 0.114 0.113 0.112 0.110
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.212 0.211 0.209 0.207 0.212 0.211 0.209 0.206	0.160 0.159 0.157 0.154 0.160 0.158 0.157 0.154	0.113 0.112 0.110 0.107 0.113 0.112 0.110 0.107

4-core Copper (PILC) SNE	0.0225in^2	2.525	0.195*	0.110*	0.067*
	0.040in^2	1.708	0.214	0.161	0.105*
	0.050in^2	1.481	0.213	0.161	0.114
	0.060in^2	1.254	0.213	0.161	0.114
	0.075in^2	1.109	0.213	0.161	0.114
	0.100in^2	0.867	0.213	0.160	0.113
	0.120in^2	0.787	0.212	0.160	0.113
	0.150in^2	0.667	0.212	0.160	0.113
	0.200in^2	0.519	0.211	0.159	0.112
	0.250in^2	0.441	0.211	0.158	0.112
	0.300in^2	0.383	0.210	0.158	0.111
	0.400in^2	0.289	0.209	0.157	0.110
	0.500in^2	0.243	0.208	0.155	0.109
4-core Copper (PILC) with N-E bond	0.0225in^2	2.266	0.195*	0.110*	0.067*
	0.040in^2	1.331	0.213	0.161	0.105*
	0.050in^2	1.115	0.213	0.161	0.114
	0.060in^2	0.899	0.213	0.160	0.113
	0.075in^2	0.764	0.212	0.160	0.113
	0.100in^2	0.540	0.211	0.159	0.112
	0.120in^2	0.479	0.211	0.159	0.112
	0.150in^2	0.390	0.210	0.158	0.111
	0.200in^2	0.304	0.209	0.157	0.110
	0.250in^2	0.255	0.208	0.156	0.109
	0.300in^2	0.221	0.207	0.155	0.108
	0.400in^2	0.159	0.204	0.152	0.105
	0.500in^2	0.137	0.203	0.151	0.104

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 5F – Distributor Data and Maximum Distributor Loop Impedance 500kVA Transformers (Cable Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION				
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (10S OPERATION)				
			200A	250A	315A	355A	400A
3-core Waveform	95mm^2	0.687	0.218	0.166	0.119	0.108	0.091
	185mm^2	0.361	0.216	0.164	0.118	0.107	0.089
	240mm^2	0.318	0.216	0.164	0.117	0.106	0.089
	300mm^2	0.291	0.215	0.163	0.117	0.106	0.089
CONSAC	95mm^2	0.659	0.218	0.166	0.120	0.109	0.091
	185mm^2	0.347	0.216	0.164	0.118	0.107	0.090
	300mm^2	0.221	0.215	0.163	0.116	0.105	0.088
4-core Waveform SNE	95mm^2	0.687	0.218	0.166	0.119	0.108	0.091
	185mm^2	0.361	0.216	0.164	0.118	0.107	0.089
	240mm^2	0.318	0.216	0.164	0.117	0.106	0.089
	300mm^2	0.290	0.215	0.163	0.117	0.106	0.089
4-core Waveform with N-E bond	95mm^2	0.528	0.217	0.165	0.119	0.108	0.091
	185mm^2	0.280	0.215	0.163	0.117	0.106	0.089
	240mm^2	0.228	0.214	0.162	0.116	0.105	0.088
	300mm^2	0.194	0.214	0.162	0.115	0.104	0.087
4-core Aluminium (PILC) SNE	70mm^2	1.200	0.219	0.167	0.120	0.109	0.092
	120mm^2	0.778	0.218	0.166	0.120	0.109	0.092
	185mm^2	0.529	0.218	0.166	0.119	0.108	0.091
	300mm^2	0.356	0.217	0.165	0.118	0.107	0.090
	0.10in^2	1.118	0.219	0.167	0.120	0.109	0.090*
	0.20in^2	0.640	0.218	0.166	0.120	0.108	0.091
	0.30in^2	0.456	0.217	0.165	0.119	0.108	0.090
	0.50in^2	0.300	0.216	0.164	0.117	0.106	0.089
4-core Aluminium (PILC) with N-E bond	70mm^2	0.856	0.219	0.167	0.120	0.109	0.092
	120mm^2	0.501	0.218	0.166	0.119	0.108	0.091
	185mm^2	0.332	0.216	0.164	0.118	0.107	0.090
	300mm^2	0.213	0.215	0.163	0.116	0.105	0.088
	0.10in^2	0.856	0.218	0.166	0.120	0.109	0.089*
	0.20in^2	0.448	0.217	0.165	0.119	0.108	0.090
	0.30in^2	0.301	0.216	0.164	0.118	0.107	0.089
	0.50in^2	0.202	0.214	0.162	0.116	0.105	0.088

4-core Copper (PILC) SNE	$0.0225in^2$	2.525	0.201*	0.117*	0.074*	0.046*	0.039*
	$0.040in^2$	1.708	0.219	0.167	0.111*	0.092*	0.066*
	$0.050in^2$	1.481	0.219	0.167	0.121	0.106*	0.076*
	$0.060in^2$	1.254	0.219	0.167	0.120	0.109	0.090*
	$0.075in^2$	1.109	0.219	0.167	0.120	0.109	0.092
	$0.100in^2$	0.867	0.218	0.166	0.120	0.109	0.092
	$0.120in^2$	0.787	0.218	0.166	0.120	0.109	0.092
	$0.150in^2$	0.667	0.218	0.166	0.120	0.109	0.091
	$0.200in^2$	0.519	0.218	0.166	0.119	0.108	0.091
	$0.250in^2$	0.441	0.217	0.165	0.119	0.108	0.090
	$0.300in^2$	0.383	0.217	0.165	0.118	0.107	0.090
	$0.400in^2$	0.289	0.216	0.164	0.118	0.107	0.089
	$0.500in^2$	0.243	0.215	0.163	0.117	0.106	0.089
4-core Copper (PILC) with N-E bond	$0.0225in^2$	2.266	0.201*	0.117*	0.074*	0.046*	0.039*
	$0.040in^2$	1.331	0.219	0.167	0.111*	0.092*	0.066*
	$0.050in^2$	1.115	0.219	0.167	0.120	0.106*	0.075*
	$0.060in^2$	0.899	0.218	0.166	0.120	0.109	0.089*
	$0.075in^2$	0.764	0.218	0.166	0.120	0.109	0.091
	$0.100in^2$	0.540	0.218	0.166	0.119	0.108	0.091
	$0.120in^2$	0.479	0.217	0.165	0.119	0.108	0.091
	$0.150in^2$	0.390	0.217	0.165	0.118	0.107	0.090
	$0.200in^2$	0.304	0.216	0.164	0.117	0.107	0.089
	$0.250in^2$	0.255	0.215	0.163	0.117	0.106	0.089
	$0.300in^2$	0.221	0.215	0.163	0.116	0.105	0.088
	$0.400in^2$	0.159	0.213	0.161	0.115	0.104	0.086
	$0.500in^2$	0.137	0.212	0.160	0.114	0.103	0.086

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 5G – Distributor Data and Maximum Distributor Loop Impedance 750kVA / 800kVA Transformers (Cable Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION						
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (10S OPERATION)						
			200A	250A	315A	355A	400A	500A	630A
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.221 0.219 0.219 0.219	0.169 0.167 0.167 0.167	0.122 0.121 0.121 0.121	0.111 0.110 0.110 0.110	0.094 0.093 0.093 0.092	0.071 0.070 0.070 0.070	0.045 * 0.053 0.053 0.052
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.221 0.220 0.218	0.169 0.168 0.166	0.123 0.121 0.120	0.112 0.110 0.109	0.094 0.093 0.092	0.072 0.070 0.069	0.045 * 0.053 0.052
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.221 0.219 0.219 0.219	0.169 0.167 0.167 0.167	0.122 0.121 0.121 0.121	0.111 0.110 0.110 0.110	0.094 0.093 0.093 0.092	0.071 0.070 0.070 0.070	0.045 * 0.053 0.053 0.053
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.220 0.219 0.218 0.217	0.168 0.167 0.166 0.166	0.122 0.121 0.120 0.119	0.111 0.110 0.109 0.108	0.094 0.092 0.092 0.091	0.071 0.070 0.069 0.069	0.045 * 0.052 0.052 0.051
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.221 0.221 0.220 0.220 0.221 0.221 0.220 0.219	0.169 0.169 0.169 0.168 0.169 0.169 0.168 0.167	0.123 0.123 0.122 0.122 0.123 0.122 0.122 0.121	0.112 0.112 0.111 0.111 0.112 0.112 0.111 0.110	0.095 0.095 0.094 0.093 0.092 * 0.094 0.094 0.093	0.063 * 0.072 0.071 0.071 0.061 * 0.072 0.071 0.070	0.035 * 0.055 0.054 0.053 0.033 * 0.054 0.054 0.053
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.221 0.220 0.220 0.218 0.221 0.220 0.219 0.218	0.169 0.169 0.168 0.166 0.169 0.168 0.167 0.166	0.123 0.122 0.121 0.120 0.123 0.122 0.121 0.120	0.112 0.111 0.110 0.109 0.112 0.111 0.110 0.109	0.095 0.094 0.093 0.092 0.092 * 0.094 0.093 0.092	0.063 * 0.071 0.070 0.069	0.035 * 0.054 0.053 0.052

								0.061 * 0.071 0.070 0.069	0.032 * 0.054 0.053 0.052
4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.203 * 0.222 0.221 0.221 0.221 0.221 0.221 0.221 0.220 0.220 0.220 0.219 0.219	0.119 * 0.170 0.170 0.169 0.169 0.169 0.169 0.169 0.169 0.168 0.168 0.167 0.167	0.077 * 0.114 * 0.123 0.123 0.123 0.123 0.123 0.123 0.122 0.122 0.122 0.121 0.121	0.050 * 0.095 * 0.109 * 0.112 0.112 0.112 0.112 0.112 0.111 0.111 0.111 0.110 0.110	0.043 * 0.070 * 0.079 * 0.093 * 0.095 0.095 0.095 0.094 0.094 0.094 0.094 0.093 0.092	- 0.035 * 0.045 * 0.054 * 0.067 * 0.072 0.072 0.072 0.071 0.071 0.071 0.070 0.070	- 0.015 * 0.023 * 0.028 * 0.043 * 0.054 * 0.055 0.054 0.054 0.054 0.054 0.053 0.052
4-core Copper (PILC) with N-E bond	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.266 1.331 1.115 0.899 0.764 0.540 0.479 0.390 0.304 0.255 0.221 0.159 0.137	0.203 * 0.221 0.221 0.221 0.221 0.220 0.220 0.220 0.219 0.219 0.218 0.217 0.216	0.119 * 0.169 0.169 0.169 0.169 0.169 0.168 0.168 0.167 0.167 0.166 0.165 0.164	0.077 * 0.114 * 0.123 0.123 0.123 0.122 0.122 0.122 0.121 0.121 0.120 0.119 0.118	0.050 * 0.095 * 0.109 * 0.112 0.112 0.111 0.111 0.111 0.110 0.110 0.109 0.108 0.107	0.043 * 0.069 * 0.078 * 0.092 * 0.095 0.094 0.094 0.094 0.093 0.092 0.092 0.091 0.090	- 0.035 * 0.045 * 0.054 * 0.066 * 0.071 0.071 0.071 0.070 0.070 0.069 0.068 0.067	- 0.015 * 0.023 * 0.028 * 0.042 * 0.053 * 0.054 0.054 0.053 0.053 0.052 0.051 0.050

* Maximum value of loop impedance limited due to the thermal limit of the cable

Table 5H – Distributor Data and Maximum Distributor Loop Impedance 1000kVA Transformers (Cable Fed)

DISTRIBUTOR DATA			MAXIMUM EARTH-FAULT LOOP IMPEDANCE (Ω) TO ENSURE DISTRIBUTOR PROTECTION						
CABLE TYPE	CONDUCTOR SECTION	EARTH-FAULT LOOP IMPEDANCE PER KM (Ω)	FUSE-LINK RATING (10S OPERATION)						
			200A	250A	315A	355A	400A	500A	630A
3-core Waveform	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.291	0.222 0.221 0.221 0.220	0.170 0.169 0.169 0.169	0.124 0.123 0.122 0.122	0.113 0.112 0.112 0.111	0.096 0.095 0.094 0.094	0.073 0.072 0.072 0.072	0.047 * 0.055 0.055 0.054
CONSAC	95mm^2 185mm^2 300mm^2	0.659 0.347 0.221	0.222 0.221 0.220	0.170 0.169 0.168	0.124 0.123 0.122	0.113 0.112 0.111	0.096 0.095 0.094	0.073 0.072 0.071	0.047 * 0.055 0.054
4-core Waveform SNE	95mm^2 185mm^2 240mm^2 300mm^2	0.687 0.361 0.318 0.290	0.222 0.221 0.221 0.220	0.170 0.169 0.169 0.169	0.124 0.123 0.123 0.122	0.113 0.112 0.112 0.111	0.096 0.095 0.094 0.094	0.073 0.072 0.072 0.072	0.047 * 0.055 0.055 0.054
4-core Waveform with N-E bond	95mm^2 185mm^2 240mm^2 300mm^2	0.528 0.280 0.228 0.194	0.222 0.220 0.220 0.219	0.170 0.169 0.168 0.168	0.124 0.122 0.122 0.121	0.113 0.111 0.111 0.110	0.095 0.094 0.094 0.093	0.073 0.072 0.071 0.071	0.047 * 0.054 0.054 0.053
4-core Aluminium (PILC) SNE	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	1.200 0.778 0.529 0.356 1.118 0.640 0.456 0.300	0.223 0.222 0.222 0.221 0.222 0.222 0.222 0.221	0.171 0.170 0.170 0.169 0.171 0.170 0.170 0.169	0.124 0.124 0.124 0.123 0.124 0.124 0.123 0.123	0.113 0.113 0.113 0.112 0.113 0.113 0.112 0.112	0.096 0.096 0.096 0.095 0.094 * 0.096 0.095 0.095	0.065 * 0.073 0.073 0.072 0.062 * 0.073 0.073 0.072	0.037 * 0.056 0.056 0.055 0.034 * 0.056 0.056 0.055
4-core Aluminium (PILC) with N-E bond	70mm^2 120mm^2 185mm^2 300mm^2 0.10in^2 0.20in^2 0.30in^2 0.50in^2	0.856 0.501 0.332 0.213 0.856 0.448 0.301 0.202	0.222 0.222 0.221 0.220 0.222 0.222 0.221 0.220	0.170 0.170 0.169 0.168 0.170 0.170 0.169 0.168	0.124 0.124 0.123 0.122 0.124 0.123 0.123 0.122	0.113 0.113 0.112 0.111 0.113 0.112 0.112 0.111	0.096 0.096 0.095 0.094 0.094 * 0.095 0.095 0.094	0.064 * 0.073 0.072 0.071 0.062 * 0.073 0.072 0.071	0.037 * 0.056 0.055 0.054 0.034 * 0.055 0.055 0.054

4-core Copper (PILC) SNE	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.525 1.708 1.481 1.254 1.109 0.867 0.787 0.667 0.519 0.441 0.383 0.289 0.243	0.204 * 0.223 0.223 0.223 0.222 0.222 0.222 0.222 0.222 0.222 0.221 0.221 0.220	0.120 * 0.171 0.171 0.171 0.171 0.170 0.170 0.170 0.170 0.170 0.169 0.169 0.169	0.079 * 0.115 * 0.125 0.124 0.124 0.124 0.124 0.124 0.124 0.123 0.123 0.123 0.122	0.051 * 0.096 * 0.110 * 0.113 0.113 0.113 0.113 0.113 0.113 0.112 0.112 0.112 0.111	0.045 * 0.071 * 0.080 * 0.094 * 0.096 0.096 0.096 0.096 0.096 0.095 0.095 0.095 0.094	- 0.037 * 0.047 * 0.056 * 0.068 * 0.073 0.073 0.073 0.073 0.073 0.073 0.072 0.072	- 0.018 * 0.025 * 0.030 * 0.044 * 0.055 * 0.056 0.056 0.056 0.056 0.055 0.055 0.054
4-core Copper (PILC) with N-E bond	0.0225in^2 0.040in^2 0.050in^2 0.060in^2 0.075in^2 0.100in^2 0.120in^2 0.150in^2 0.200in^2 0.250in^2 0.300in^2 0.400in^2 0.500in^2	2.266 1.331 1.115 0.899 0.764 0.540 0.479 0.390 0.304 0.255 0.221 0.159 0.137	0.204 * 0.223 0.222 0.222 0.222 0.222 0.222 0.221 0.221 0.220 0.220 0.219 0.218	0.120 * 0.171 0.171 0.170 0.170 0.170 0.170 0.169 0.169 0.169 0.168 0.167 0.167	0.079 * 0.115 * 0.124 0.124 0.124 0.124 0.124 0.123 0.123 0.122 0.122 0.121 0.120	0.051 * 0.096 * 0.110 * 0.113 0.113 0.113 0.113 0.112 0.112 0.111 0.111 0.110 0.109	0.045 * 0.071 * 0.080 * 0.094 * 0.096 0.096 0.095 0.095 0.095 0.094 0.094 0.093 0.092	- 0.036 * 0.047 * 0.056 * 0.068 * 0.073 0.073 0.072 0.072 0.072 0.071 0.070 0.070	- 0.018 * 0.025 * 0.030 * 0.044 * 0.055 * 0.056 0.055 0.055 0.054 0.054 0.053 0.053

* Maximum value of loop impedance limited due to the thermal limit of the cable

13.6 Protection of Transformers by Switch-Fuse Gear and Circuit Breakers

The range of distribution transformers to be protected on the Electricity North West Limited network is from 200kVA to 1000kVA and the ratings of low voltage distributor fuse-links connected to the transformer secondaries are up to 630A.

NOTE:

Settings are also included for transformer ratings up to 1500kVA to cover customer owned HV transformers of sizes above 1000kVA.

HV protection settings are given for all forms of distribution transformer protection employed throughout the Network.

Settings are arranged to afford discrimination with stated LV distributor fuse-links under the most onerous condition, namely, a 2 phase fault on the LV side. In addition, the HV protection settings have been chosen to give acceptable clearance times under transformer LV terminal zone fault conditions.

Where a high source impedance or a long low voltage cable connection unduly limits the fault currents, due allowance shall be made in the rating of the high voltage fuse-link protecting the transformer. The likely effect of this is to reduce the effective rating of the transformer and to increase the risk of maldiscrimination with LV fuses. In these cases if fuse-links of lower rating than called for in this CP are installed, the switch-fuse shall bear a label to that effect, and state the rating of the required fuse-links. For these purposes any fault level less than 50MVA shall be considered as a high source impedance. Also, LV tail lengths of 7m or longer shall be classed as long, but tails shorter than this may require more detailed consideration in some cases. The effects of high source impedance and long LV tail length can be checked by hand calculation. Methods for calculating HV fuse size protection and guidance on LV cable arrangements can be found in Appendix I of CP258.

In order not to impose any restrictions on system design, all distribution transformer settings allow for 150% loading.

If, in exceptional circumstances it has been found necessary to increase the LV fuse-link current rating over the maximum stated value owing to current loading on a distributor then maldiscrimination between HV and LV protection may occur. It is stressed that this shall be allowed only under exceptional circumstances: in general discrimination across the distribution transformer shall be maintained under all distributor fault conditions.

HV fuse-links installed in accordance with this CP will not necessarily discriminate with industrial type LV fuse-links or circuit breakers.

13.6.1 High Voltage Switch-Fuse Protection

Tables 6A, 6B, 6C and 6D give high voltage fuse-link ratings for use in switch-fuse units incorporating HV fuses under oil and in air. HV fuse-link ratings have been selected to accord with the principles outlined in ENA TS 12-8 "The application of fuse-links to 11kV x 6.6kV/415V distribution networks." Attention is drawn to the notes under Tables 6A, 6B, 6C and 6D.

It is not policy to protect more than one transformer banked onto a single switch-fuse. There are particular problems associated with this practice; if in doubt refer each case to the Policy and Standards section, for consideration.

13.6.2 Current Transformer Release and Time Fuses

Tables 6E, 6F, 6G and 6H give settings for protection by means of current transformer release and non-deteriorating time fuses in accordance with ENA TS 12-6. The 200/100/50/5A settings are the preferred settings (Tables 6E & 6G). The 80/40/5A settings are alternative settings (Tables 6F & 6H), which are to be used only on existing installations when the preferred setting cannot easily be applied. (e.g. The preferred settings would require a current transformer change on an existing 80/40/5A installation.)

Where, on existing installations, protection is by means of time fuses used in conjunction with 5A release coils the release coil shall be set at its minimum marked setting (usually 60% or 80%) and tested for definite operation at that setting.

13.6.3 Inverse Time Relays

Tables 6I and 6K give settings for protection by means of inverse time relays of the type having an extremely inverse time/current characteristic in accordance with BS EN 60255. Settings are given for 200/1A and 100/50/5A current transformer installations and also for those existing installations equipped with 80/40/5A current transformers.

The 200/1 current transformers are used with VIP relays on Schneider units, which also have hard wired connections for x2 or x4 setting range. The range to be used is shown in brackets after the current transformer ratio. The settings for VIP relays are given in ampere rather than % as this is how they are set. Note that the settings in the tables are those as applied directly to the VIP300 relay. To convert to the equivalent inverse settings the conversion table on the relay must be used.

Tables 6J and 6L include settings for existing installations employing relays having either a “standard inverse” or “very inverse” time/current characteristics in accordance with BS EN 60255. Settings are given for 200/1A, 100/50/5A and 80/40/5A and current transformer installations.

All settings given in Tables 6I to 6L are maximum settings and shall not be increased under any circumstances.

The alternative settings in Tables 6J and 6L for standard IDMT relays have been chosen to ensure that LV terminal zone faults are definitely cleared. This relay type has an inherently unsuitable characteristic, which may result in maldiscrimination for LV phase-phase faults.

Inverse time relay protection of distribution transformers shall be done using three pole overcurrent units. Two pole and earth fault relays are not ideal for this application but can be used if a three pole unit is not available.

Where earth fault protection is available in addition to three pole overcurrent protection i.e. VIP relays it shall be set using the following principles. As the HV earth fault protection is not discriminating with the LV side and only protecting the transformer HV winding and short length of conductors between the CTs and winding it can be set quite low. It is recommended that a minimum setting of 40% of rated current (including overload), but not below 40A is used up to a maximum of 64A and a standard inverse curve with a time multiplier of 0.1 applied. The earth fault settings for VIP relays are shown in Tables 6I and 6K and the same settings apply to the equivalent transformer ratings in Tables 6J and 6L.

13.6.4 HV DIN Type Full Range Fuse-Link Protection

These fuse-links are for use in Padmount type transformers with no associated HV switchgear. The use of full range fuse-links is to provide protection down to the lowest level of overload possible with a fuse-link as they are not working in conjunction with a tripping mechanism.

Tables 6M and 6N give high voltage fuse-link ratings for use in Padmount type transformers. These fuse-links shall comply with BS EN 60282-1 and dimensionally with DIN 43625.

Table 6A – Protection of Distribution Transformers – Ratio 11000/433 High Voltage Switch-Fuse Protection HV Fuse-Link Types for use Under Oil

TRANSFORMER RATING (KVA)	ENA TS FUSE REF.	HV FUSE-LINK RATING (A)	MAXIMUM LV FUSE-LINK RATING (A)
200	O1	25	200
300/315	O2	31.5	315
500	O3	50[1]	400
750/800	O4	80	630
1000	O5	90	630
1250[2]	O6	100	630
1500[2]	O6	125	630

NOTE:

- Fuse-links must be orientated for correct striker operation.
- When any fuse of a set operates the whole set shall be removed and returned to the Technical Laboratory for attention.
- Fuses that do not comply with the above tabulation shall be changed on the following basis:-

  (a) Fuses providing source-end protection of feeder transformers shall be changed on an urgent basis.

  (b) All other non-complying fuses shall be changed before the next switch-fuse maintenance is completed.

[1] The 50A fuse (ENA TS Ref 03) replaces the obsolete 56A fuse previously used. The 50A fuses will provide adequate grading margins with 400A LV fuses on 11kV networks.

[2] Transformer ratings above 1MVA shall be used only for customer owned HV transformers

Table 6B – Protection of Distribution Transformers – ratio 11000/433 High Voltage Switch-Fuse Protection HV Fuse-Link types for Use in Air

TRANSFORMER RATING (KVA)	ENA TS FUSE REF.	HV FUSE-LINK RATING (A)	MAXIMUM LV FUSE-LINK RATING (A)
200	A1	20	200
300/315	A2	32	315
500	A3	50	400
750/800	A4	71	630
1000	A5	-[1]	630

NOTE:

- Fuse-links must be orientated for correct striker operation.
- When any fuse of a set operates the whole set shall be removed and returned to the Technical Laboratory for attention.
- Fuses that do not comply with the above tabulation shall be changed before the next switch-fuse maintenance is completed.

  (a) These transformers cannot be protected by equipment containing fuses in air due to insufficient cooling of the fuses.

Table 6C – Protection of Distribution Transformers – Ratio 6600/433 High Voltage Switch-Fuse Protection HV Fuse-Link Types for use Under Oil

TRANSFORMER RATING (KVA)	ENA TS FUSE REF.	HV FUSE-LINK RATING (A)	MAXIMUM LV FUSE-LINK RATING (A)
200	O2	31.5	200
300/315	O3	50[1]	315
500	O4	80	400
750/800	O6	125	630
1000[2]	O7	140	630

NOTE:

- Fuse-links must be orientated for correct striker operation.
- When any fuse of a set operates the whole set shall be removed and returned to the Technical Laboratory for attention.
- Fuses that do not comply with the above shall be changed on the following basis: -

(a) Fuses providing source-end protection of feeder transformers shall be changed on an urgent basis.

(b) All other non-complying fuses shall be changed before the next switch-fuse maintenance is completed.

[1] The 50A fuse (ENA TS Ref 03) replaces the obsolete 56A fuse previously used. The 50A fuses will provide adequate grading margins with 315A LV fuses on 6.6kVnetworks.

[2] Although not normally approved at 6.6kV, some HV customer installations exist with transformers above 1MVA. Refer to the Policy and Standards section, for advice on replacing fuses on such sites.

Table 6D – Protection of Distribution Transformers – Ratio 6600/433 High Voltage Switch-Fuse Protection HV Fuse-Link Types for use in Air

TRANSFORMER RATING (KVA)	ENA TS FUSE REF.	HV FUSE-LINK RATING (A)	MAXIMUM LV FUSE-LINK RATING (A)
200	A2	32	200
300/315	A3	50	315
500	A4	71	400
750/800	A6	-[1]	630
1000	A7	-[1]	630

NOTE:

- Fuse-links must be orientated for correct striker operation.
- When any fuse of a set operates the whole set shall be removed and returned to the Technical Laboratory for attention.
- Fuses that do not comply with the above tabulation shall be changed before the next switch-fuse maintenance is completed.

[1] These transformers cannot be protected by equipment containing fuses in air due to insufficient cooling of the fuses.

Tables 6E & 6F – Protection of Distribution Transformers – Ratio 11000/433 Current Transformer Release and Time Fuses

TABLE 6E PREFERRED SETTINGS			
TRANSFORMER RATING (KVA)	NON-DETERIORATING TIME FUSES		MAXIMUM LV FUSE-LINK RATING (A)
	CT RATIO	FUSE (A)	
200	50/5	3	200
300/315	50/5	5	315
500	50/5	10	400
750/800	100/5	7.5	630
1000	100/5	10	630
1250[1]	100/5	12.5	630
1500[1]	100/5	15	630

TABLE 6F ALTERNATIVE SETTINGS			
TRANSFORMER RATING (KVA)	NON-DETERIORATING TIME FUSES		MAXIMUM LV FUSE-LINK RATING (A)
	CT RATIO	FUSE (A)	
200	40/5	3	200
300/315	40/5	7.5	315
500	40/5	12.5	400
750/800	80/5	10	630
1000	80/5	12.5	630

NOTE:

[1] Transformer ratings above 1MVA shall be used only for customer owned HV transformers

Tables 6G & 6H – Protection of Distribution Transformers – ratio 6600/433 Current Transformer Release and time Fuses

TABLE 6G PREFERRED SETTINGS			
TRANSFORMER RATING (KVA)	NON-DETERIORATING TIME FUSES		MAXIMUM LV FUSE-LINK RATING (A)
	CT RATIO	FUSE (A)	
200	50/5	5	200
300/315	50/5	10	315
500	100/5	7.5	400
750/800	100/5	12.5	630
1000[1]	100/5	15	630

TABLE 6H ALTERNATIVE SETTINGS			
TRANSFORMER RATING (KVA)	NON-DETERIORATING TIME FUSES		MAXIMUM LV FUSE-LINK RATING (A)
	CT RATIO	FUSE (A)	
200	40/5	7.5	200
300/315	40/5	12.5	315
500	80/5	10	400
750/800	80/5	15	630
1000[1]	80/5	15	630

NOTE:

[1] Although not normally approved at 6.6kV, some HV customer installations exist with transformers above 1MVA. Refer to the Policy and Standards section, for advice on replacing fuses on such sites.

Table 6I – Protection of Distribution Transformers – Ratio 11000/433 Inverse Time Relays

TABLE 6I PREFERRED SETTINGS						
TRANSFORMER RATING (KVA)	CT RATIO	EXTREMELY INVERSE CHARACTERISTIC		EARTH FAULT SETTING STANDARD INVERSE[3]		MAXIMUM LV FUSE-LINK RATING (A)
		CURRENT	TM	CURRENT	TM	
200	40/5 50/5	100% 75%	0.15 0.15			200
300/315	40/5 50/5	125% 100%	0.20 0.20			315
500	80/5 100/5 200/1(x2)[1]	100% 75% 64A	0.15 0.15 0.15	40A	0.3	400
750/800	80/5 100/5 200/1(x4)[1]	150% 125% 112A	0.15 0.15 0.15	48A	0.3	630
1000	80/5 100/5 200/1(x4)[1]	150% 125% 112A	0.15 0.15 0.15	48A	0.3	630
1250[2]	80/5 100/5 200/1(x4)[1]	150% 125% 112A	0.15 0.15 0.15	48A	0.3	630
1500[2]	80/5 100/5 200/1(x4)[1]	150% 125% 112A	0.15 0.15 0.15	64A	0.3	630

NOTE:

[1] These are the settings as applied directly to the VIP300 relay.

[2] Transformer ratings above 1MVA shall be used only for customer owned HV transformers

[3] These are the earth fault settings as applied directly to the VIP300 relay. These use a Standard Inverse curve only and the setting above equates to a time multiplier of 0.1. These settings also apply to Table 6J for the same Transformer Rating.

Table 6J – Protection of Distribution Transformers – Ratio 11000/433 Inverse Time Relays

TABLE 6J ALTERNATIVE SETTINGS						
TRANSFORMER RATING (KVA)	CT RATIO	STANDARD INVERSE CHARACTERISTIC		VERY INVERSE CHARACTERISTIC		MAXIMUM LV FUSE-LINK RATING (A)
		CURRENT	TM	PLUG	TM	
200	40/5 50/5	100% 75%	0.15 0.15	100% 75%	0.15 0.15	200
300/315	40/5 50/5 80/5 100/5	150% 125% 75% 75%	0.15 0.15 0.15 0.15	125% 100% 75% 50%	0.20 0.20 0.15 0.20	315
500	40/5 50/5 80/5 100/5 200/1 (x2)[1]	200% 175% 100% 75% 72A	0.15 0.15 0.15 0.20 0.60	200% 175% 100% 75% 80A	0.15 0.15 0.15 0.15 0.20	400
750/800	80/5 100/5 200/1 (x4)[1]	150% 125% 112A	0.20 0.20 0.60	150% 125% 96A	0.15 0.15 0.30	630
1000	80/5 100/5 200/1 (x4)[1]	175% 150% 128A	0.15 0.15 0.40	150% 125% 96A	0.15 0.15 0.30	630

NOTE:

[1] These are the settings as applied directly to the VIP300 relay.

Table 6K – Protection of Distribution Transformers – ratio 66000/433 Inverse Time Relays

<table>
<tr><th colspan="7">TABLE 6K PREFERRED SETTINGS</th></tr>
<tr><th rowspan="2">TRANSFORMER RATING (KVA)</th><th rowspan="2">CT RATIO</th><th colspan="2">EXTREMELY INVERSE CHARACTERISTIC</th><th colspan="2">EARTH FAULT SETTING STANDARD INVERSE[3]</th><th rowspan="2">MAXIMUM LV FUSE-LINK RATING (A)</th></tr>
<tr><th>CURRENT</th><th>TM</th><th>CURRENT</th><th>TM</th></tr>
<tr><td>200</td><td>40/5
50/5</td><td>125%
100%</td><td>0.20
0.20</td><td></td><td></td><td>200</td></tr>
<tr><td>300/315</td><td>80/5
100/5
200/1 (x4)[1]</td><td>100%
75%
60A</td><td>0.15
0.20
0.20</td><td>48A</td><td>0.3</td><td>315</td></tr>
<tr><td>500</td><td>80/5
100/5
200/1 (x4)[1]</td><td>150%
125%
96A</td><td>0.15
0.15
0.20</td><td>48A</td><td>0.3</td><td>400</td></tr>
<tr><td>750/800</td><td>80/5
100/5
200/1 (x4)[1]</td><td>200%
200%
180A</td><td>0.30
0.20
0.20</td><td>48A</td><td>0.3</td><td>630</td></tr>
<tr><td>1000[2]</td><td>100/5
200/1 (x4)[1]</td><td>200%
180A</td><td>0.20
0.20</td><td>64A</td><td>0.3</td><td>630</td></tr>
</table>

NOTE:

[1] These are the settings as applied directly to the VIP300 relay.

[2] Although not normally approved at 6.6kV, some HV customer installations exist with transformers above 1MVA. Refer to the Policy and Standards section, for advice on replacing fuses on such sites.

[3] These are the earth fault settings as applied directly to the VIP300 relay. These use a Standard Inverse curve only and the setting above equates to a time multiplier of 0.1. These settings also apply to Table 6J for the same Transformer Rating.

Table 6L – Protection of Distribution Transformers – Ratio 6600/433 Inverse Time Relays

TABLE 6L ALTERNATIVE SETTINGS						
TRANSFORMER RATING (KVA)	**CT RATIO**	**STANDARD INVERSE CHARACTERISTIC**		**VERY INVERSE CHARACTERISTIC**		**Maximum LV Fuse-Link Rating (A)**
		PLUG	**TM**	**PLUG**	**TM**	
200	40/5 50/5	125% 100%	0.20 0.20	125% 100%	0.20 0.20	200
300/315	40/5 50/5 80/5 100/5 200/1 (x4)[1]	175% 150% 100% 75% 72A	0.20 0.20 0.20 0.20 0.60	200% 150% 100% 75% 72A	0.15 0.20 0.15 0.20 0.30	315
500	80/5 100/5 200/1 (x4)[1]	125% 100% 96A	0.20 0.20 0.60	150% 125% 128A	0.15 0.15 0.20	400
750/800	80/5 100/5 2001 (x4)[1]	- 175% 180A	- 0.20 0.60	200% 200% 200A	0.25 0.20 0.30	630
1000	80/5 100/5 200/1 (x4)[1]	- 200% 200A	- 0.20 0.60	200% 200% 200A	0.30 0.20 0.30	630

NOTE:

[1] These are the settings as applied directly to the VIP300 relay.

Table 6M – Protection of Padmount Type Transformers – ratio 11000/433 High Voltage Fuse Protection HV DIN Type Full Range Fuse-Link

TRANSFORMER RATING (KVA)	HV FUSE-LINK RATING (A)	MAXIMUM LV FUSE-LINK RATING (A)
50	10	200
100	16	200
200	20	200

Table 6N – Protection of Padmount Type Transformers – Ratio 66000/43 High Voltage Fuse Protection HV DIN Type Full Range Fuse-Link

TRANSFORMER RATING (KVA)	HV FUSE-LINK RATING (A)	MAXIMUM LV FUSE-LINK RATING (A)
50	16	200
100	20	200
200	31.5	200

13.7 Protection of Transformers by HV Drop Out Expulsion Fuses

The range of distribution transformers to be protected is from 16kVA single phase to 315kVA three phase. Split phase transformers are also included.

It is policy generally to use solid links in Drop Out Expulsion Fuse (DOEF) mounts, with fast acting source protection incorporating auto reclose (see EPD321). These links then provide a means of isolation only. However it is recognised that in many cases local protection is required.

Where the transformer terminal zone is thought to be at unusually high risk to faults, then local DOEF protection shall be applied e.g. EPD282 (sub-section 4.3.7.3) requires that a PMT that has a ground mounted LV 'take off' (i.e. without LV fuses at high level) shall have its own local 11/6.6kV protection to cover the LV connections.

NOTE:

The standard arrangement of LV fuses mounted on poles with short single core connections to the transformer does not usually offer such a risk.

Ground mounted transformers with conventional LV terminal zone arrangements shall have local protection of the LV terminal zone in accordance with this section, or with Section 13.6.

Industrial supplies afforded from a DOEF protected transformer shall be given individual consideration for the fuse sizes to be used; both HV and LV. In these cases, subject to the approval of the Policy and Standards section fuses sizes differing from this CP may be installed.

13.7.1 Protection of Individual Transformers

Tables 7A, 7B and 7C for 11kV and Tables 7D, 7E and 7F for 6.6kV give the DOEF to be employed for the protection of individual transformers. Attention is drawn to the notes under these tables. In compiling these tables the following conditions have been assumed:

Expulsion fuses are arranged to ensure discrimination with LV fuses for the most onerous LV fault condition.

Smaller ratings of DOEF are not used. Their performance has been found to be unsatisfactory because they are insufficiently mechanically robust. A minimum rating of 20A has therefore been adopted.

The maximum allowable LV fuse size is shown against each transformer rating.

13.7.2 Group Fusing

Tables 7G and 7H provide DOEF sizes for group fusing. The following conditions have been assumed to apply:

An empirical overload factor of 1.2 has been allowed for. This takes into account the overload factor of the transformers and allows for some diversity.

The tables show the minimum individual transformer rating that is adequately protected by the group fuse. This small risk must sometimes be accepted, subject to the provisos of 13.7.1 above. The alternative is to split the group into smaller sections.

Table 7A-7C – Protection of Distribution Transformers – Ratio 11000/433 Drop Out Expulsion Fuses

TABLE 7A SINGLE PHASE TRANSFORMERS		
TRANSFORMER RATING (KVA)	**MAXIMUM LV FUSE (A)**	**DROP OUT EXPULSION FUSE (A)**
16	100	25*
25	160	25*
50	200	25*

TABLE 7B SPLIT PHASE TRANSFORMERS		
TRANSFORMER RATING (KVA)	**MAXIMUM LV FUSE (A)**	**DROP OUT EXPULSION FUSE (A)**
25	100	25*
50	160	25*
100	200	25+

TABLE 7C THREE PHASE TRANSFORMERS		
TRANSFORMER RATING (KVA)	**MAXIMUM LV FUSE (A)**	**DROP OUT EXPULSION FUSE (A)**
25	100	25*
50	160	25*
100	200	25+
200	200	25
300/315	315	40

NOTE:

- Indicates that the fuse does not adequately protect the transformer LV terminal zone; the fault will probably persist until the transformer is damaged.
- Indicates that an LV earth fault will persist until at least two phases are involved. For split phase transformers this means until either both windings fault to each other, or until the transformer is damaged.

Table 7D-7F – Protection of Distribution Transformers – Ratio 6600/433 Drop Out Expulsion Fuses

TABLE 7D SINGLE PHASE TRANSFORMERS		
TRANSFORMER RATING (KVA)	**MAXIMUM LV FUSE (A)**	**DROP OUT EXPULSION FUSE (A)**
16	100	25*
25	160	25*
50	200	25

TABLE 7E SPLIT PHASE TRANSFORMERS		
TRANSFORMER RATING (KVA)	**MAXIMUM LV FUSE (A)**	**DROP OUT EXPULSION FUSE (A)**
25	100	25*
50	160	25+
100	200	25

TABLE 7F THREE PHASE TRANSFORMERS		
TRANSFORMER RATING (KVA)	**MAXIMUM LV FUSE (A)**	**DROP OUT EXPULSION FUSE (A)**
25	100	25*
50	160	25*
100	200	25
200	200	25
300/315	315	40

NOTE:

- Indicates that the fuse does not adequately protect the transformer LV terminal zone; the fault will probably persist until the transformer is damaged.

- Indicates that an LV earth fault will persist until at least two phases are involved. For split phase transformers this means until either both windings fault to each other, or until the transformer is damaged.

Table 7G – Group Fusing of Distribution Transformers – Ratio 11000/433 Drop Out Expulsion Fuses

GROUP RATING (kVA)	D O E F AND MINIMUM TRANSFORMER SIZE PROTECTION	
	D O E F SIZE (A)	MIN TX (kVA)
400	25A	100
500	25A	100

Table 7H – Group Fusing of Distribution Transformers – Ratio 6600/433 Drop Out Expulsion Fuses

GROUP RATING (KVA)	D O E F AND MINIMUM TRANSFORMER SIZE PROTECTION	
	D O E F SIZE (A)	MIN TX (KVA)
400	25A	100
500	40A	100

NOTE:

- Where the Group Rating exceeds 500kVA refer to EPD282

13.8 Fusing of Domestic Cut-Outs

13.8.1 Earth Loop Impedance

The purpose of the cutout fuse is to disconnect an overload or fault in the property from the Network before damage is caused to the network and to protect the wiring between cutout and the domestic distribution unit. For protection against faults the maximum fuse size is determined by the earth loop impedance measured at the cutout. The recommended maximum values of earth loop impedance for single phase supplies up to 100A given in ENA ER P23 are to be applied for Networks:

- PME networks 0.35Ω (higher values can be accepted up to 0.80Ω)
- Non-PME system 0.80Ω

All new installations shall be designed to have an earth loop impedance of 0.35Ω or less where possible. Higher values, up to a maximum 0.80Ω, are allowable if the lower value cannot be achieved. The maximum fuse size to be installed shall be determined by reference to Table 8A.

In existing properties where values in excess of 0.80Ω, are encountered the supply may remain connected up to a maximum value of 1.60Ω, subject to the fitting of a reduced fuse size, as determined by reference to Table 8A. Remedial action shall be instigated urgently to reduce the earth loop impedance to an acceptable value, as detailed in CP606.

13.8.2 Maximum Fuse Sizes

Table 8A shows the maximum cutout fuse sizes to be installed dependent on the measured earth loop impedance.

Table 8A – Maximum Cutout Fuse Size (240V Supply Voltage)

LOOP IMPEDANCE	MAXIMUM CUTOUT FUSE SIZE
< 0.54Ω	100A
0.55Ω to 0.84Ω	80A
0.85Ω to 1.04Ω	60A
1.05Ω to 1.24Ω	50A
1.25Ω to 1.60Ω	40A
> 1.60Ω	Disconnect supply

13.9 Fusing of Street Lighting Cut-Outs

13.9.1 Earth Loop Impedance

The purpose of the cut-out fuse is to disconnect a fault in the street lighting/street furniture installation (SLI) from the network before damage is caused to the network and to limit the damage to the wiring within the SLI. For protection against faults the maximum fuse size is determined by the earth loop impedance measured at the cut-out.

All new installations shall be designed to have an earth loop impedance of 2.30Ω or less where possible. Higher values, up to a maximum 13.5Ω, are allowable if the lower value cannot be achieved, subject the use of the appropriately sized fuse link compliant with BS-HD 60269: 2010 / BS 88-2: 2010.

The allowable combinations of maximum earth loop impedance and maximum fuse size which can be installed are set out in Table 9A.

In existing installations, where values are in excess of those in the table, are encountered the supply may remain connected up to a maximum value of 13.5Ω, subject to the fitting of a reduced fuse size, as determined by reference to Table 9A. Where the earth loop impedance is determined to be in excess of 13.5Ω Remedial action shall be instigated urgently to reduce the earth loop impedance to an acceptable value, as detailed in CP610.

13.9.2 Maximum Fuse Sizes

Table 9A shows the maximum cutout fuse sizes to be installed dependent on the measured earth loop impedance.

Table 9A – Maximum Cutout Fuse Size (230V Supply Voltage)

MAXIMUM CUTOUT FUSE SIZE	LOOP IMPEDANCE[1]
25A	< 2.31Ω
16A	< 2.92Ω
6A	<13.51Ω
Disconnect supply	≥ 13.51Ω

The recommended maximum values of earth loop impedance for single phase supplies up to 25amps are derived from BS7671, table 41.4.

[1] These values have been taken from BS7671 (2008), Table 41.4.
They may have been revised (marginally) in amendments 1 (2011) and 2 (2013) but remain appropriate as set out above and within the safe margin which is required for reliable operation.

14 Module Eleven – LV Service Connections and Application of PME

Contents

14.1 Foreword

This Code of Practice (CoP) draws on ENA Engineering Recommendation (EREC) G12/4 2013, ENA EREC G87 2010 and takes into account:

- The Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR)
- The publication of other documents such as British Standard (BS) 7671 (Electrical Installations of Buildings).

This CoP is primarily concerned with the detailed engineering requirements pertaining to LV PME service connections and the network from which they are derived. Due to the practice of mixing PME and non-PME services within a network, this CoP also covers non-PME connections, and in particular provides guidance on when not to provide PME service connections.

To assist users in the interpretation of this CoP, a decision tree is included in Appendix V. This diagram shall be used in conjunction with the text of this CoP.

14.2 Scope

This CoP sets out the requirements that shall be adopted when protective multiple earthing (PME) is applied to overhead and underground LV distributors forming part of the electricity distribution network (Network) owned and operated by Electricity North West Limited. The CoP describes the actions to be taken to satisfy the requirements of the ESQCR and other current documents.

This CoP also considers situations where PME should not normally be used.

Electricity Policy Documents (EPDs) and Specifications (ESs) are a source of Electricity North West Limited policy and this CoP takes account of EPD332 - Customer Installation Earthing, EPD333 - Supply System Earthing and ES287 - Connections to Multiple Occupancy Buildings.

14.3 Risk Assessments

The following areas of work associated with this CoP require special consideration and attention to detail in order to avoid the risks identified herein.

14.3.1 Driving of Earth Rods

All practical steps shall be taken to ensure that rods are not driven into any buried services such as gas or water pipes, or telephone or electricity cables. The use of approved instruments for the detection of buried services is essential.

14.3.2 Equipotential Bonding

On no account shall any customer use a PME earthing terminal unless it is confirmed that equipotential bonding has been provided in accordance with the requirements of BS7671. The omission of equipotential bonding could subject a customer to hazardous potential differences within his installation should a supply neutral become open circuited.

14.3.3 Polarity Check

An approved means of ensuring the correct polarity of phase and neutral of a PME connection shall be used. An incorrect polarity could result in the exposed metal parts of the installation being elevated to phase potential, creating danger for persons who could make simultaneous contact between such metalwork and earth or other earthed metalwork.

14.3.4 Neutral Connections

The loss of a supply neutral can create overvoltage for customers' single phase equipment, and for a PME system it can cause a voltage between earth and exposed metal parts of equipment. Care shall be taken to avoid open circuit supply neutrals by compliance with the methods and standards of construction in CP411LV and CP430.

14.4 Historical Background

It is over 40 years since the first practical form of PME earthing was introduced. It was first used to provide rural customers with effective earth fault protection using a continuous metallic return path. Prior to the 1960's (after which time the use of plastic water pipes became widespread) many customers relied on direct earthing via their metal water services. The fourteenth edition of the IEE Wiring Regulations deprecated the use of water pipes as a means of earthing and following this change and the introduction of CNE type cable, the use of PME expanded rapidly.

During the 1960's Electricity Boards began to develop comprehensive earthing policies with the main aim of providing every customer with effective earthing via a continuous metallic return path. This is generally accepted as the most satisfactory means of providing earth fault protection in the customer's installation. The Electricity Supply Industry's policy in respect of the provision of earthing facilities is given in ENA EREC P20/1. The requirement to provide each newly connected customer with an earth terminal from the Network is now embodied in the ESQCR (Regulation 24).

14.5 The Electricity Safety, Quality and Continuity Regulations 2002

14.5.1 General

The ESQCR replaced the Electricity Supply Regulations (1988) as amended.

The earthing requirements of the ESQCR apply to all substations, and in addition affect those customers who are connected as PME customers.

The wording of Part II of the ESQCR in particular with regard to PME has been greatly simplified. However, the intent of the Regulations has not changed.

14.5.2 Regulation 8 – System Earthing

In 8 (2)(b) it states that any distributor shall ensure that in any high voltage system the earth electrodes are designed, installed and used in such a manner so as to prevent danger occurring in any low voltage network as a result of any fault in the high voltage network and,

In 8 (3)(b) it states that any distributor, in respect of any low voltage network he owns or operates, shall ensure that every supply neutral conductor is connected with earth at, or as near as is reasonably practicable to, the source of voltage except that where there is only one point in a network at which consumer's installations are connected to a single source of voltage, that connection may be made at that point, or at another point nearer to the source of voltage. This latter part contains the relaxation necessary for the application of Protective Neutral Bonding (PNB).

14.5.3 Regulation 9 – Protective Multiple Earthing

Where PME is to be used regulation 9(2) states, in addition to the neutral with earth connection required under regulation 8(3)(b), as stated in 14.5.2 above, a distributor shall ensure that the supply neutral conductor is connected with earth at –

(a) a point no closer to the distributing main's source of voltage (as measured along the distributing main) than the junction between that distributing main and the service line which is most remote from the source; and

(b) such other points as may be necessary to prevent, so far as is reasonably practicable, the risk of danger arising from the supply neutral conductor becoming open circuit.

Under 9(4) the distributor shall not connect his combined neutral and protective conductor to any metalwork in a caravan or boat.

14.5.4 Regulation 10 – Earthing of Metalwork

Requires that distributors shall ensure that any metalwork enclosing, supporting or otherwise associated with his equipment in a network and which is not intended to serve as a phase conductor is, where necessary to prevent danger, connected with earth.

This restriction shall not apply:

(a) to any metalwork attached to, or forming part of, a wooden pole support, the design and construction of which is such as to prevent, so far as is reasonably practicable, danger within 3 metres of the ground from any failure of insulation or failure of insulators; or

(b) to any wall-mounted metal bracket carrying an overhead line not connected with earth, where the line is both supported by an insulator and the part of the line in contact with the insulator is itself surrounded by insulation.

14.6 Network Change Affecting Customers

Electricity North West Limited's earthing policy is set out in EPD332 – Customer Installation Earthing.

All new connections shall preferably include a PME arrangement.

Following changes to the Network which affect existing customers using non-PME earthing terminals connected to the Network (but not customer-provided earth terminals utilising lead water pipes or similar), those customers will be offered the continued use of an earthing terminal, free of charge. This shall be achieved by maintaining SNE type services. If a customer specifically requests conversion to PME, then he shall pay for the installation of a new CNE service cable and make his own arrangements for the necessary bonding of his installation if required.

The types of permitted service arrangements are listed below and shown on the following pages in Figures 1 and 2

14.6.1 SNE or CNE Main

- SNE utilising a suitable SNE service cable.

- PME utilising a CNE service cable (on SNE main only providing it has been converted to PME).

- Separate earth electrode with RCD controlled main incoming switch(es), ie TT system as defined in the BS7671.

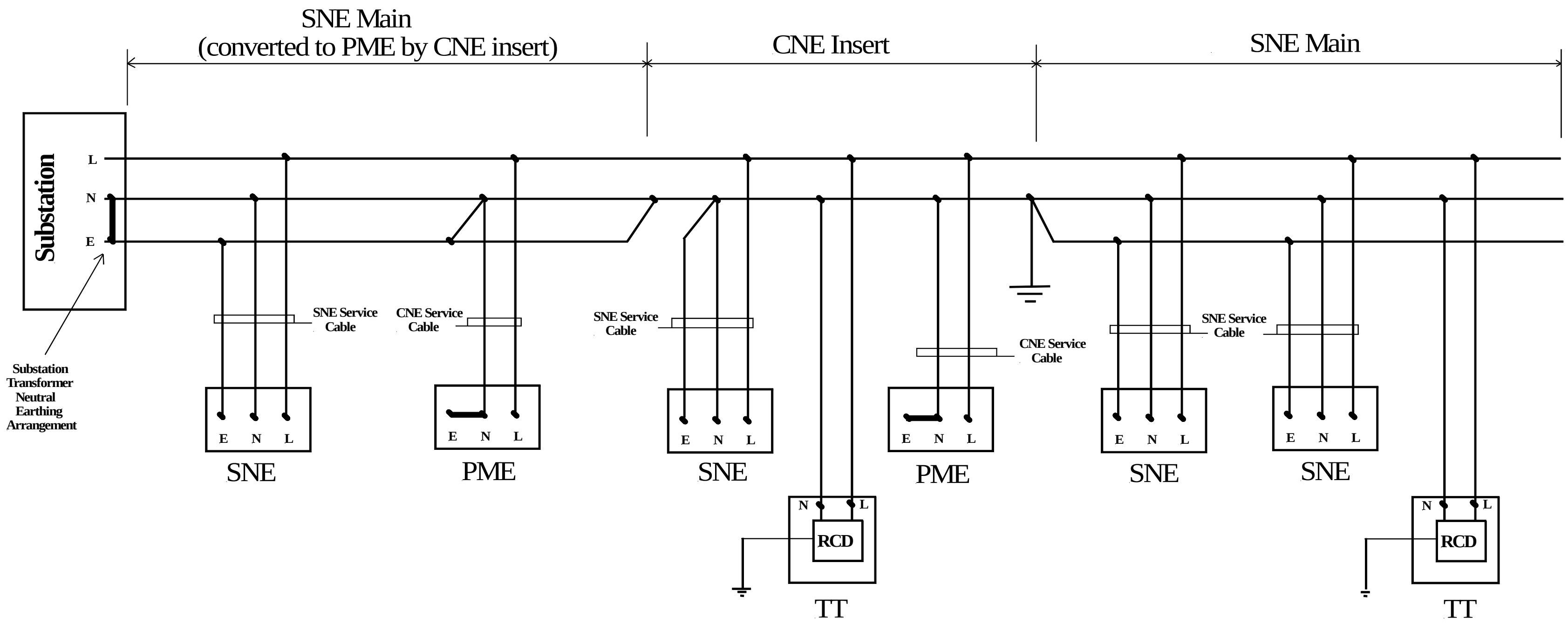
Services with a SNE cable **shall not** be converted to PME by the insertion of the neutral/earth link in the cut-out without the written agreement of the Protection Systems Manager, Electricity North West. If PME is required then the service cable shall be replaced with a CNE cable at the cost of the customer. Alternatively where the existing SNE service cable is long and the costs of the additional joints can be justified, the SNE cable may be reconnected. In such case:

- At the service termination, a short length of CNE cable terminated in the cut-out shall be installed; and

- At the main, the prescribed neutral-earth bond shall be applied in the joint and, if necessary, a short length of CNE cable and straight joint installed.

Figure 1 – Approved PME/SNE Arrangements

Approved PME/SNE Service Arrangements



Notes:

1) Only one phase of three-phase main cable shown for clarity.

2) Earthing of mains shall be in accordance with CP332.

3) Exceptions shall be only with the written agreement of the Protection Policy Manager, Electricity North West.

15 April 2002

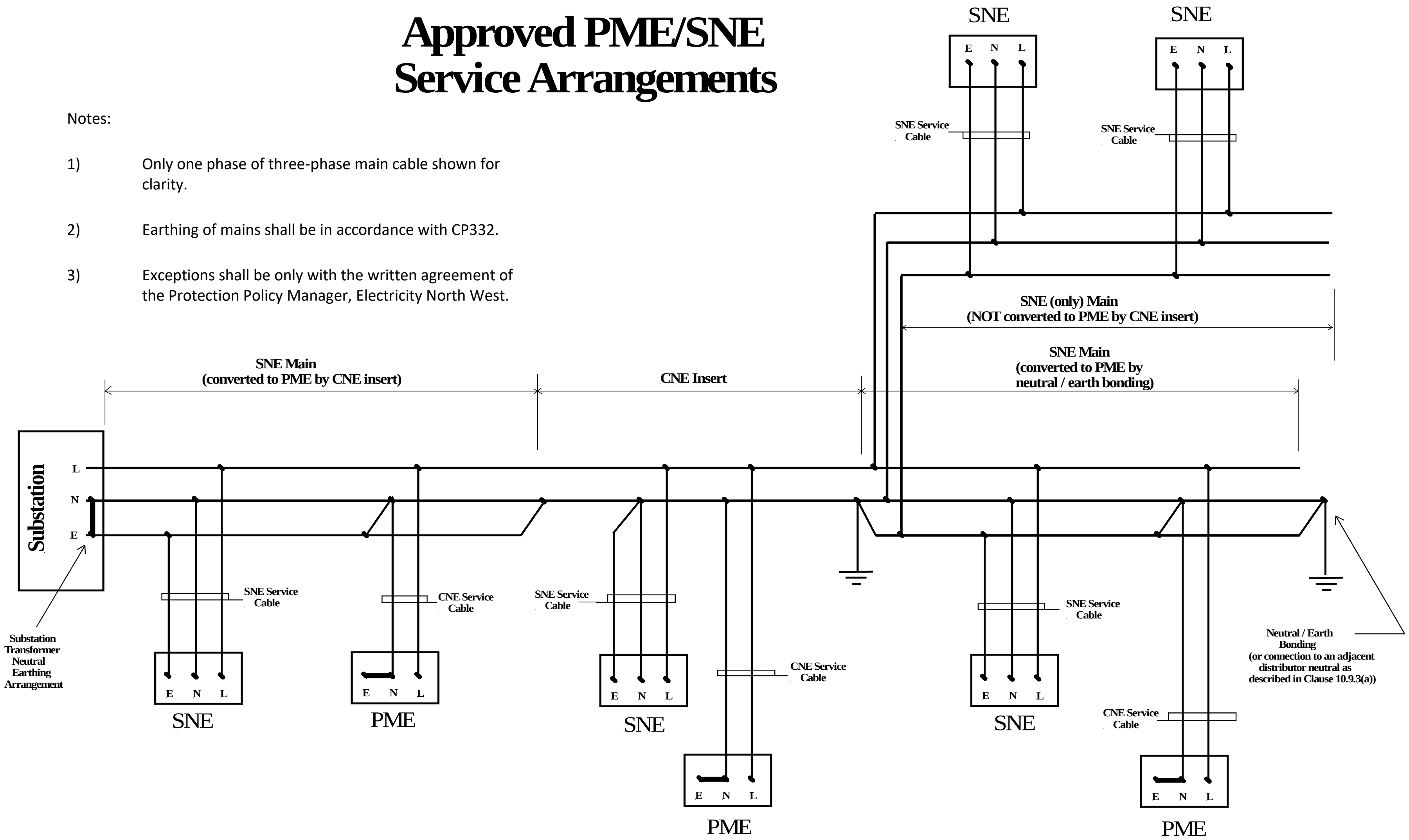
Figure 2 – Approved PME/SNE Arrangements

Notes:

1) Only one phase of three-phase main cable shown for clarity.

2) Earthing of mains shall be in accordance with CP332.

3) Exceptions shall be only with the written agreement of the Protection Policy Manager, Electricity North West.



In the case of RCD controlled services, generally the product of the operating current in ampere and the main electrode resistance value in ohm shall not exceed 50 volt. The provision of other RCDs for power and lighting circuits may be necessary and may affect the design of the main incoming RCD. General guidance only can be given here, because each installation will need to take account of the customer's existing arrangements. For detailed guidance, reference shall be made to the BS7671 section 411 and, in the case of farms or horticultural premises, to section 705.

In the case of existing installations that do not have electricity earth terminals provided from the network (not counting customer-provided earth terminals utilising lead water pipes or similar) then:

Where work on the electricity main is part of a refurbishment scheme, an earthing facility and connection shall be provided free of charge, provided certain conditions are met. The means of earthing shall be that chosen as least cost to Electricity North West Limited and may be the provision of a new PME or SNE service.

Typical refurbishment relevant to this sub-section would include the application of PME to a main, which provides no earthing facility or an inadequate one, or the replacement of a 4-wire non-PME overhead line with a length of Waveform cable.

Customers affected by such a refurbishment shall be given ample notice of the work together with an explanation of the benefits of the improved earthing arrangement. Advance notice should allow adequate time for those customers, who wish to improve the earthing and bonding of their installations, in order to take advantage of this improvement, to complete any necessary work prior to work on the Network. It shall be pointed out that where a customer requests work which requires Electricity North West Limited to visit the premises after the completion of the scheduled work, Electricity North West Limited reserves the right to make a charge for any such visit.

Where a SNE earthing terminal can be installed for the first time, this shall be done and the customer's earth connection made at the time of the Electricity North West Limited work free of charge.

Where a PME earthing terminal is installed for the first time and the customer's installation complies with the necessary earthing and bonding requirements of BS 7671 such that the customer's earth connection can be made to the PME terminal at the time of the Electricity North West Limited work, this shall be done free of charge.

Where a PME earthing terminal is installed, but the customer is not willing to upgrade his installation, in order to make use of it, connection of the customer's installation to the PME terminal shall be withheld. If the earthing of the customer's installation is inadequate and the customer does not already have a RCD, the customer shall be advised, in writing, of the dangers of inadequate earthing and of the need, at least, for a RCD to be installed. Should this advice be ignored, the customer shall be advised, in writing, that the connection cannot be continued unless the installation is modified. As a last resort, in order to avoid the immediate disconnection of the customer, a temporary RCD shall, if possible, be installed, in accordance with Appendix A of Procedure G20 of CP606/610.

Where the work on the Network is NOT part of a refurbishment scheme (e.g., diversion or reinforcement for a third party, or fault repair), the design of the work and the materials used (e.g. 4-core cable) shall be such as to ensure that existing customers, not instigating the work, shall not have their earthing arrangements made less effective as a consequence of the work. Should such a customer be obliged, as a direct consequence of the work, to carry out work of improving the earthing or bonding of his installation, the costs of this work shall be borne by the third party instigating the work, or, in the case of a fault repair, by Electricity North West Limited. It shall, however, be borne in mind that work of this kind could give rise to enquiries from customers.

Where it is discovered during the course of substantial work on a service connection (e.g. the replacement of a defective aerial service flight or mural wiring) that the earthing of the customer's installation is inadequate and an earth terminal from the network cannot readily be provided, procedure G20 of CP606/610 shall be applied. It is the responsibility of customers to ensure that they have adequately earthed installations. Prior to the fitting of a temporary RCD, Electricity North West Limited staff shall confirm this with the customer.

Voltage-operated Earth Leakage Circuit Breakers (ELCBs) do not meet the requirements of the latest edition of BS7671 and shall be considered to provide inadequate protection for a customer's installation.

14.7 Requirements for PME Networks

14.7.1 Distribution Substations

All new LV networks shall use CNE conductors for PME operation, except in the case of a PNB installation. Accordingly, all new distribution substations shall comply with the requirements of this section. Additionally, where any distributing main is converted to PME any substation likely to be used to feed that main shall be converted to meet the requirements of this section.

Substation earthing shall be in accordance with EPD333 – Supply System Earthing and CP333 – Earthing Design for High Voltage Substations and Equipment.

All ground mounted transformer connections shall be in accordance with CP333.

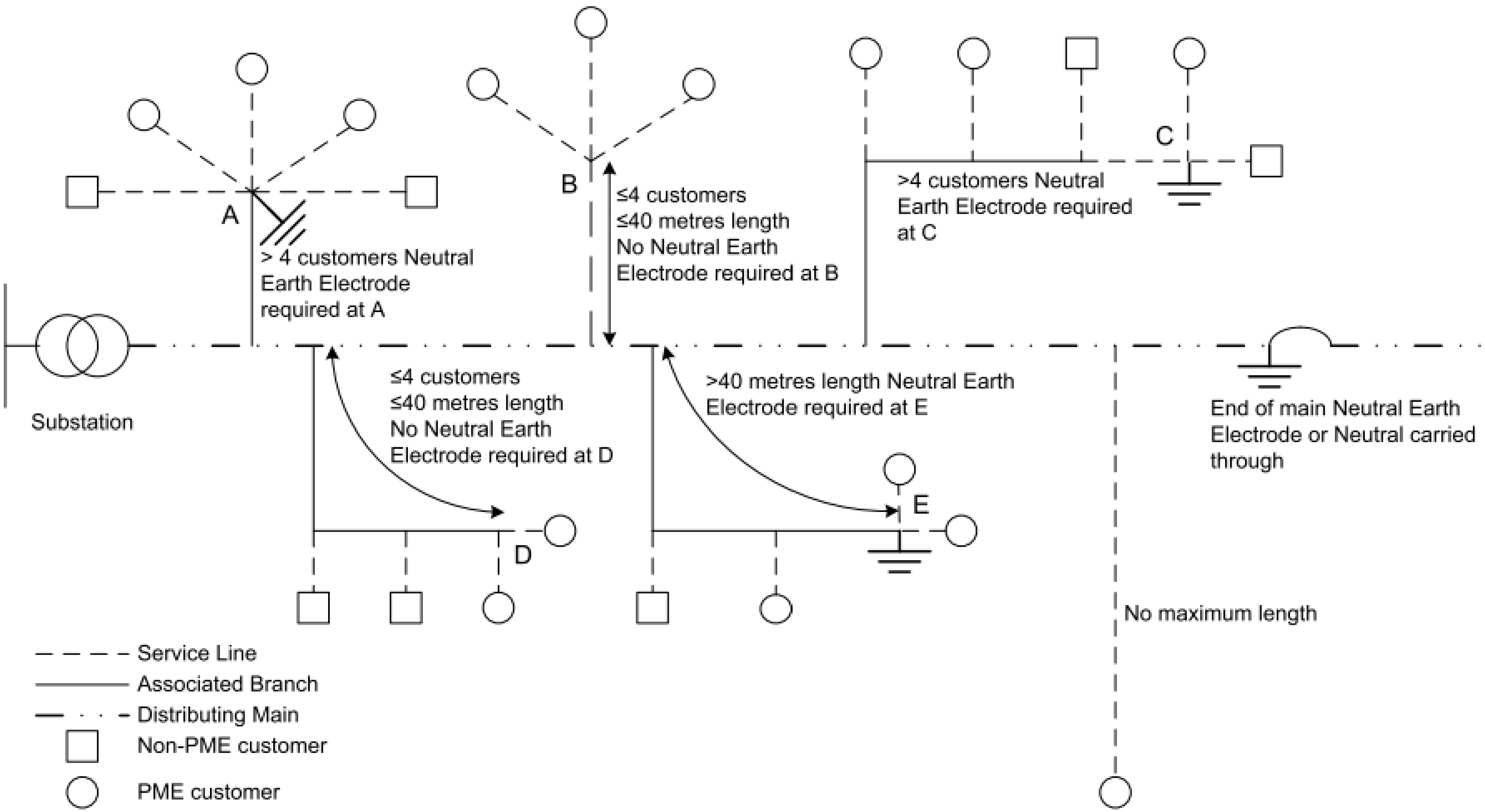
14.7.2 Neutral Earthing

Where PME is to be used, it is a requirement of Regulation 9 of the ESQCR that the supply neutral conductor is connected to earth at a point no closer to the distributing main's source of voltage (as measured along the distributing main) than the junction between that distributing main and the service line which is most remote from the source; and such other points as may be necessary to prevent, so far as is reasonably practicable, the risk of danger arising from the supply neutral conductor becoming open circuit. The examples shown in Figure 3, illustrate likely practical examples. Wherever practicable distributing mains shall be earthed at their remote ends, and at the remote end of every branch.

The PME neutral earth connections shall, if available, be an adjacent system neutral.

The alternatives to using a neutral of an adjacent live system are a driven rod, or the metallic sheath of a SNE cable that is part of a live system and is effectively in contact with the soil. In the case of a metallic sheath, the sheath shall be electrically continuous for at least five metres to be considered as equivalent to that of a single 1.2m earth rod.

Figure 3 – Neutral Earth Electrode Requirements



In order to meet the requirements of Regulation 9(2) of the ESQCR it is necessary to implement the guidelines in ENA ER G12/4. Section 4.7 of ENA ER G12/4 states that the substation LV neutral earth electrode resistance shall be sufficiently low for HV protection to clear an interwinding fault. Therefore, the overall resistance to earth of a PME neutral conductor (measured anywhere on the distributing main) shall not exceed 20Ω. If necessary, additional intermediate earth electrodes shall be introduced along the distributing main until this criterion is met. The final overall earth resistance shall be measured at the time the connection is made, to ensure compliance.

All neutral conductors which are multiply earthed shall have a conductivity which is either equal to that of the phase conductor for a single or two-phase main or service, or greater than or equal to half that of the phase conductor for three-phase mains or services. This is a requirement of Section 4.3.1 of ENA ER G12/4. Modern CNE cables (including consac, waveform and plastic concentric service cables as used on the network) comply with this requirement.

14.7.3 Protective Neutral Bonding

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.

The transformer tank and associated HV metalwork will be connected to a HV earth electrode. All uninsulated parts of this electrode shall be separated from any part of the LV earth electrode and any earthed metalwork connected to it.

PNB can apply to both three phase and single phase connections.

Earth terminals provided using PNB shall be treated in all respects as PME earth terminals.

14.7.4 Type and Size of Earthing and Bonding Connections

Earthing and bonding connections where buried direct in the ground shall preferably be of copper conductor. Where aluminium connections are used both the conductor and the joint to the earth electrode shall be adequately protected against corrosion.

The minimum size of earthing and bonding connections for copper conductors shall be as shown in Table 1. For non-copper conductors or copper alloys, the cross sectional area shall be such as to give a conductance (or continuous rating) equivalent to that of copper. Currents in PME earthing conductors may flow for an extended duration. In calculating the 'copper equivalent' cross sectional area of a conductor it is therefore not appropriate to use short-time equivalent ratings such as are typically quoted for protective conductors.

.

Table 1 – Earth and Bond Sizes

TYPE OF CONDUCTOR	MINIMUM COPPER EQUIVALENT CSA
Earth leads to neutral earth electrode	$16mm^2$
Bonding connection between neutral busbar and earth busbar at substation	To be not less than half the current carrying capcity (where appropriate) of the largest phase conductor in the distributing main
Bonding connections to link boxes and netwrok feeder pillars (where applicable)	$32mm^2$
At consumers' premises, connection between service neutral and earthing terminal	$16mm^2$ or half the size of the neutral meter tail whichever is the larger
At consumers' premises, connection between the earthing terminal and the earth bar of the consumer unit	See BS7671 (Wiring regs)
Connection between sheath of SNE cable and neutral of CNE cable	$32mm^2$
At consumers' premises the main equipotential bonding connections between the earthing terminal and all emtal structures, metal pipes and other extraneous-conductive parts	See BS7671 (Wiring regs)

To assist with the sizing of earthing and main protective bonding conductors, the copper equivalent cross-sectional areas of the supply line and neutral conductors for a range of typical DNO incoming cables are listed in Table 2.

Table 2 – Copper Equivalent Cross-Sectional Areas

TYPICAL INCOMING CABLE	COPPER EQUIVALENT CROSS-SECTIONAL AREA OF SUPPLY LINE CONDUCTOR	COPPER EQUIVALENT CROSS-SECTIONAL AREA OF SUPPLY NEUTRAL CONDUCTOR
$35mm^2$ Al CNE	$22mm^2$	$22mm^2$
$95mm^2$ Al CNE	$60mm^2$	$60mm^2$
$185mm^2$ Al CNE	$116mm^2$	$116mm^2$
$300mm^2$ Al CNE	$190mm^2$	$116mm^2$
$300mm^2$ Cu CNE	$300mm^2$	$150mm^2$

14.8 Requirements for Underground Networks

14.8.1 Use of CNE Cables

All **new** underground distribution systems shall use CNE cables for mains and services.

For **existing** underground cable systems CNE cables shall be used for the following:

- All new connections (including new services to refurbished properties having equipotential bonding). At the time of the first new connection the distributing main shall be modified to comply with the requirements of sub-section 14.7.3. The method of providing earth terminals to existing customers can remain unchanged.

- Reinforcement, extension, diversion or repair of distribution cables, subject to the requirements of sub-sections 14.6.1 and 14.8.4.

> **NOTE:**
>
> A SNE service cable shall not be replaced with a CNE cable, unless the customer requests it, or otherwise agrees to the change.

14.8.2 Exceptions from the Use of CNE Cables

SNE mains or services may be used for:

- All repairs on cables associated with existing overhead distributors carrying aerial earth wires.

- Small diversion and extensions of non-PME overhead lines by cable.

- Extension, diversion or repair of existing services (including services to street electrical fixtures).

- Situations where, after reference to sub-sections 14.6.1 and 14.8.4 of this CoP, a continuation of SNE cable is considered the best option.

- Fault repairs of SNE distributing mains - see clause 14.8.5.

14.8.3 Conversion of an Existing SNE Distributing Main to PME

On conversion of an existing SNE distributing main to permit PME connections to be made (this does not cover replacement of any section of the SNE distributing main by CNE type, for which see 14.8.5 below) the following points shall be checked:

- The substation earthing shall be checked to ensure that no obvious problems exist. The requirements of Section 14.5 of this document meet present day standards and shall be referred to for guidance.
- Remote end main earths (and possibly intermediate earths) will be required in accordance with section 14.7.2.

- Although it is expected that neutral conductor sizes will conform to the requirements of 14.7.2 above, they shall be checked to ensure that this is so.

- If practicable, the load balance on three phase distributing mains shall be checked. This may reveal the existence of severe unbalance that shall be corrected either immediately or at a future planned date. This action will help to minimise the effects of an open circuit neutral.

- Customers' installations for conversion to PME shall comply with Section 14.10 of this CoP.

- Existing SNE customers may retain their earthing arrangements (subject to their continuing to be connected to the main by SNE service cable).

14.8.4 Reinforcement, Extension or Partial Replacement of SNE Underground Cable Distributing Mains by CNE Type Cables

Reinforcement, extension or partial replacement of existing underground distributing mains using CNE cable shall be planned taking account of Section 14.6 of this document. A decision to proceed with CNE cable may be made only if satisfactory arrangements are made for the earthing of existing customers who use an Electricity North West Limited earth terminal.

At the junction of a SNE distributing main and a CNE distributing main the sheath of the SNE cable shall be bonded to the neutral conductor with a connection of minimum cross section 32mm^2 copper equivalent.

Existing SNE customers, connected to the CNE insert or downstream of it, may retain their existing earthing arrangements (whether or not they have equipotential bonding) as long as either:

(a) the neutral of the distributing main is connected to an adjacent neutral (beyond the CNE insert) either via a link box or a phase disconnection joint, as shown in Figure 1.

Figure 1

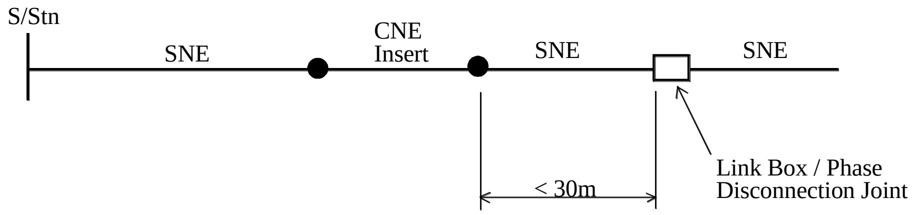


Figure 1

OR

(b) there is at least 30m of uninsulated metallic cable (plain lead or hessian served lead with or without tape or wire armours) beyond the CNE insert, as shown in Figure 2. This acts as an earth electrode sufficient to limit the voltage rise following a broken neutral to an acceptable level. Grip type joints shall not be included in the 30m, but service cables of this type, branching from the main, may be.

NOTE:

ENA EREC G12/4 requires a value of 10Ω for the earth electrode based on assumptions about the load unbalance. 30m of buried conductor in soil of average resistivity 100Ωm provides this. For the Network it has been decided, in view of the reliability of the cables and hence small risks involved, to limit the requirement to a check on the 30m length described.

Figure 2

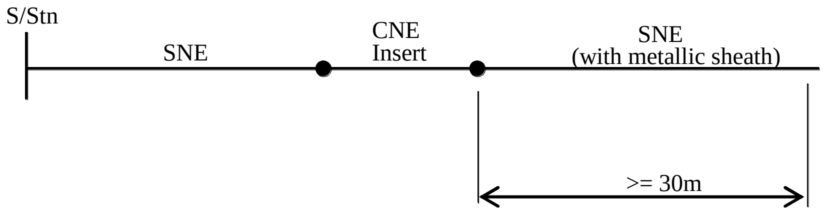


Figure 2

In addition to the above it is essential that all SNE customers' service cables be SNE from the cut-out to the main.

NOTE:

The fundamental requirement is that an open circuit of a combined neutral earth conductor will still leave a SNE customer's earth terminal connected to a low impedance earth, i.e. either at least 30m of uninsulated metallic sheath or an adjacent neutral.

If the above conditions cannot be met, then existing SNE customers from the start of the CNE cable shall have their installations checked, and if necessary modified at Electricity North West's expense, either in accordance with Section 14.10 (i.e. equipotential bonding applied) or by other means identified in Section 14.6.

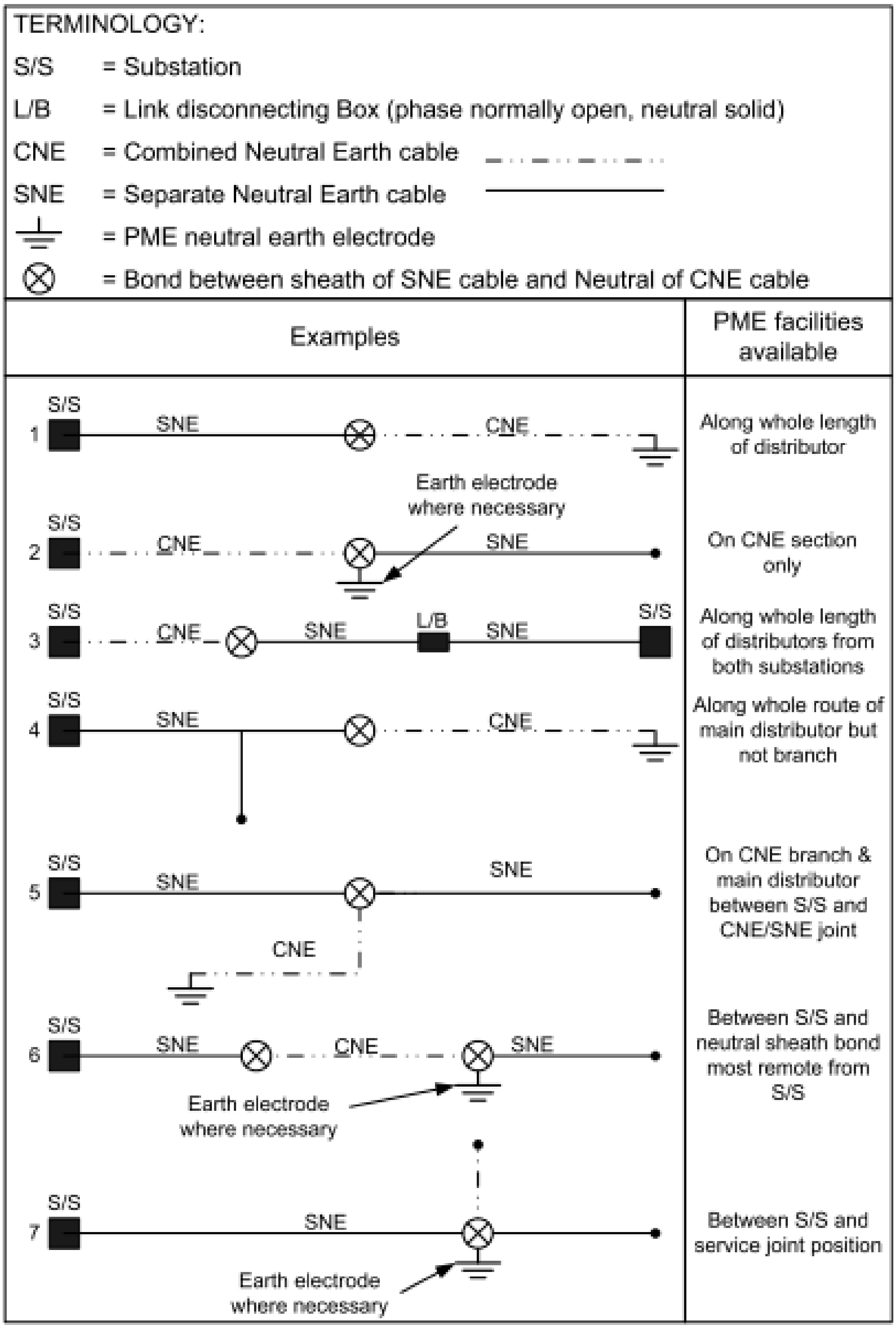
14.8.5 Fault Repairs

Replacement of cable (e.g. fault repairs) may be required within such short time scales that no satisfactory checks can be made on existing network earthing arrangements. In this case, SNE cable shall be replaced with SNE cable (e.g. by the use of 4 core waveform). If checks can be made, then work shall be in accordance with Section 14.8.3.

14.8.6 Typical Applications

Typical applications of PME on networks with both SNE and CNE cables are shown in Figure 4 below.

Figure 4 – Typical Application of PME to Networks with SNE and CNE Cables



14.9 Requirements for Overhead Networks

The principles applied in PME underground systems also apply to overhead or mixed overhead and underground systems.

This section 73 will identify where any additional considerations apply to the overhead situation and makes reference to a number of other points worthy of special attention.

Because of the greater vulnerability to damage of overhead systems compared with underground, it is considered necessary to safeguard existing SNE customers following any insertion of CNE conductor (such as four wire ABC) in an existing SNE distributing main (such as five wire open line). This requires additional earth connections to the neutral downstream of the last SNE-connected customer on each CNE-connected branch of the main. The methods of providing such additional earth connections shall be one of the methods described in 9.4.3 or by means of an earth electrode of 10Ω or less resistance.

The resistance to earth of a length of buried uninsulated cable sheath (or bare copper conductor) depends upon the soil resistivity. The length L required to achieve 10Ω is given by: L = 30 x (R/100) where L is the length in metres, R is the soil resistivity in Ωm (eg if R = 1000Ωm, L = 300m).

Typical soil resistivity values are given in Table 3 below:

Table 3

GROUND TYPE	RESISTIVITY (ΩM)
Loams, garden soils etc	5 to 50
Clays	10 to 100
Chalk	30 to 100
Clay, sand & gravel mixture	40 to 250
Marsh, peat	150 to 300
Sand	250 to 500
Slates and slatey shales	300 to 3000
Rock	1000 to 10000

Table 3 may be used to assess the likely resistance to earth of existing buried cable sheaths or conductor. It may prove useful for assessing the likely lengths required of additional conductor laid to form electrodes. The 10Ω value may be obtained from distributed electrodes (such as cable sheaths) along the main beyond the CNE insert and may include service cables and rod electrodes.

For mains, the use of ABC will provide greater integrity of the neutral than an open wire system. Other benefits of ABC include greater safety, less future maintenance costs, and better performance due to the insulated conductor system.

Historically five-core ABC has been available with the fifth core being a 25mm^2 aluminium conductor wrapped helically around the insulated phase and neutral cores. However, this reduced section fifth core shall **not** be used to provide a low enough loop impedance for maintaining a separate earth in a SNE system. (The intended purpose of the fifth core of this type of ABC is as a street-lighting switch wire.)

There are three and five core versions of ABC now available where the additional core is the same size as the main conductor and this can be used as an earth wire. These versions of ABC can be used as like for like replacements for three or five wire bare conductor overhead line.

Where existing SNE services are to be connected to ABC, to which PME has been applied, both the neutral and earth conductors of the service shall be connected to the ABC neutral conductor. When an OH network is converted to PME with ABC, being newly installed, this shall be 4-core only without any provision for street lighting switching. (See Module One)

At the point of connection of a new PME service line to an overhead main, a bond shall be made between the main's neutral and any earth wire using a minimum size of connection of 16mm^2 copper equivalent cross section. This bond is made to protect customers' installations against the possibility of an open circuit of the main's neutral causing excessive current flow along the service neutral, through the equipotential bonding connections and into earthed services which may be shared with other non-PME customers. (Although these customers' installations may be connected via SNE line or cable, they may be bonded in accordance with BS7671 and the 16mm^2 bond will also protect their bonding connections). These bonds provide a substantial connection between the main's neutral and earth wires, which ideally on a SNE only system would remain separate. However, on mixed PME and SNE systems there will almost certainly be connections via metallic services between properties, and the proposals herein are considered to be the safest option for this situation. This approach is electrically identical to that of an underground cable situation.

At any position on the main where a PME electrode is to be installed, the neutral shall also be connected to any aerial earth wire using a size of connection of at least the same cross sectional area as the neutral wire of the main line (minimum 16mm^2)

At any point where a five wire line's neutral connects to a four wire line's neutral, the neutrals and earth wire shall be connected together and an earth electrode installed.

As exceptions from the use of CNE conductors (see also the general policy in Section 14.6) SNE mains or services may be used for:

- All refurbishment where it is clear that the cost of providing equipotential bonding (if required) to customers who already use a SNE earth terminal connected to the Network, outweighs the benefits of using CNE conductors.

- All repairs on line conductors and cables associated with an existing overhead system carrying aerial earth wires.

- Small diversions and extensions of overhead distributing mains by overhead conductors or cable.

- Extension, diversion or repair of existing SNE services.

Wherever SNE underground cable is connected to the overhead distributing main, including at both ends of a cable closure, the neutral conductor shall be bonded to the cable sheath.

Where a neutral to earth electrode connection is made at a pole position, a disconnection facility shall be provided by means of approved type compressed lugs bolted together at a position on the pole approximately 2.5m above ground level and in all cases above the Anti-Climbing Device. The earthing lead shall be a minimum of $16mm^2$ copper section.

Figures 1 and 2 may be applied to overhead situations.

Where mural wiring extends a distributing main, the mural wiring shall be treated as though it is an associated branch of the distributing main. Accordingly, an earth electrode shall be placed at the remote end of the mural wiring. However, if there are no more than four customers (one at least being PME) connected to the mural wiring and it is 40m or less in length, an earth electrode is not required (see Figure 1). Where mural wiring employing a separate earth conductor (i.e. single conductors) is being converted to PME, the neutral and earth shall be bonded together at each service termination and at the point of connection of the mural wiring with the main line. Conversion to PME shall be at the customers cost and if provided, the N-E shall be bonded together where the service junction joins the mural main.

The general policy relating to the supply and use of RCDs following network alterations by Electricity North West Limited is included in Section 14.6. As noted in Section 14.6, the provision of RCDs following network alterations is a least preferred option.

14.10 Requirements for Customers' Premises

Customers offered a PME terminal shall be provided with a modern approved cut-out equipped with integral neutral and earth terminal blocks and labelled in accordance with Module Six.

Customers with a SNE service cable shall not be offered PME facilities unless the service cable is replaced by a CNE cable or is re-terminated.

The PME earthing terminal shall not be made available to the customer unless:

A main equipotential bond of not less than the copper equivalent area specified in BS7671 is installed to bond the incoming metallic gas and water services to the customers' protective conductors; and

Other exposed metalwork in the premises which is directly connected to or in contact with metalwork buried in the ground is also bonded to the PME earth terminal using conductors of size specified in BS7671. Note that such bonds are also main equipotential bonds; and that telecommunication cables are exempt from the requirements of this paragraph.

NOTE:

A customer's installation might have been made in compliance with an earlier edition of the Wiring Regulations, whereby the bonding conductors are of smaller cross-section than those in the current Wiring Regulations. However, where a PME terminal has not previously been available, connection to a PME terminal shall not be made unless the customer's bonding conductors are upgraded to comply with the latest edition of the Wiring Regulations.

The connection between any metal structure or pipe, other than a gas or water pipe, necessary for compliance with paragraph above shall not be made without the permission of the owner of that pipe or structure.

It is a requirement of ENA ER G12/4 that the attachment of bonding conductors shall be done in such a way so as to avoid electrolytic action at the connection.

Electricity North West Limited shall not connect or permit the connection of a PME earthing terminal to the customer's protective conductors, unless satisfied as far as reasonably practicable that the necessary bonding has been made. A contractor's certificate will normally be required for this purpose.

Regulation 8(4) of the ESQCR prohibits customers using CNE systems in their own installations.

The procedure detailed below in paragraph below shall be carried out at customers' premises before energising a new PME connection, or following any modifications of the network which could have resulted in any of the following for existing PME customers:

- Incoming phase and neutral crossed
- Supply neutral open circuit
- Elevated earth potential

The service polarity shall be checked in accordance with the procedure described in cable jointing CP411LV and overhead CP430. For single phase services it is important to use the approved design of polarity indicator and earth probe set. The full procedure in CP411 includes a test of the earth loop impedance that in general shall not exceed 0.35Ω for a PME service.

In the case of complex buildings, the connection to the building shall be tested in accordance with the above, and subsequent services throughout the building can then be checked to the nearest tested termination using a temporary connecting lead to the known neutral earth.

Costs associated with customers' installations and visits to their premises shall be treated as follows:

Generally, the cost of bonding associated with PME earthing will be borne by the owner of the installation. In some cases, e.g. village refurbishment, where there are a small percentage of SNE services, it may be more cost effective to convert these customers to PME, the cost of conversion shall be borne by Electricity North West Limited.

Bonding associated with the provision of a PME terminal where no terminal was previously provided from the Network shall be done at the expense of the customer. In cases where United Utilities Water PLC has removed an existing lead water pipe that is used as an earth connection, the cost of bonding shall be borne by United Utilities.

Where a customer seeks advice as to the satisfactory condition of the earthing of his installation, Electricity North West Limited shall offer to visit the premises, in order to inspect and assess the situation. Where a satisfactory earthing terminal, provided from the Network, is already available for the customer's use, a charge may be made for the visit.

14.11 Street Lighting and Other Street Furniture

14.11.1 Street Lighting and Road Signs with Electrical Load of 500W or Less

Part II of the Electricity Safety, Quality and Continuity Regulations 2002, as amended, which covers protection and earthing, applies to supplies to street lighting installations and other street electrical fixtures.

An earth electrode shall be provided at the end of every service supplying more than one street lamp or road sign.

An earth electrode shall be provided at the source pillar or supply point servicing more than one street lamp or road sign. Where the load on the pillar is greater than 500W, the earth electrode shall be in accordance with section 14.11.2 of this Engineering Recommendation.

Where a street lamp or road sign is installed within an insulated foundation such as a plastic or non-conductive collar, an earth electrode shall be installed and connected to the earth terminal at each such installation.

In accordance with BS 7671, bonding conductors shall have a minimum size of $6mm^2$ copper equivalent for supply neutral conductors with copper equivalent cross-sectional areas up to $10mm^2$. For larger sized supply neutral conductors, the main bonding shall comply with Table 1.

These requirements apply to street lighting and road signs supplied by a DNO and by a street lighting authority when using CNE cables. In this latter case supply from the DNO is usually to a pillar. See Figure 5 below.

Private installations and local authority installations using SNE cables which are supplied from PME services must comply with Figure 6 below.

The following principles apply:

(a) Bonding of small isolatable metal parts. Small isolatable metal parts, for example small metallic doors and door frames, need not be bonded to earth.

(b) Earth electrodes. All earth electrodes installed must comply with ENA EREC G12/4 paragraph 4.8.

(c) Earthing terminal. Until the requirements of BS 7671, ENA EREC G12/4 and this document have been complied with, the earthing terminal should be rendered electrically inaccessible so as to prevent unauthorised connection.

Figure 5 – Lighting Authority CNE Distributor Fed from PME Service

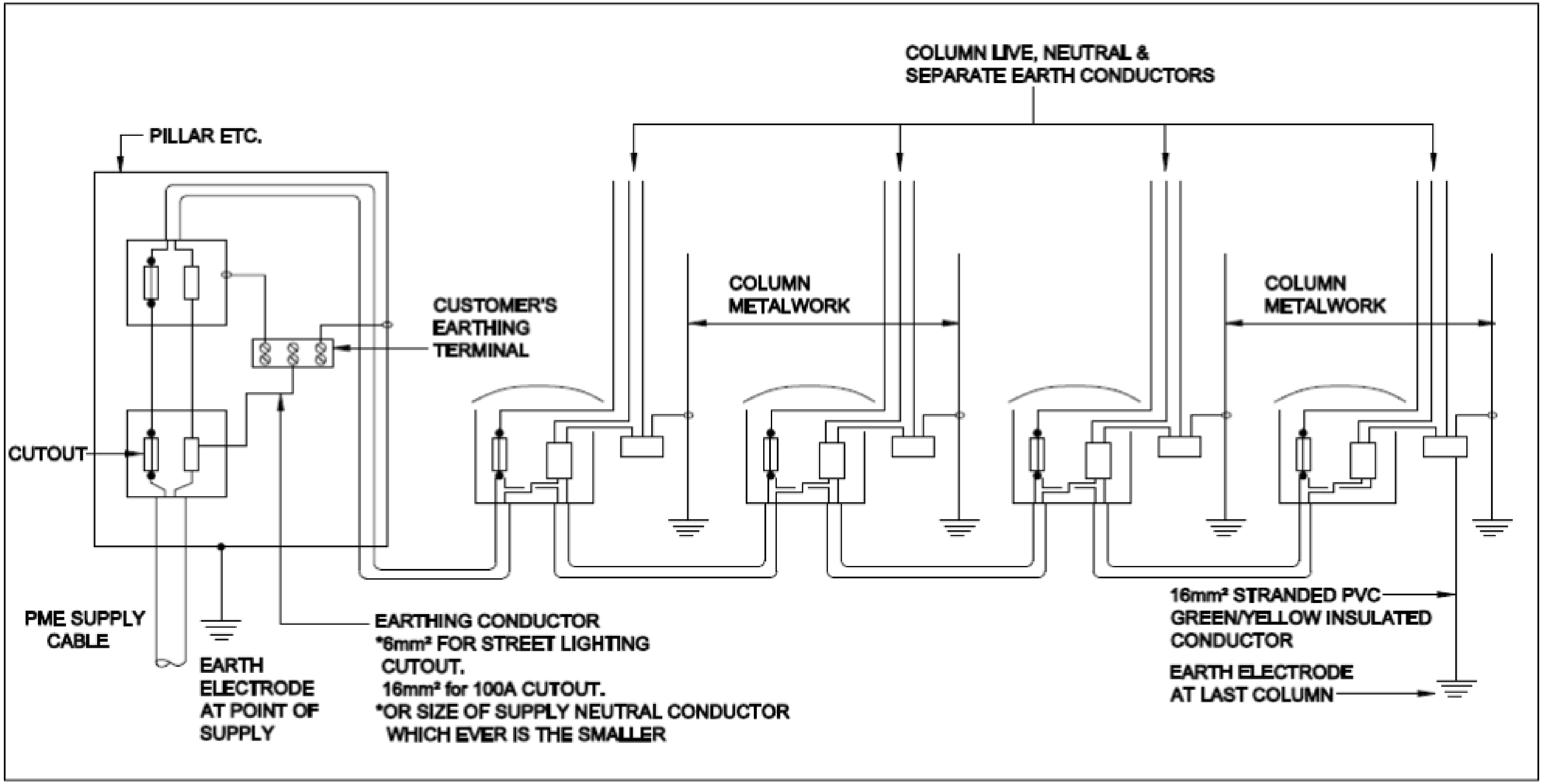
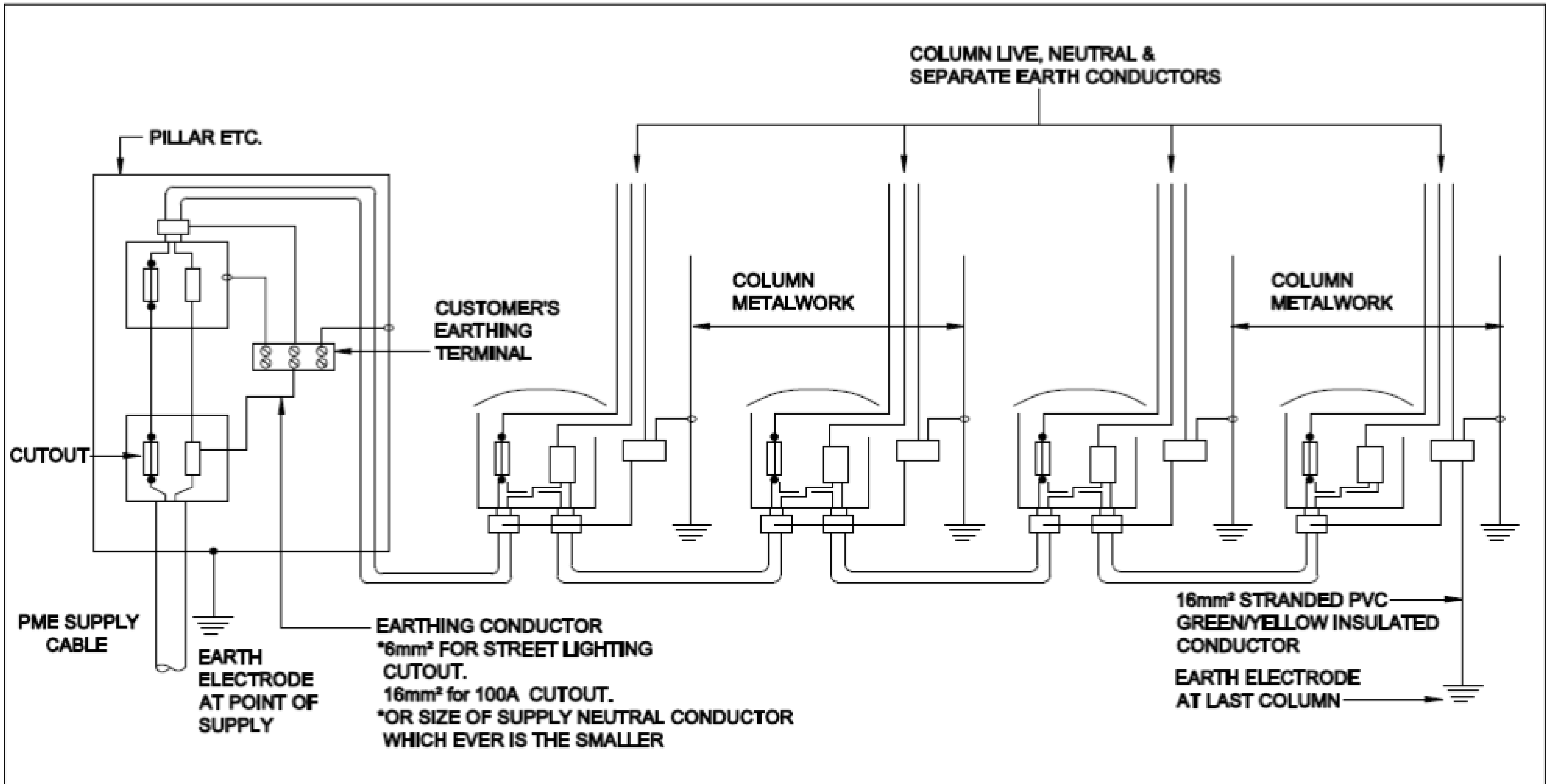


Figure 6 – Lighting Authority SNE Distributor Fed from PME Service



14.11.2 Street Electrical Fixtures Not Covered by 12.1

This section covers roadside housings accessible to the public; examples are: cable television distribution cabinets, electric vehicle charging points, electrical distribution cabinets with load above 500W.

> **NOTE:**
>
> A code of practice for electric vehicle charging equipment installation has been published by the IET.

Street electrical fixtures should preferably be of Class II construction or equivalent as defined in BS 7671. Examples are public telephones, pedestrian crossing bollards, ticket machines. No mains-derived earthing terminal is required, neither is a residual current device needed for earth fault protection.

Where the street electrical fixture is of Class I construction as defined in BS 7671, (examples include metal enclosures containing pumps, controls or communications equipment), a PME earth terminal may be provided if the requirements of BS 7671 are met and:

(a) For 3-phase equipment, the load is balanced, or:

(b) For 1-phase equipment and 3-phase equipment with unbalanced load, the maximum load and consumer earth electrode resistance bonded to their main earth terminal fulfil the requirements of Table 4. Maximum 1-ph Load or, maximum consumer earth connection for 3-phase, maximum electrode resistance overall load unbalance bonded to main earth terminal

Table 4

CONNECTION	MAXIMUM 1-PH LOAD OR, FOR 3-PHASE, MAXIMUM OVERALL LOAD UNBALANCE	MAXIMUM CONSUMER EARTH ELECTRODE RESISTANCE BONDED TO MAIN EARTH TERMINAL (SEE NOTE)
1-phase or unbalanced 3-phase	500W	100Ω
	1kW	60Ω
	2kW	20Ω
	3kW	14Ω
	4kW	11Ω
	5kW	9Ω

If the conditions for a Class I installation cannot be met, a PME terminal should not be offered. The earthing system of the installation should form part of a TT system by installing a separate earth electrode and fitting appropriate protection in accordance with BS 7671 (e.g. an RCD). Extraneous-conductive-parts (e.g. safety barriers, pedestrian guard rails) should not be connected to a PME earth terminal.

14.12 Special Cases and Unusual Installations

14.12.1 Auxiliary LV Supplies Associated with Railways and Tramways

For any supply with a PME earth terminal:

(a) All installations shall comply with the requirements of BS 7671, including equipotential bonding under PME conditions;

(b) The housing at the intake position shall not expose a member of the general public to dangerous touch potentials.

(c) Metal housings containing LV equipment are not permitted at the intake position or where they may expose a member of the general public to dangerous touch potentials.

The above measures do not necessarily provide full protection against touch potentials for railway personnel. It is the responsibility of the railway operator to assess and control such risks.

14.12.2 LV Supplies Associated with AC Electrified Systems

Specific information about the compliance of individual railway operators is set out in ENA EREC G12/4 Appendix 2.

(a) LV auxiliary supplies at traction supply points

The requirements for auxiliary LV supplies at traction supply points for ac systems are set out in ENA EREC P24. Because of the traction return currents that will be flowing through earth at these sites PME earth terminals are not permitted at these locations.

(b) LV auxiliary supplies at locations other than traction supply points

The requirements for earthing of electrical installations on railway lines with AC electrification are governed by railway sector design standards that can result in higher touch voltages than are permitted on the PME network.

NOTE:

These standards include BS EN 50122-1 and the Railway Group Standard GL/RT1255.

Therefore, more stringent limits than those set by these standards are required to ensure that dangerous voltages are not exported to DNO LV networks through a PME earth conductor. PME supplies may be made available subject to the railway operator confirming that their design standards will ensure that:

(a) In the case of traction supply faults, the earthing standards will limit the rise of earth potential to the following values as specified by ENATS 41-24:

- 430V for faults with a duration greater than 0.2s, but not greater than 3s;
- 650V for faults with a duration not greater than 0.2s.

(b) The rise of voltage on the traction rail due to traction return current shall not exceed 25V under frequent traction peak starting or running current conditions.

14.12.3 LV Supplies Associated with DC Electrified Systems

PME Earth Terminals may be provided to premises and trackside cubicles associated with lines electrified using 3rd or 4th rail systems subject to the following conditions:

(a) The traction current supply (3rd rail or overhead) and return (running rails and/or 4th rail) rails are insulated from earth in accordance with the requirements of BS EN 50122-2.

(b) Neither pole of the traction supply is directly connected to earth.

(c) Any connection to earth is solely for the purpose of the detection of earth fault conditions.

(d) The LV supply, including the protective earthing conductor, and all earthed metal associated with it is segregated from all DC conductors by the maximum practicable distance, subject to a minimum distance of 1m in accordance with BS EN 50122-2.

(e) In the event that the railway operator detects corrosion due to stray DC current on any of their equipment they shall advise the DNO providing associated PME earthing facilities.

These requirements are set in place in order to minimise the risk of electrolytic corrosion of earthing systems due to stray DC currents. They are based on a recognition that, if stray currents exist, there will be paths electrically closer to the traction system which will take larger stray currents than will flow through a DNO LV earthing system. In this case corrosion of cable sheaths, structures and earthing systems, which are subject to regular inspections, will quickly become apparent to the railway operator.

These measures will also ensure that for PME systems no external voltage is impressed on the neutral/earth conductor.

Further information on methods of construction of DC electrified systems in the UK is given in ENA EREC G12/4 Appendix 3.

NOTE:

The requirements concerning DC electrified systems are also applicable to supplies using SNE service cables.

14.12.4 LV Supplies for Sites with both AC and DC Traction Systems

Where sites have both AC and DC electrified systems, a PME earthing terminal shall not be provided.

14.12.5 Other Electrified Systems

Requirements for the provision of earthing terminals to premises and equipment at the trackside of operators of other traction system are subject to agreement between the traction system operator and the relevant DNO.

In the case of Light rapid transit systems reference should be made to ENA EREP 123.

14.12.6 Temporary Connections to Construction and Demolition Sites

Construction and Demolition Sites

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.

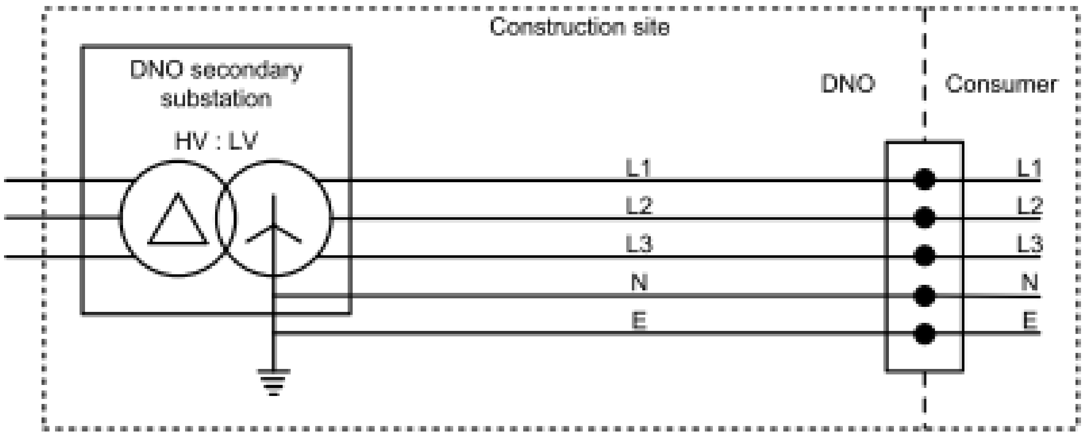
In addition to the arrangements shown in 14.12.4 and 14.12.5, if the site does not have a dedicated transformer, i.e. the transformer supplies other consumers or other parts of the LV network, it is still possible to provide a TN-S earthing system within the boundary of the site via a suitable isolating 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.

TN-S from a Dedicated Transformer

If the site has a dedicated secondary substation that only supplies the consumer it will usually be possible to provide a TN-S earth terminal directly from the transformer neutral - see figure 7. This arrangement will also enable a permanent supply to be provided more easily when required. The developer/contractor will be responsible for maintaining the LV supply.

Figure 7



TT Earthing System with RCD Protection

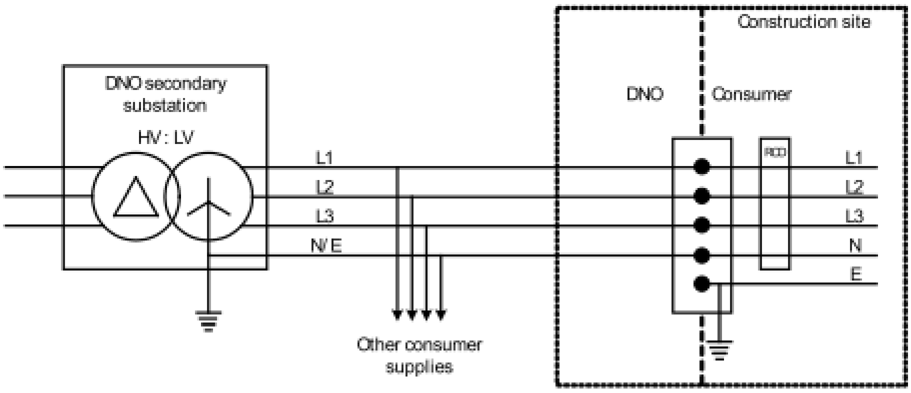
In the absence of any other earthing system a TT earthing system shall be used, as shown in figure 8. The supply must be protected in accordance with BS 7671; this will usually include a residual current device (RCD) on the consumer's side of the cut-out. There shall be no exposed- conductive-parts before and/or enclosing the RCD. The earth electrode must be separated from any PME earth electrode or metallic cable sheath.

For low voltage connections of up to 100A single or three phase there shall be no earthing terminal provided. In particular, the earthing facility within the cut out shall either have the manufacturer's means of preventing access fitted in place or, be completely removed. Additionally, a suitable label shall be fitted adjacent to the cut out bringing attention to the fact that no earthing facility from the Network is available to the customer.

For low voltage connections above 100A capacity the customer's switchgear for these levels of capacity generally have appreciable amounts of exposed conductive parts. Suitable arrangements shall be agreed for the electrical and physical segregation between Electricity North West Limited's and the customer's exposed and extraneous conductive parts.

Under ESQCR Regulation 28 part (b) Electricity North West Limited is obliged to provide, upon request, the maximum earth loop impedance of the earth fault path outside the customer's installation. The customer shall be informed that the resistance to earth of the Network will never exceed 40Ω.

Figure 8



Electricity North West Limitedhas a statutory duty to be reasonably satisfied that an installation is safe before providing a connection to that installation. Normally a completion certificate from a competent electrical contractor will suffice. The confirmation that the installation is satisfactory shall be provided by a suitably qualified or experienced person and be in writing.

Transition of Permanent Supply

A permanent supply using PME may be provided to a building provided that:

(a) The permanent building is complete and there are no reasonable grounds to believe that the installation does not meet the requirements of BS 7671;

(b) Any scaffolding is not bonded to the construction site TT system earth.

14.12.7 Supplies to Temporary Installations (not associated with construction sites)

Exhibitions, Shows and Stands

PME shall not be offered if this would allow the connection of the PME earth terminal to any metalwork of exhibitions, shows or stands.

Mobile or Transportable Units

The connection of mobile or transportable units to consumer's installations is governed by the Electricity at Work Regulations and Section 717 of BS 7671. Further guidance on the connection of mobile or transportable units to existing installations can be found in BS 7909. PME shall not be offered for a dedicated supply to a mobile or transportable unit except as permitted by BS 7671:

- Where the installation is continuously under the supervision of a skilled or instructed person, and

- The suitability and effectiveness of the means of earthing has been confirmed before the connection is made' and
- Subject to the normal PME requirements.

Examples of these situations are outside broadcast vehicles, medical services vehicles/cabins, transportable catering units, technical/facilities vehicles for firefighting etc. The definition does not include caravans, pleasure craft, mobile machinery and generating sets and traction equipment of electric vehicles.

14.12.8 Temporary Electrical Installations for Structures, Amusement Devices and Booths at Fairgrounds, Amusement Parks and Circuses

PME shall not be offered if this would allow the connection of the PME earth terminal to any metalwork of temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses.

14.12.9 Supplies to Other Temporary Buildings

For temporary buildings, e.g. temporary classrooms, a PME earthing terminal may be supplied if the installation is constructed so that a person in contact with the general mass of earth cannot touch any metalwork of the temporary installation and the installation complies with the bonding and earthing requirements of BS 7671. In such cases, a temporary building may be treated in the same manner as a permanent building. A PME terminal shall not be offered for a temporary building which is not constructed as above (e.g. metalclad buildings).

14.12.10 Agricultural and Horticultural Premises

Agricultural and horticultural premises are considered to be 'Special Locations' within BS 7671; Section 705 of that standard sets out requirements and recommendations regarding the use of PME (TN-C-S) earthing, equipotential bonding and the application of RCDs.

NOTE:

Rooms, locations and areas for household applications and similar are not covered by this section.

Safety issues include:

- Damp locations
- Possibility of contact of the body with true Earth potential
- Presence of livestock

NOTE:

In addition to normal electric shock hazards to persons, livestock are sensitive to small potential differences and may experience low level shocks or tingles from voltages imported via the neutral/earth conductor of the DNO TN-C-S system.

BS 7671 notes that PME (TN-C-S) earthing is not recommended where a metal grid cannot be laid in the floor and included in the installation's equipotential bonding. In this case each building should be provided with its own earthing installation as part of a TT system by installing a separate earth electrode and fitting appropriate protection in accordance with BS 7671 (e.g. an RCD).

NOTE:

In practice this means that the main service position can be provided with a PME terminal.

The consumer's electrician:

- May use the PME terminal to earth the farm house / offices/ shop etc.
- May use the PME terminal to earth the farm buildings where a metal grid is installed in the floor and included in the equipotential bonding of the installation.
- May segregate the earthing conductor / wire armouring of each circuit and install a separate earth electrode for each building where the full equipotential bonding provision of BS 7671 Section 705 cannot be fully applied.
- Should, in accordance with Guidance Note 5 to BS 7671, advise the consumer that if PME is to be used and the metal grid in the concrete floor cannot be bonded or does not exist, the small voltage differences referred to above may adversely affect livestock feeding and milking.

Where in remote buildings all extraneous-conductive-parts cannot be bonded to the earthing terminal, the pipes and metalwork of isolated buildings, whether or not they have an electricity supply, shall be segregated (using insulated inserts) from metalwork connected to the PME earthing terminal. Such buildings should be provided with their own earthing installation as part of a TT system by installing a separate earth electrode and fitting appropriate protection in accordance with BS 7671 (e.g. an RCD). The earth electrode and protective conductor shall be segregated from any metalwork connected to the PME earthing terminal.

Where segregation is not possible then the alternative of converting the whole of the installation to form part of a TT system should be considered.

14.12.11 Protective Neutral Bonding

Where isolated premises are connected to a local transformer which meets the requirements of section 14.7.3 for customers and service length, for example, it is possible to use Protective Neutral Bonding (PNB). PNB is not PME and is not subject to the PME provisions of the ESQCR excepting that Regulation 8(3)(b) makes specific provision for this method of earthing. In this method of earthing, the LV neutral is not earthed at the transformer, but instead is earthed at the cut-out. No bonding is required. In this way a broken neutral anywhere on the system does not result in elevated potentials on metalwork. PNB is the preferred method of earthing in these cases and is particularly effective where livestock is involved. All PNB installations shall be recorded on the mains records. The resistance to earth of the earth electrode shall be such that twice the current necessary to operate the HV protection will flow following an inter-winding fault on the transformer. A value of 40Ω or less shall be achieved.

14.12.12 Swimming Pools and Other Basins

Locations containing swimming pools and other basins are considered to be 'Special locations' within BS 7671. Section 702 of that standard sets out requirements and recommendations relating to the use of supplementary equipotential bonding and RCDs in electrical installations in such locations.

BS 7671 recommends that where PME (TN-C-S) earthing is adopted, an earth mat or electrode should be installed for Zone 2.

Safety issues include:

- Wet locations
- Possibility of contact of the body with true earth potential
- Presence of wet barefoot persons

NOTE:

In addition to normal electric shock hazards, persons may experience low level shocks or tingles from the out of balance voltages imported via the neutral/earth conductor of the DNO TN-C-S system.

Competent persons enquiring about the suitability of PME for swimming pool supplies should be advised:

- The main service position can be provided with a PME terminal. It is the electrician's decision whether or not to utilise the PME terminal for all or part of the installation.

Where the pool is in a separate building or outdoors the consumer's electrician:

- May decide to use the PME terminal to earth the house / offices/ shop etc. or,
- May decide to segregate the earth conductor / wire armouring of the pool building circuit, install a separate earth electrode for the pool building and apply supplementary equipotential bonding as required by BS 7671 Section 702 or,
- May decide to use the PME earth if a metallic grid is installed under the poolside areas and bonded to the equipotential bonding.

Where the pool is within the same building the consumer's electrician:

- May decide to use a TT system to earth the entire installation or,
- May decide to use a TT system to earth the pool installation, and segregate the metalwork and pipes from the rest of the building and connect them to a separate earth electrode or,
- May decide to use the PME earth if a metallic grid is installed under the poolside areas and connected to the equipotential bonding.

14.12.13 Caravans, Boats, Marinas, Camp Sites and Amenity/Shower Blocks Including Sports Pavilions

Caravans

The Electricity Safety, Quality and Continuity Regulations 2002, as amended, preclude the provision of a PME earthing terminal to a caravan. Supplies to caravans should be from a TT system utilising a separate earth electrode segregated from the PME earth and protected by an RCD which must be provided by the consumer or site owner.

NOTE:

This does not preclude the provision of PME to mobile homes which are not of caravan construction (See 14.12.14)

Caravan Sites, Campsites and Amenity Shower Blocks

Due to the higher probability of persons being barefooted at toilet and amenity shower blocks (including sports pavilions with shower facilities) the extension of PME earthing is not recommended unless a buried bonded metal grid has been installed. This requirement also applies to other locations where toilet or shower blocks have been provided for general public use where people are likely to be barefoot e.g. beachside locations, parks etc. Where outside showers have been provided, provision of PME earthing is not recommended as providing a reliable equipotential cage may prove impractical.

Where no shower area exists nor is likely to exist in a sports pavilion, PME may be offered provided the appropriate metalwork is bonded and due consideration is given to the construction of the building, i.e. wooden or brick construction.

NOTE:

This does not preclude a PME earthing terminal being provided for use in permanent buildings on a caravan site such as the site owner's living premises and any bars or shops. Particular care shall be taken to ensure that bonded metalwork does not exist in a position where it can be touched from outside the building.

Boats and Marinas

The Electricity Safety, Quality and Continuity Regulations preclude the provision of a PME earthing terminal to a boat. Supplies to boats should be from a TT system utilising a separate earth electrode segregated from the PME earth and protected by an RCD which must be provided by the consumer or site owner.

NOTE:

This does not preclude a PME earthing terminal being provided for use in permanent buildings on a marina site such as the site owner's living premises and any bars or shops.

14.12.14 Mobile Homes

BS 7671 section 721 states that for mobile homes the general requirements apply. However, to cover the possibility that certain mobile homes could fall within the scope of a caravan for the purposes of the Electricity Safety, Quality and Continuity Regulations 2002, as amended, the following guidance is given.

For the purposes of this Engineering Recommendation, a mobile home is to be treated as a caravan if:

- Any metalwork connected to the earth terminal is within reach of a person in contact with the general mass of earth, or
- It is not permanently sited, or
- It is not permanently connected to water or sewerage services.

This definition does not include mobile or transportable units (e.g. outside broadcast vehicles) which are covered in paragraph 14.12.7.

14.12.15 Mines and Quarries

Provided the building's electrical installation wiring conforms to BS 7671, a PME earth terminal can be provided to mine/quarry permanent buildings (e.g. permanent offices and canteens). This excludes amenity shower blocks unless an earth grid is installed. Supplies to underground shafts, the production side of quarries or associated amenity shower blocks shall be from a TT system having a separate connection with earth, independent of the PME earth terminal. Where a mine or quarry requires a supply both to a permanent building and either an underground shaft or the production side of the quarry, precautions must be taken to ensure that these latter supplies have an earth system segregated from the PME earth system.

If the site has a dedicated secondary substation that only supplies the consumer it will usually be possible to provide a TN-S earth terminal directly from the transformer neutral.

NOTE:

The requirements for supplies to the working areas are covered by specific statutory legislation (see BS 7671, section 110.1).

14.12.16 Fuel Filling Stations

The filling station area should be supplied from a TT system. BS 7671 clause 331.1 and BS 7671 Appendix 2 give references for the requirement for supplies to fuel filling stations.

Where the filling station is part of a larger site, PME facilities may be provided for permanent buildings such as restaurants and shops, provided the filling station area has an earth system segregated from the PME earth system.

14.12.17 Multiple Occupancy Buildings

There are a number of issues with regard to the application of PME within multi-occupancy buildings, in particular the requirement for an end-of-main electrode and problems associated with neutral currents flowing within structural steelwork. Whilst a PME supply may be provided at the main intake position, PME is not generally recommended for distribution within multi-occupancy buildings, including multi-storey and single storey buildings. For supplies to new and refurbished multiple occupancy buildings and the provision of an earth terminal, reference should be made to ES287 and ENA EREC G87.

14.12.18 Existing Installations

The refurbishment of existing connections to individual customers shall provide only SNE type service arrangements as described in ES287.For existing arrangements, where rising or lateral connections are owned and maintained by Electricity North West, and the individual connections are PME then: -

(a) The connection shall be by CNE cable and an individual PME terminal shall have been made available to each customer provided the customer's installation meets the equipotential bonding requirements. In addition to the bonding in the customer's premises the gas, water and other services and accessible steel structures shall be bonded to the incoming cable's earthing terminal as close as possible to the point of entry of these services into the building. BS 7671 gives the required bonding sizes.

(b) As a consequence of the type of building, difficulties can arise with CNE cables used for internal distribution and servicing in meeting the requirements for end of main electrodes.

(c) In all cases an earth electrode shall be installed at the intake position.

(d) Internal services

There is no need for a remote end of internal service neutral earth connection if the service connects no more than 4 customers and is 40m or less in length. If this is not the case, a connection to an earth electrode shall be made to the extreme ends of the neutral. If this is impracticable then a separate earth continuity conductor shall be run to the extreme end of the service.

(e) Internal distributing mains capable of interconnection

The connection together of the supply neutral conductors at their far ends will satisfy the requirements of the ESQCR and a separate electrode or earth continuity conductor is unnecessary. The neutral of the smaller cable shall not be less than half the cross sectional area of the phase conductor of the larger cable.

14.12.19 Building Complexes with Interconnecting Services

Where there is one customer occupying several separate buildings on the same site, there will normally be only a single service for the whole site. The subservices from one building to another will be afforded by private cables. The ESQCR Regulation 8(4) prohibits customers from using CNE within their installations and BS 7671 gives guidance on the sizes of bonding conductor to be used. The required bonding sizes are related to the size of the incoming cable's neutral conductor. This is important in cases where a cable is laid between two separate buildings belonging to a customer on his own premises. If there are incoming metallic services in a remote building which are separate from those in the building containing the Network PME connection, the bonding between the two buildings is related to the size of the incoming service, and not to the size of the cable linking the two buildings. The reason for this is that the bonding might have to carry diverted neutral current following a fault on the Network. It shall be pointed out that whilst the wire armouring of a PVC insulated cable may provide adequate capacity for short duration faults within the installation it will almost certainly be too small for equipotential bonding purposes. In these cases, then either a separate protective conductor sized in accordance with BS 7671 shall be run, or, as a non-preferred option the cable shall be converted to CNE, and an ad-hoc approval sought via the Protection Systems Manager, Electricity North West Limited.

14.12.20 External Exposed Metalwork Connected to the Internal Earth System (including outside water taps)

Under an open-circuit supply neutral condition the potential of external metalwork could rise above earth potential if it is connected to the internal earth. A person coming into contact with it could receive an electric shock and the shock could be severe if that person were barefooted. The probability of these two conditions occurring together is considered to be so small that the use of PME where external exposed metalwork exists is not precluded.

An insulating insert may be incorporated in the pipe to an outside water tap. However, care should be taken to ensure that simultaneous contact with metal pipework on each side of the insert is not possible if there is likely to be a potential across the insert under this condition.

14.12.21 Metal Clad Buildings

Where metal clad buildings incorporate a steel frame, the steel frame will provide a good connection with the earth which will effectively limit the rise of earth potential. A PME supply may be provided to a metal clad building provided that:

The metal cladding is bonded to the steel frame.

The supply is either:

(a) three-phase with less than 40% unbalance,

(b) or single-phase, provided the frame to earth impedance is less than 20 ohms.

14.12.22 Lightning Protection Systems

For the majority of situations, it is acceptable for lightning protection to be connected to the consumer's earthing arrangements and thus to the DNO PME terminal, where PME is provided. Guidance on the connection of lightning protection conductors to the consumer's earthing is provided in BS EN 62305.

Consideration should be given to the size of bonding conductor, because in the event of an open circuit neutral the consumer's earth electrode may carry most of the diverted neutral current. The size of the consumer earthing and bonding connections may be insufficient for this current, particularly where the service size is small. Where necessary, DNOs should provide guidance on the bonding requirements.

When periodic testing of the lightning protection system is undertaken, precautions are necessary when breaking the link between the lightning protection electrode and the consumer's earth since the consumer's earth may be at a potential above true earth.

14.12.23 Cathodic Protection Installations

The usual source of power for cathodic protection installations is a mains supplied transformer rectifier unit. Such installations should be supplied from a TT system.

Substation earth electrodes, end of main electrodes and stay wires should be situated as far as possible from the cathodic protection ground bed.

14.12.24 Communication Stations

There are a variety of types of ‘communication station’ including radio/television sites, mobile phone base stations and amateur radio (or ‘radio ham’) domestic installations. This section is limited to consumer communication stations connected to DNO networks at low voltage.

14.12.25 Communication Stations with an Independent Earth Electrode

Some communication stations require an independent earth electrode for functional/lightning purposes. Where such an earth is installed its earth, resistance may be comparable or less than that of the DNO earthing system. On a PME network, in the event of an open circuit neutral the consumer earth electrode may carry most of the diverted neutral current. The size of the consumer earthing and bonding conductors may be insufficient for this current, particularly where the service size is small.

In order to prevent the possible neutral current diversion detailed above, the consumer should be advised to create a TT earthing system that meets BS 7671 for either:

(a) The whole installation, or

(b) The part of the installation feeding the radio/communication equipment and any associated metalwork

In the case of b), the TT installation earthing must be segregated from the earthing/bonding in the rest of the consumer installation and DNO earthing. With the TT installation, a RCD shall be provided to comply with the earth fault disconnection time requirements in BS 7671.

Where disruption due to possible RCD nuisance tripping would be unacceptable, an alternative to the above TT earthing system is to use TN-C-S earthing for the whole installation and increase the size the consumer earthing and bonding conductors; these shall not be less than the cross-sectional area of the service neutral.

Communication stations with freestanding housings/structures accessible to the public (e.g. some mobile phone base stations) may fall within the scope of paragraph 14.11.2. and/or 114.12.25.

14.12.26 Shared Communication Tower/Mast

Communication sites can be sensitive to the effects of diverted neutral current passing through earthing/bonding paths. This can arise with PME at multi-user sites sharing a common communication tower/mast. The neutral current due to load of one user/consumer can cause noise problems with certain consumer earthing practices by passing through equipment, chassis, signal wires, screening braids etc of other consumers. The noise problems may be overcome if consumers employ earthing practices that eliminate parallel paths for neutral current in earthing/bonding connections. With PME, the practice of providing only a single service connection per communication tower/mast will reduce the above effect. If more than one service is provided, then see requirements in 14.12.28.

14.12.27 TN-S Alternative

An alternative non-PME arrangement that avoids the above problems is a TN-S system (e.g. cable sheath earth returns with no PME connections), where available.

14.12.28 Communication Stations on/in Other Buildings

Where a communication station is located in or on a building that has its own Connection Point, the communication station consumer may ask the DNO for a separate Connection Point (e.g. mobile phone base station on an office building). The issues arising with respect to PME in this case can be similar to those with multiple occupancy buildings (section 14.12.17).

In the following, the term ‘Main Building’ refers to the building which has the communication station located on/in it.

In general, where the ‘Main Building’ has a PME earth terminal at its Connection Point then provision of an additional Connection Point to the communication station is not recommended; alternative options to provide an electrical supply to the communication station are as follows:

(a) Private sub-service to communication station from ‘Main Building’ consumer – see Figure 9 below, or

(b) Convert the ‘Main Building’ service and earthing arrangement to provide a TN-S earthing arrangement and provide an additional service with TN-S earthing arrangement to the communication station, or

(c) Convert the ‘Main Building’ service and earthing arrangement to provide a TT earthing arrangement and provide an additional service with TT earthing arrangement to the communication station.

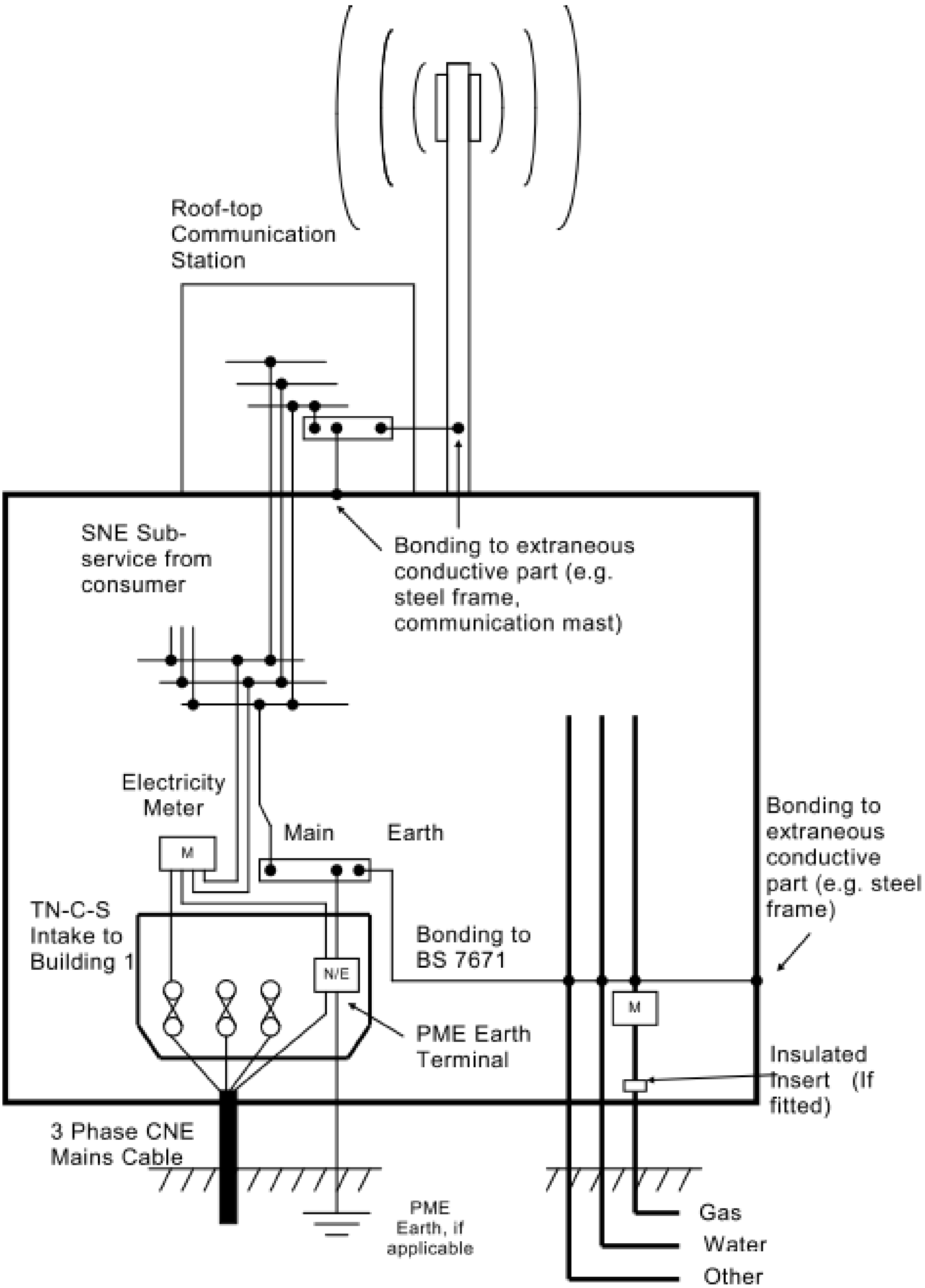
In general, where the ‘Main Building’ has a TN-S or TT earthing arrangement then it is not recommended to provide an additional Connection Point with a PME earth terminal.

In general, where an additional Connection Point is provided it is recommended that it shall be from either the same DNO distributing main/service line or the same multi-service distribution board as the ‘Main Building’.

NOTE:

In the case of additional service(s) into or onto a building there are requirements concerning isolation that must be met in BS 7671, the Electricity at Work Regulations 1989 and the Provision and Use of Work Equipment Regulations 1998.

Figure 9


Roof-top
Communication
Station
SNE Sub-
service from
consumer
Bonding to extraneous
conductive part (e.g.
steel frame,
communication mast)
Electricity
Meter
M
Main
Earth
Bonding to
extraneous
conductive
part (e.g. steel
frame)
TN-C-S
Intake to
Building 1
Bonding to
BS 7671
N/E
M
PME Earth
Terminal
Insulated
Insert (If
fitted)
3 Phase CNE
Mains Cable
PME
Earth, if
applicable
Gas
Water
Other

14.12.29 Supplies to Electric Vehicle Charge Points (EVCPs)

Feb 24

The latest edition of BS 7671 permits the use of a PME earthing facility for EVCP connections, subject to one of a number of criteria being met. These criteria are set out in detail in BS 7671 722.411.4 and are summarised below. Readers shall consult BS 7671 for the detailed requirements.

I. The charging point forms part of a three phase installation that also supplies other loads other than for electric vehicle charging. The characteristics of the load mean the voltage between the main earth terminal and Earth shall not exceed 70V for an open circuit fault of the PEN conductor.
II. The main earth terminal of the installation is connected to an installation earth electrode by a protective conductor which complies with BS 7671 544.1.1. The resistance of the earth electrode shall be such that the maximum voltage between the main earthing terminal of the installation and Earth does not exceed 70V rms following an open circuit fault in the PEN conductor.
III. Protection against electric shock is provided by a device which electrically disconnects the vehicle from the live conductors of the supply and from protective earth in accordance with Regulation 543.3.3.101(ii) within 5 seconds if the voltage between the protective conductor and Earth exceeds 70V rms for more than 4 seconds. The devices shall not reset or close if this voltage exceeds 70V rms. The functionality may be within the charging equipment.
IV. Protection against electric shock in a single phase installation is provided by a device which electrically disconnects the vehicle from the live conductors of the supply and protective earth in accordance with Regulation 543.3.3.101(ii) within 5 seconds in the event of the utilisation voltage at the charging point, between line and neutral conductors, being greater than 253V rms or less than 207V rms. The device shall provide isolation and be selected in accordance with Table 537.4. Equivalent means of functionality could be included within the charging equipment. Closing or resetting of the device shall only be possible if the voltage between line and neutral is in the range 207V rms and 253V rms.
V. Alternative devices which provide at least the same level of safety as III and IV above.

Installers shall provide a statement of compliance against the requirements as detailed in 722.411.

14.13 Documents Referenced

Non-Electricity North West Limited Documents

The following documents, legislation, national standards and ENA publications, cannot be supplied by Electricity North West Limited to persons outside those companies:

DOCUMENTS REFERENCED	
ACE Report 105 (1986)	Design of Low Voltage Underground Networks for New Housing.
BS 1361:1971	Specification for Cartridge Fuses for AC Circuits in Domestic and Similar Premises
BS 480	Specification for impregnated paper-insulated lead or lead alloy sheathed electric cables of rated voltage up to and including 33000V.
BS 5649	Lighting Columns

BS 5669	Part 2 – Specification for Wood Chipboard
BS 6004:2000	Specification for PVC-insulated Cables (non-armoured) for Electric Power and Lighting
BS 6360	Specification for conductors in insulated cables and cords
BS 6480	Specification for impregnated paper-insulated lead or lead alloy sheathed electric cables of rated voltage up to and including 33000V.
BS 7375: 2010	Distribution of electricity on construction and demolition sites.
BS 7654	Specification for Single-phase Street Lighting Fuses (cut outs) for Low Voltage Public Electricity Distribution Systems.
BS 7671	Requirements for Electrical Installations (IET Wiring Regulations)
BS 7870	LV and MV polymeric insulated cables for use by distribution and generation utilities - Part 3: Section 3-10 2001: PVC insulated combined neutral and earth copper wire concentric cables with copper or aluminium conductors; Section 3-11 2001: XLPE insulated combined neutral and earth copper wire concentric cables with copper or aluminium conductors; Section 3-20 2001: PVC insulated split concentric cables with copper or aluminium conductors; Section 3-21 2001: XLPE insulated split concentric cables with copper or aluminium conductors; Section 3-40 2001: XLPE insulated, copper wire waveform concentric cables with solid aluminium conductors.
BS 7889	Electric cables. Thermosetting Insulated, Non-armoured Cables with a Voltage of 600/1000V for Fixed Installations
BS7909	Code of Practice for temporary electrical systems for entertainment and related purposes
BS 88 Part 5	Specification of Supplementary Requirements for Fuse-Links for use in a.c. Electricity Supply Networks
BS 9999	Code of Practice for Fire Safety in the Design, Management and Use of Buildings

BS EN 312	Particleboards. Specifications.
BS EN 50122-1: 2011	Railway Applications. Electrical Safety, Earthing and the Return Circuit. Protective provisions against electric shock
BS EN 50122-2:2010	Railway Applications. Electrical Safety, Earthing and the Return Circuit. Provisions against the effects of stray currents caused by dc traction systems
BS EN 50160	1995 - Voltage Characteristics of Electricity Supplied by Public Distribution Systems.
BS EN 60255	Electrical Relays
BS EN 60269-1	Low Voltage Fuses
BS EN 60947-1	Specification for Low Voltage Switchgear and Control Gear
BS EN 61000-3-2	Limits for harmonic current emissions (equipment input current <= 16A per phase)
BS EN 61000-3-3	Limitations of voltage changes, voltage fluctuations and flicker in public low voltage supply systems – equipment with rated current <16A
BS EN 61000-3-11	Limitations of voltage changes, voltage fluctuations and flicker in public low voltage supply systems – equipment with rated current <75A and subject to conditional connection
BS EN 62305 2011	Protection Against Lightning
BS EN 61000-3-12	Limits for harmonic currents produced by equipment connected to public low voltage systems with input current >16A and <75A
BS HD 60269-3:2010 +A1:2013, BS 88-3:2010	Low-voltage fuses. Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications). Examples of standardized systems of fuses A to F
Construction (Design and Management) Regulations 1994	
Construction (Health, Safety and Welfare) Regulations 1996	
Control of Substances Hazardous to Health Regulations 1988	
EA Engineering Recommendation G5/4 Planning Levels for Harmonic Distortion and the Connection of Non-Linear	

Equipment to Transmission Systems and Distribution Networks in the United Kingdom.	
EA Engineering Recommendation P2/5 Security of Supply.	
EA Engineering Recommendation P28 Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom	
WaWR	Electricity at Work Regulations 1989
Electricity Act 1989	
Electricity Safety, Quality and Continuity Regulations 2002	
ENA ER EB/BT2	Conditions for BT and Public Electricity Suppliers' Joint Use of Poles
ENA EREC G 12/4	Requirements for the application for protective multiple earthing to low voltage networks
ENA EREC G87	Supplies to Multi-Occupancy Buildings IET Code of Practice for Electric Vehicle Charging Equipment Installation
ENA EREC P 20/1	Earthing policy in relation to customers installations
ENA EREC P24	AC Traction Supplies to British Rail
ENA EREP123	Guidelines for Managing the Interface between Utility Services and Light Rapid Transit Systems
ENA ER G81	Framework for Design and Planning, Materials Specification, Installation and Records
ENA ER L13-2	Street Lighting Brackets; Recommendations for Attachment to Joint User Poles
ENA ER L22/1	Attachment of Post Office Letter Boxes and Signs to Poles Supporting LV or MV Overhead Lines

ENA TS 09-8	Impregnated Paper Insulated 600/1 000 Volt Cable with Three Solid Aluminium Phase Conductors and Aluminium Sheath/Neutral Conductor (CONSAC).
ENA TS 09-9	Polymeric insulated 3 phase combined neutral/earth (CNE) cables with solid aluminium phase conductors and concentric copper neutral/earth wires.
ENA TS 12-6	Time Fuse-Links (for use with Current Transformer Release on Circuit-Breakers), Issue 2, 1973
ENA TS 12-8	The Application of Fuse-Links to 11kV/415V and 6.6kV/415V Underground Distribution Networks - Issue 2 - 1986
ENA TS 41-24	Guidelines for the design, installation, testing and maintenance of earthing systems in substations
ENA TS 43-30	Low Voltage Overhead Lines on Wood Poles.
ENA ER G5/4	Planning Levels for Harmonic Voltage Distortion
ENA ER G12	Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks
ENA ER P5	Design methods for LV underground networks for new housing developments
ENA ER P25/1	The Short Circuit Characteristics of PES LV Distribution Networks and the Co-ordination of Overcurrent Protective Devices on 230V Single phase Supplies up to 100A
ENA ER P26	The Estimation of the Maximum Prospective Short Circuit Current for 3-Phase 415V Supplies
ENA ER P28	Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment
ENA ER P28	Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom.
ENA TS 12-3	Outdoor Meter Cupboards
ENA TS 35-1	Distribution Transformers
ENA TS 50-19	Standard Numbering for Small Wiring
EREC G98	Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks on or after 27 April 2019

EREC G99	Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019
ESQCR	Electricity Safety, Quality and Continuity Regulations 2002 (as amended)
IET COP	Code of Practice for Electric Vehicle Charging Equipment Installation
Meter Operators' Code of Practice Agreement (MOCoPA)	
New Roads and Street Works Act 1991	
NJUG 7	Recommended Positioning of Utilities' Apparatus for New Works on New Developments and in Existing Streets
PUWER	Provision and Use of Work Equipment Regulations 1998
The Electricity Safety, Quality and Continuity Regulations 2002	
The Electricity at Work Regulations - 1989	
Specification for the Reinstatement of Openings in Highways, a Code of Practice (published by HMSO).	
The Distribution Code of Licensed Distribution Network Operators of Great Britain	

Electricity North West Limited Documents

The following documents are available from Electricity North West Limited:

DOCUMENTS REFERENCED	
CP012	Electricity Geographical Information System (GIS)
CP203	Current Ratings for Underground Cables
CP204	Network Component Impedance Data.
CP205	Network Component Impedance Data – Supporting Document

CP206	Current Ratings for Overhead Line Conductors.
CP221	Low Voltage Network Design for Domestic Premises with Microgeneration
CP258	Connections for Industrial & Commercial Customers
CP306	Fitting Manual - Procedure FM1004 - Inspection of Distribution Substations.
CP333	Earthing Design for High Voltage Substations and Equipment
CP411 LV	Mains Practice; Cable Jointing
CP411 Part 1	LV Jointing
CP430	Mains Practice – Linesman's Manual
CP578	Sealing of Service Termination Equipment
CP605	System Operations
CP606	Operations Manual
CP606 G20	Earth Loop Impedance Testing at LV Service Terminations
CP610	LV Operations Manual
CP810	Charging Conditions for New Connections to the Electricity Distribution Network
CP820	Charging Conditions for Reinforcement and Replacement of the Electricity Distribution Network
CP430	Linesman's Manual - Wood Poles
Electricity Distribution Licence	
Electricity North West Electrolink Publication No. 5 - Outdoor Meter Reading Facilities	
Electrolink No.5	Outdoor Meter Reading Facilities
EPD201	Recovery and Identification of Idle Services
EPD279	Distribution System Design – General Requirements
EPD280	Distribution System Design -132kV Network

EPD281	Distribution System Design - 33kV Network
EPD282	Distribution System Design - 11/6.6kV Network
EPD301	Inspection & Maintenance of Electrical Plant & Substation Security
EPD307	Plant Approved for Use
EPD332	Customer Installation Earthing
EPD333	Supply System Earthing
EPD405	Inspection, Maintenance and Risk Classification of Overhead Lines
EPD473	Policy for Overhead Line Standards
ES215	Design Specification for Third Party Provided New 11kV Connections from 1000kVA to 9MVA (6.6kV) or 15MVA (11kV) Capacity
ES216	Design Specification for a Third Party Provided New 33kV Connection at a Primary Substation with a Maximum Capacity of 60MVA
ES217	Design Specification for Third Party Provided New Connections from either Bulk Supply Point (BSP) Transformers with a Capacity up to 120MVA (33kV) or from the 132kV Network with a Capacity up to 240MVA
ES281	Company-specific Appendices to ENA ER G81
ES287	Connections to Multiple Occupancy Buildings
ES314	12kV and 7.2kV 21.9kA Switchgear
ES319	LV Distribution Fuseboards
ES322	Ground Mounted Distribution Transformers
ES332	100 A House Service Cut-Outs
ES334	HV and LV Fuses
ES352	Distribution Substations
ES387	Electrical Installations within Distribution Substations
ES400C6	Street Lighting Cut Outs

ES400C8	LV Service Cables
ES400C9	11kV Distribution Cables
ES400C11	Low Voltage Mains Cables
ES400D4	Specification for the Supply of Plastic Ducts, Conduit & Accessories
ES400E4	Installation, Commissioning and Repair of Solid Type Underground Cables Operating on the Electricity North West Low and Medium Voltage Systems and the Restoration of Excavated Areas
ES400G1	Cable Guards
ES400I3	Combined Double Pole Switch Fuse Isolators for use in Street Lighting and Other Street Furniture
ES400RL1	Installation of Low Voltage Rising and Lateral Mains and Services
ES501	Metering Current & Voltage Transformers
The Distribution Code	

14.14 Keywords

Design; Network; Planning; Policy; System; 400V; 230V; LV; ADMD; Flicker; Fuse; Voltage; Fault; Impedance; Extension; Third Party; Connection; Circuit; Asset; Lighting; Service; PME; Cut-out; Disconnector; Earth; Fuse; Substation; Relay; Protection; Underground; Overhead; Services; SNE; PNB

15 Appendices Contents

Appendix A – Demand Connection Process

A.1 Introduction

This process provides a 'first pass' assessment of new single and three phase demand applications. The largest, closest passing main is assessed as the point of connection.

Application:

- For 3 phase loads up to 60kVA
- For single phase loads up to 20kVA
- For new loads only
- Motor loads included but not welding equipment, disturbing loads, or loads typically known to contribute harmonic currents
- Applies to urban networks only (all cable)

Assessments are based on modern waveform cable with Aluminium conductors. To allow assessment of imperial cable size, the conversion table below should be used. The passing main size is the minimum cable size.

MODERN CABLE	HISTORIC EQUIVALENT CABLES			RATING (A, CYCLIC, LAID DIRECT)
	COPPER	SOLID AL	STRANDED AL	
300mm² WF	0.3Cu	0.5Al		580
240mm² WF	0.25Cu			515
185mm² WF	0.2Cu	0.3Al	0.5Al	440
95mm² WF	0.1Cu	0.2Al	0.25Al	300

Table A1 below shows, for the stated sizes of passing main, the maximum three phase connection capacity permissible without a detailed connection study and the relevant process diagram to be followed.

Table A1

THREE PHASE CONNECTIONS

CABLE	MAXIMUM POSSIBLE NEW CONNECTION WITHOUT STUDY (3Φ, KVA)	PROCESS DIAGRAM
300mm² WF	60	A
240mm² WF	60	B
185mm² WF	60	C
95mm² WF	45	D

Table A2 below shows, for the stated sizes of passing main, the maximum length of main to substation permissible without a detailed connection study for four single phase domestic non-electric heating connections (with a maximum service cable length of 30m) and the relevant process diagram to be followed.

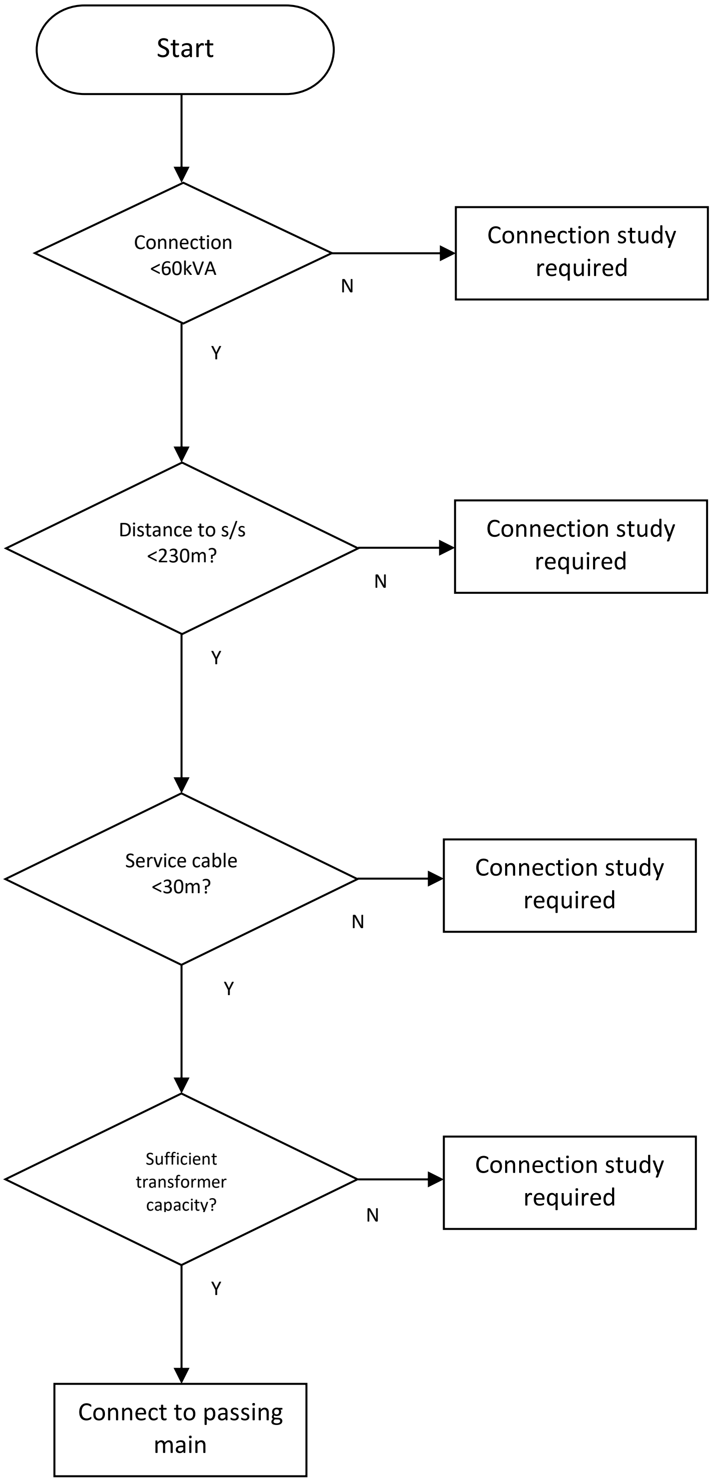
Table A2

SINGLE PHASE CONNECTIONS		
CABLE	**MAXIMUM LENGTH OF MAIN TO SUB FOR 4 X SINGLE PHASE DOMESTIC NON-ELECTRIC HEATING (1Φ, 14 KVA). MAX SERVICE CABLE LENGTH 30 METRES**	**PROCESS DIAGRAM**
300mm² WF	150m	E
240mm² WF	140m	E
185mm² WF	120m	E
95mm² WF	70m	E

A2 Process Diagram A

Passing Main 300mm^2 Al Waveform or equivalent

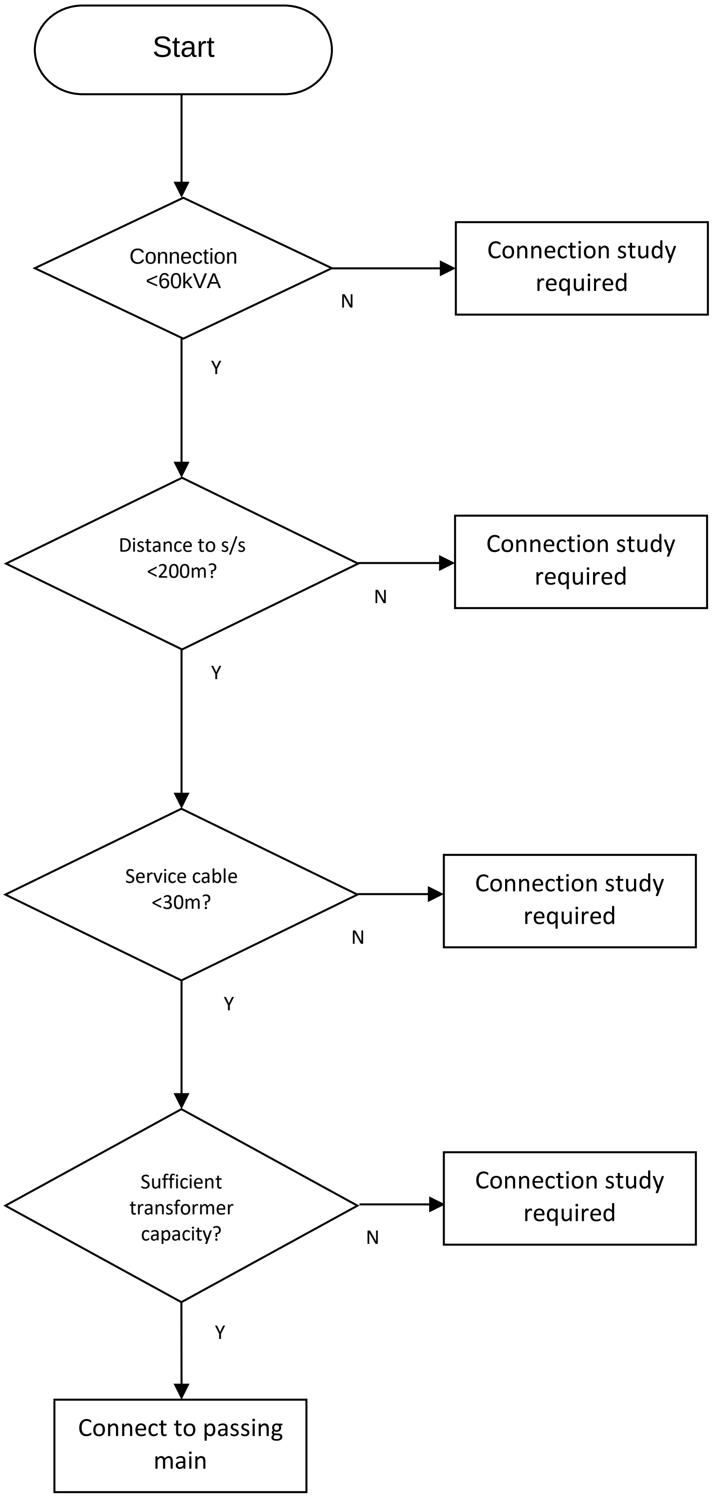
3 Phase demand connection



A3 Process Diagram B

Passing Main 240mm^2 Al Waveform or equivalent

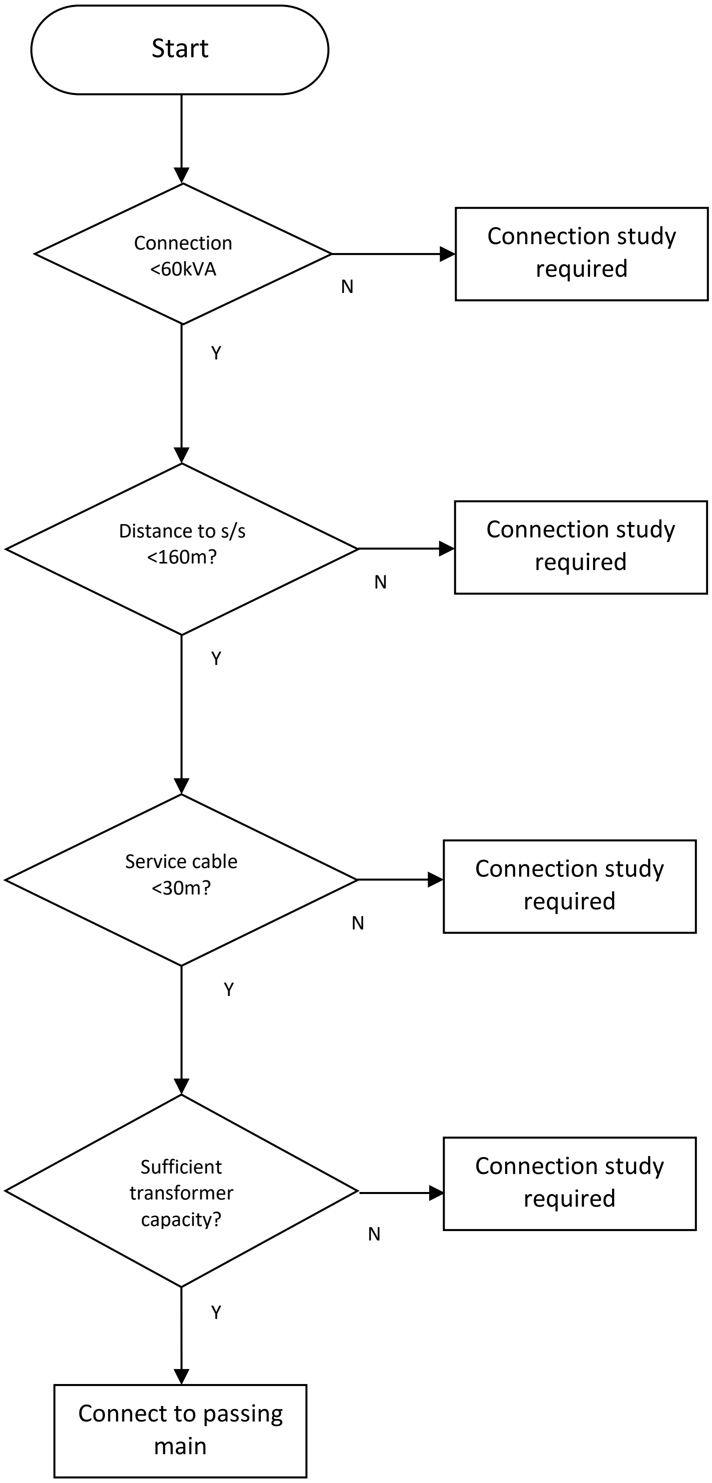
3 Phase demand connection



A4 Process Diagram C

Passing Main 185mm² Al Waveform or equivalent

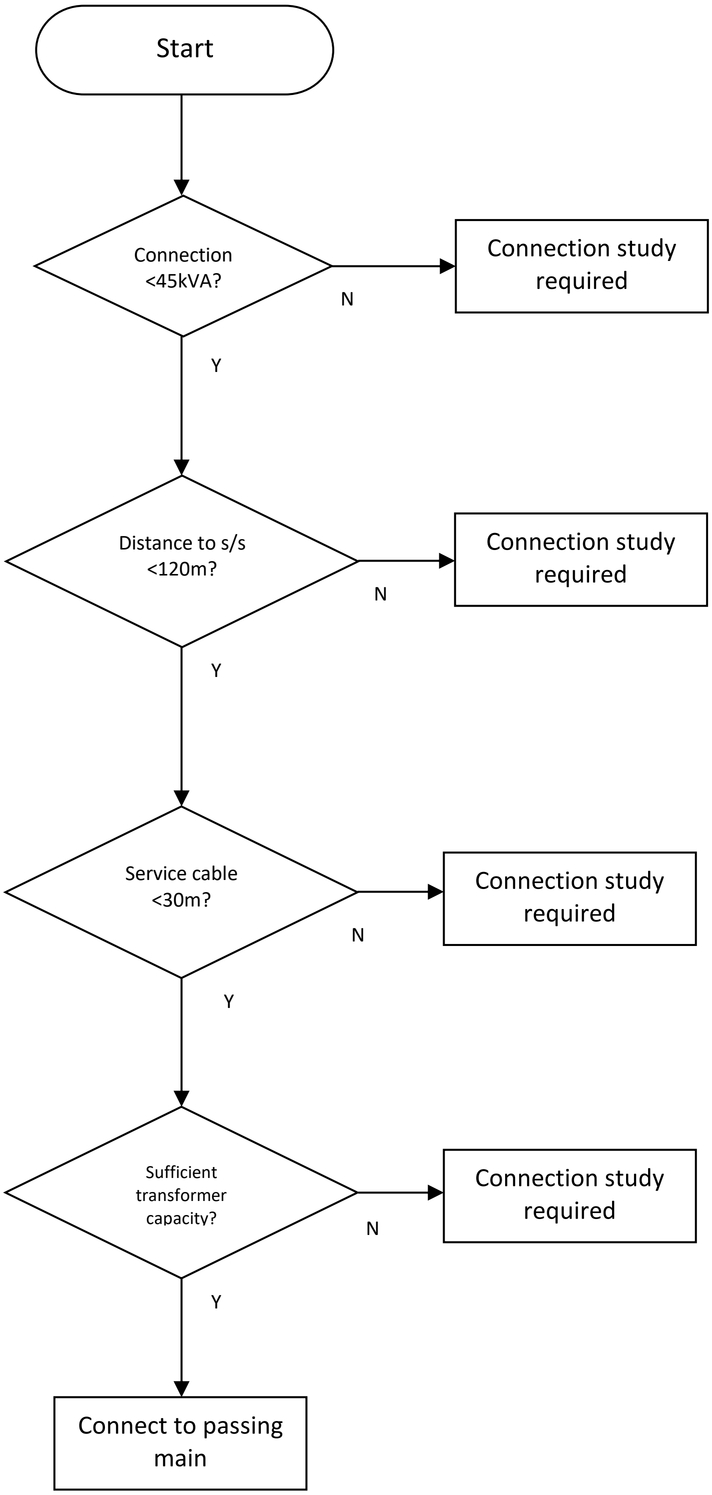
3 Phase demand connection



A5 Process Diagram D

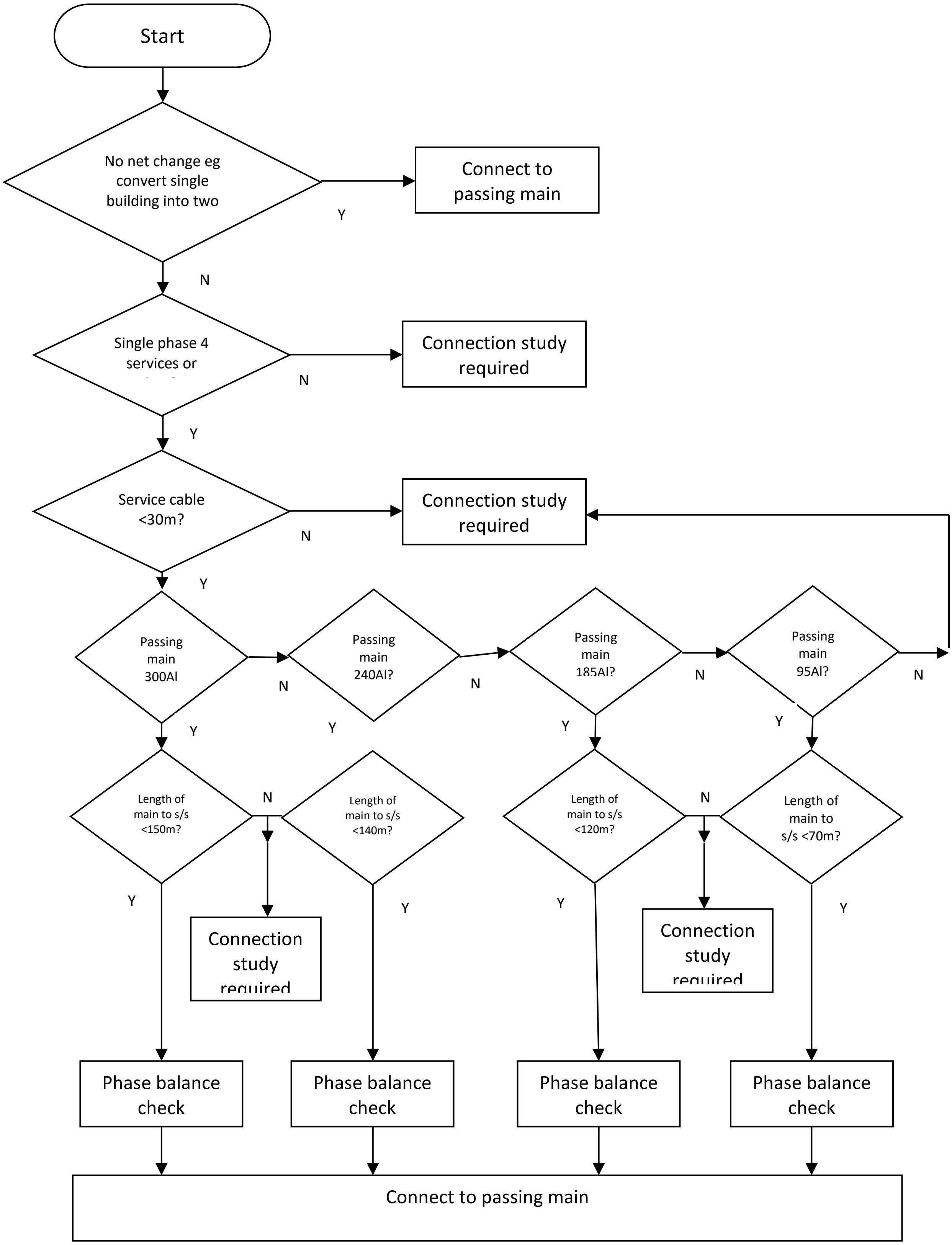
Passing Main 95mm^2 Al Waveform or equivalent

3 Phase demand connection



A6 Process Diagram E

Single Phase demand connection



A7 Motor Loads

Very frequently started motors (<1 minute intervals) for connection onto 185 Al or larger. Table A3 shows the maximum normal running rating permissible without a detailed connection study.

Table A3

TYPE	NORMAL RUNNING RATING EXPRESSED IN TERMS OF EITHER	
	Output (kW)	Input (kW)
Single Phase 240V	0.37	1.0
Single Phase 480V	1.50	3.0
3 phase 415V	2.25	4.0

Motors where the common coupling is the LV busbar at a HV/LV substation, starting intervals 10 minutes or longer. Table A4 shows the maximum normal output rating permissible without a detailed connection study.

Table A4

TRANSFORMER RATING (KVA)	NORMAL OUTPUT RATING (KW)
200	22.5
300/315	30.0
500	45.0
750/800	50.0
1000	75.0

Appendix B – Instructions in the use of LV Affirm (Version 6.4)

B.1 Appendix Heading Level 1

LV AFFIRM (Low Voltage Approved Fusing, Flicker, Impedance and Regulation Model) is a Microsoft Excel workbook. The workbook is available in the form of a template (.xltm), comprising nine worksheets entitled:

- Inputs and Results
- HP and EV load
- Motors and Flicker
- Detailed Calculation
- Data
- Inputs and Results Extension
- Unprotected Lengths
- Loadings and Ratings
- Slow Fault Clearance
- Microgeneration

Although users have access to view all parts of all these worksheets, it is the first three, in which they can enter design parameters and from which they can read results, to which they will need frequent access. As issued, the five sheets, 'Detailed Calculation', 'Data', 'Inputs and Results Extension', 'Slow Fault Clearance' and 'Microgeneration' will be hidden, but available for the users to "unhide". (In Excel 2003, use the 'Format' menu and then click on 'Sheet' and then on 'Unhide'; in Excel 2007/2010/2013, on the 'Home' tab, in 'Cells', click on 'Format', then move the cursor to 'Visibility', 'Hide & Unhide' and click on 'Unhide sheet'.) Each worksheet is locked, except for the white entry cells on the first two worksheets, and 'Inputs and Results Extension' and 'Microgeneration'. Detailed documentation of the function of each cell is contained in CP227.

LV AFFIRM is capable of calculating voltage drop, loop impedance, fuse rating and the largest acceptable motor starting current, for most network conditions and also calculates voltage conditions arising from the operation of small generating units, connected at LV. (See CP221 - Low Voltage Network Design for Domestic Premises with Microgeneration.) Modern and historical line types, three-phase, split-phase and single-phase transformers and circuits, and distributed housing and point loads can be accommodated.

B2 Worksheet: Inputs and Results

B2.1 Project Name/Number

A suitable reference for the project shall be entered in free format.

B2.2 Designer

Each registered designer is provided with a named, password-protected copy of the template. The designer's name is shown in a locked cell. This is to prevent unregistered use of LV AFFIRM and unauthorised use of a designer's name.

B2.3 Date

The current date shall be entered. It may be entered in any Microsoft recognisable format; however, it is shown in the format dd Month yyyy.

B2.4 Substation Details

B2.4.1 Name

The substation name or reference shall be entered in free format.

B2.4.2 HV Fault Level

A value for the 3-phase HV fault level at the substation shall be entered. This may be from a drop-down list (200, 150, 100, 50, 25, 10 (MVA)) or entered as a number from the keyboard. Where the value of the HV fault level is not known, one of the following default values may be used:

- for an underground HV network - 50MVA
- for an overhead HV network - 10MVA

Values outside the range 10 to 250 are shown in red.

B2.4.3 Transformer Description

Selection is from a drop-down list. Each description includes the number of phases and the nominal rating.

B2.5 Domestic Loading

B2.5.1 Loss of Diversity Allowance

The value may be selected from a drop-down list or entered directly from the keyboard. This shall be set to 8 (kW), except when considering the night-time loading of domestic heating on off-peak tariffs, when the value 4 (kW) is accepted. If no domestic load is being considered, the cell may be left blank. On attempting to enter a number of houses, when no Loss of Diversity Allowance has been entered, a warning message is shown. The allowance is included in the form of a load at the end node of each section, which has houses connected to it (either distributed or at the end-node), or has houses connected downstream of it. The allowance is applied only once to each such section; it is not added into the load imposed upstream. The corresponding figures used in the calculation of service cable loadings are not dependent on this input. (See B2.7.4.)

B2.5.2 House ADMD

For the house type, those values shown in the table at 5.2.1 may be selected from a drop-down list. Otherwise entries may be made directly from the keyboard. The workbook accommodates up to three different house types (A, B and C) with correspondingly different ADMDs. ADMDs over 5kW are assumed to be associated with off-peak tariffs and are shown in red. Cells for unused house types may be left blank.

Where applicable, the 'HP and EV load' worksheet should be populated to ensure that HP load and EV load is included in the total ADMD value (see subsection 5.3.3).

Once the 'HP and EV load' worksheet has been populated, the total ADMD value is displayed (House + HP + EV) and automatically used for the 'Inputs and Results' calculations.

B2.6 LV Mains Sections

The LV main being analysed shall be divided into appropriate sections, generally determined by branch positions and positions of changes of cross section or type. The positions of point loads may also influence this division. Up to twenty sections can be accommodated within Sheet 'Inputs and Results', designated by letters of the alphabet A to V (I and O are not used). Where it is necessary to model more than 20 sections, Sheet 'Inputs and Results Extension' may be used, the additional sections being designated "ZA", "ZB" etc. Each section is represented by a horizontal row in the main body of the worksheet and the details shall be entered as listed below. Cells in unused rows may be left blank.

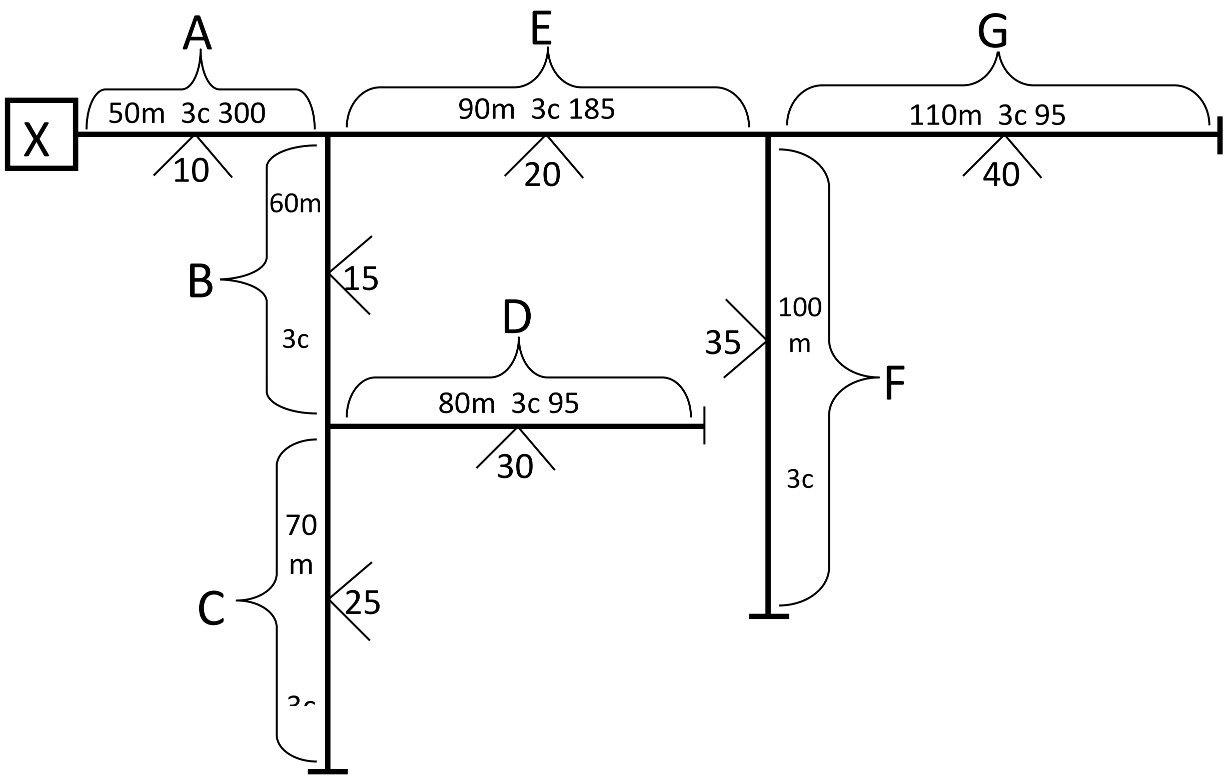
NOTE: These rows do NOT operate independently. Connections between sections are taken into account. (See B2.6.1.) Load connected downstream is automatically added into the load on each section; voltage drops and loop impedances in upstream sections are automatically added into the corresponding cumulative values for each section. The rows on Sheet 'Inputs and Results Extension' operate exactly as if they continued below the Section V row of Sheet 'Inputs and Results'.

B2.6.1 Upstream Section

In order to identify how the various sections are connected, the single letter (or on the 'Extension' sheet, two letters) corresponding to the section immediately upstream shall be entered. Letters lower down the worksheet (later in the alphabet) are not permitted. This is in order to ensure that sections cannot be modelled as if connected in loops. However, in practice, this does not limit the complexity of a branching distributing main, which may be modelled. Hence, Section A must be connected immediately downstream of the substation, which is designated "X". This does not prevent (an)other section(s) also being connected directly to the same substation fuseway. Entries are not case sensitive. In order to temporarily disconnect a section from the model, the Upstream Section cell may be made blank. However, it shall be borne in mind that this action will also effectively disconnect any section further downstream of the section so disconnected. (See Note at B2.6.4, on the treatment of single-phase loads.)

A sample network and the corresponding entries in the workbook, showing how the connection of sections is indicated, are illustrated in Figure B1, overleaf.

Figure B1 – Sample Network and Workbook Entries, Illustrating Connection of Sections



Line Sect'n	Up-stream Section	Length (m)	Description	Sect φs	No of φs	Dist'd Houses Type A
A	X	50	3c 300 Waveform		3	10
B	a	60	3c 185 Waveform		3	15
C	b	70	3c 95 Waveform		3	25
D	b	80	3c 95 Waveform		3	30
E	a	90	3c 185 Waveform		3	20
F	e	100	3c 95 Waveform		3	35
G	e	110	3c 95 Waveform		3	40

B2.6.2 Length

The circuit length (m) of the section shall be entered. Lengths in excess of 500m are shown in red.

B2.6.3 Description

The description of the cable or overhead line, comprising the section, shall be entered from the drop-down list. Particular note shall be made of the following:

Three-phase service cables are included in the list of mains types. Where it is appropriate for the model to include three-phase services, they shall be included here. (The calculations in the Services section of the worksheet are appropriate to single phase operation only but see B2.7.1 regarding the display of loop-impedance values, and B8.8 regarding the display of Service Voltages.) Since no attempt is made to protect services with the substation fuses, the inclusion of services in the mains section is such that the service cables have no influence on the calculation of fuse ratings.

Each four-core cable type (i.e. a cable with a non-concentric neutral core) is listed, without the presence (Bond) or absence (SNE) of a neutral-earth bond being indicated. However, either "(SNE)", or "(Bond)" is added automatically as the entry is made, the default being "(SNE)". This may be changed to "(Bond)" or restored to "(SNE)" as required, by means of a separate drop-down list. This facility is to take account of the reduction in loop impedance effected by bonding neutral and earth together, e.g. where a downstream cable is CNE. However, such bonds have their full effect only on the part of the distributor downstream of the bond. Accordingly, the network shall first be modelled using the (SNE) values. Only, if loop impedances are shown to be high, but only downstream of known bonded sections, may the (Bond) description be substituted in those sections upstream of such bonds.

NOTE: Fault-impedance values for 4c cables are based on the following assumptions:

(a) a cable operating as SNE, i.e. with no CNE branch, extension or insert, will have its armour bonded to its sheath at all joints (plumbed joints); and

(b) where a CNE cable has been jointed to a 4c cable, the neutral will have been bonded to the sheath, but the armour will not have been bonded (resin joints). (This ignores the reality that early Consac jointing systems used plumbed joints.)

Each size of ABC is listed twice, once for the preferred fault clearance time of 10s and once for the alternative time of 30s. This is to take account of the difficulties, sometimes encountered, in designing ABC distributors, such that their fuses will operate in 10s. The longer 30s clearance times may be used in circumstances where the additional risk is acceptable.

B2.6.4 Number of Phases.

Some distributors, particularly those with overhead lines and old types of cable, have single phase and two-phase sections, even though the transformer is three-phase. Such sections shall be identified by entering the number of phase conductors used in the 'Section ϕs' (Section Phases) column. The presence of such a section forces any downstream section also to be single-phase or two-phase, even though it might be installed with 3-phase cable. This is taken into account, as may be seen from the "No of Phases" column. Where the transformer is single-phase, all calculations are based on single-phase loading. (There is then no need to enter a '1'.) Similarly, where the transformer is two-phase (split-phase), calculation is based on two-phase distribution, unless '1' is entered.

NOTE:

Voltage-drops caused by single-phase loads are calculated based on the impedance of the phase-neutral loop within single phase sections and similarly for single-phase end loads within their own polyphase sections. Voltage drops caused by "balanced" (connected equally) loads in two-phase sections of three-phase distributors are calculated based on there being a current in the neutral, equal in value to that in each of the phases. However, where these sections are fed by upstream sections with a greater number of phases, it is assumed that the out-of-balance reduces, such that the additional neutral current may be ignored in the upstream sections. In order to model the voltage-drop in the phase conductors of the polyphase upstream sections, the single-phase loads (and two-phase loads (per phase)) are applied per phase to all three phases, effectively imposing the same load on each of the upstream phases. Hence, where groups of three single-phase or two-phase branches are connected to the same three-phase distributor (eg, as in parts of Blackpool, Bolton, Colne and Preston), only one (in particular the worst case) of each set of three branches should be included in the model at any one time. (See B2.6.1 regarding the facility to disconnect sections temporarily within the model.)

B2.6.5 Number of Houses

The number of houses of each type shall be entered in the appropriate column, according to whether they are distributed along the section or connected as a block at its end. On attempting to enter a number of houses, when no Loss of Diversity Allowance has been entered, a warning message is shown. On attempting to change the total number of houses connected to the distributor to a number exceeding 200, a warning message is shown. If this warning is ignored all housing numbers (totalling more than 200) are shown in red.

NOTE: In entering these numbers of houses, it is not necessary to take account of houses connected to further sections downstream; the workbook will add in the load that they impose and the resulting voltage-drop automatically. The number of "End Node Houses" entered for each section shall be only those actually connected at the end of that section.

B2.6.6 End Load

The size (kVA) of any point loads, poly- or single-phase, connected at the downstream end of the section shall be entered in the appropriate column. Values of poly-phase loads entered, where the "No of ϕs" is 1, are shown in red and are accompanied by the legend "Invalid End Load". (Such invalid entries take no part in the calculation.)

NOTE:

(a) As with entering house numbers, it is not necessary to take account of point loads connected to further sections downstream.

(b) Loads shall be expressed as electrical input quantities, not to be confused with the mechanical output ratings of motors.

B2.6.7 Voltage Drop

Where the load on the section exceeds its rating, the legend "Section Overloaded" is shown. Otherwise, the voltage-drop (%) at the downstream end of each mains section may now be read. Values in excess of 6.99 are shown in red.

B2.6.8 Mains Loop Impedance

The total distributor load (A) may be read. This value is shown in red, where it exceeds the rating of Section A. There may be cases, where Section A is not the only section immediately downstream of the substation and the total load is shared between two or more sections. However, such cases are expected to be rare. There will also be situations in which the rating used by LV AFFIRM is inappropriate. (Underground cable ratings are derived from CRATER, assuming cyclic loading of cables laid direct in UK winter conditions.) Reference shall then be made to the 'Loadings and Ratings' sheet, where, for each section, up to ten ratings (cables laid in ducts, in groups and continuously loaded) are shown.

B2.6.9 Mains Loop Impedance

The cumulative earth-fault loop-impedance at the downstream end of each section may be read. These values take account of the loop impedance in mains and three-phase service sections only, ie excluding the impedance contribution of the HV network and the distribution transformer. Values in excess of 0.35 (Ω) are shown in red.

These values are of particular use when giving information to ICPs, concerning Points of Connection, since they are consistent with the maximum values of loop impedance, tabulated in CP331, according to the various sizes of transformer, fuse and mains.

Total loop impedance values are also available. See subsection B2.7.5.

B2.6.10 High Loop Impedance

Where any of the loop impedance values, as described in subsection B2.6.9, exceeds 0.8 (Ω), the legend "Z excessive" appears in red. Otherwise, where any value exceeds 0.35 (Ω), the legend "Loop Z high" appears.

B2.7 Services

There is provision for each house type to have a different service type. Details shall be entered for each of the house types used, or, alternatively, where it is obvious which is the worst case (eg, greatest ADMD or longest length), details for that type only.

B2.7.1 Upstream Section

The single letter (or on the 'Extension' sheet, two letters) corresponding to the section on which the service is to be connected shall be entered. The worst case may be determined by examining the list of voltage drops at end nodes and, if necessary, by trial and error. Where a three-phase service has been entered in the Mains Section of the worksheet, enter only the section letter of the three-phase service in any of the three left hand cells in the Services Section, in order to read off the loop impedance. (See B2.7.5.) (In such a case, the corresponding Length and Description cells should be left blank.)

B2.7.2 Length

The length (m) of the service shall be entered. If lengths in excess of 30m are entered a warning message is shown and if this is ignored the entries are shown in red.

B2.7.3 Description

The description of the cable, comprising the service, shall be entered from the drop-down list.

B2.7.4 Voltage Drop

The total voltage-drop (%) at the end of the services may now be read. Values in excess of 7 are shown in red. The calculation of service voltage-drop uses the demand values, as shown in 5.4.6.3. The workbook assumes that where the Loss of Diversity allowance is 4 (kW), the use of off-peak tariffs causes the peak demand to occur at night.

B2.7.5 Loop Impedances

The total loop impedance, including that of the services and the contribution from the HV network and the distribution transformer, may now be read. Values in excess of 0.35 are accompanied by a warning, “Loop Z high for CNE network”; values in excess of 0.54 are accompanied by a warning, “Loop Z high; max c/o fuse 80A”; and values in excess of 0.8 are shown in red and accompanied by a warning, “Loop Z excessive”.

B2.7.6 Street Lighting Services

Street lighting services may be entered in order to check the service voltage drop and loop impedance. The “ADMD” entered should be the normal load of the lamp. No loss of diversity allowance is applied to the load on a street-lighting type service cable. No attempt should be made to model the effect of street-lighting load on the distributor; it is normally expected to be negligible.

B2.8 Fuses

Four fuse ratings are shown:

- the maximum fuse for the transformer to allow for discrimination with the HV protection;
- the maximum recommended fuse for Section A (See CP331, Tables 3A and 4A.);
- the maximum fuse to provide full protection to the distributor; and
- the minimum fuse required to carry the load.

Where any of these conflict, their ratings are shown in red. If the total load on the fuseway exceeds 630A, the legend “Fuseway Overloaded” is shown.

When modelling alterations to a distributor, where the existing load requires the fuses to have ratings too high to fully protect the distributor, it might not be immediately apparent that the altered part of the distributor will subsequently be fully protected (as required by EPD279, subsection 4.7.1). In such a case, reference shall be made to Sheet ‘Unprotected Lengths’. (See section B5)

NOTE: The maximum recommended fuse for Section A (Fuse for Section A Rating) is determined only from the line size and type of Section A, without regard for the rating of the fuseway to which it is connected. Where any line section is connected via a distribution fuseboard, FP or LB, it might be necessary to reduce the rating of the section to that of the appropriate link- or fuse-way.

B3 Worksheet: HV and EV Load

This worksheet 'HP and EV Load' is used when customers have a HP or EV load which must be accounted for in the ADMD values on the 'Inputs and Results' worksheet.

B3.1 HP / EV Present

The option 'Yes' or 'No' shall be selected from the dropdown menu to confirm whether HP and/or EV load is connected to the customer supply.

B3.2 Common Details

The Project Name, Designer, Date, Substation details and House ADMD are copied automatically from the "Inputs and Results" worksheet.

B3.3 HP Load

There are three sizes of HP available to calculate an ADMD value which should be used depending on what the customers have installed i.e. some customers may have a 3.68kW HP whilst others may have a 5.75kW HP.

B3.3.1 Number of Customers

The number of customers with the particular HP size should be entered.

B3.3.2 In-line Heater Details

The size of in-line heater should be selected as appropriate.

- Standalone HP which may include heater for legionella protection – in-line heater is 0kW
- 3.68kW or 5.75kW HP – in-line heater would typically be 3kW
- 7.36KW HP – in-line heater would typically be 6kW

B3.4 EV Load

There are three sizes of EV available to calculate an ADMD value which should be used depending on what the customers have installed i.e. some customers may have a 3.68kW EV whilst others may have a 5.75kW EV.

B3.4.1 Number of Customers

The number of customers with the particular EV size should be entered.

B3.5 Calculated ADMD

The total value for the ADMD for each customer type is calculated (summation of House ADMD, HP ADMD and EV ADMD) and this value is automatically used for the calculation on the 'Inputs and Results' worksheet.

B4 Worksheet: Motors and Flicker

This worksheet deals only with motor starting and other causes of flicker and considers the flicker caused by one machine, without taking account of the operation of other machines on the same network. The normal loads imposed by all disturbing loads shall, in addition, be entered in the appropriate cells in the Worksheet: 'Inputs and Results' (or 'Inputs and Results Extension'), in order to assess their effect on the loading of the network and the voltage drop arising. The assessment is based on the requirements of ENA ER P28.

B4.1 Common Details

The Project Name, Designer and Date and the Substation details are copied automatically from the "Inputs and Results" worksheet.

B4.2 Stage 2 – Basic Assessment

B4.2.1 Point of Common Coupling (PCC)

The single letter (or from the 'Extension' sheet, two letters) representing the section immediately upstream of the PCC shall be entered.

B4.2.2 Number of Phases

The number of phases to which the disturbing load is to be connected shall be entered. This shall be equal to or less than the number of phases available at the PCC.

B4.2.3 Power Factor

The power factor of the disturbing load is set to 0.30, based on the typical power factor of a motor when starting, in accordance with ENA ER P28. However, this value may be overwritten with any value between 0 and 1. Values other than 0.30 appear in red.

B4.2.4 Flicker Voltage and Largest Acceptable Step Change

The flicker voltage per ampere of step-change current at 0.3 power factor and the largest acceptable step changes in current, both frequent and infrequent, may be read.

NOTE: "Frequent", in this context, means at intervals of less than 2 hour.

B4.2.5 Customer's Point of Connection

The single letter (or from the 'Extension' sheet, two letters) representing the section from which the customer's connection is taken may be entered. Where the service connection is three-phase, this needs to be entered as a Line Section in Sheet 'Inputs and Results' (See B2.6.3) and the letter(s) to be entered here is the letter(s) corresponding to that section. Where the service connection is single-phase, details of the service need to be entered in the Services Section of 'Inputs and Results' before (higher up the list than) any other services connected to the same section.

B4.2.6 Voltage Dip at Customer's Terminals

The voltage dips (%) at the customer's terminals caused by the largest acceptable step-changes in current (at the PCC) may be read.

NOTE:

(a) The impedance of a single-phase service is taken into account, only where the number of phases of the disturbing load is entered as 1.

(b) Otherwise, if the section letters representing the PCC and the customer's connection are the same, the results here, as might be expected, will be 1.0% (frequent start) and 3.0% (infrequent start).

(c) The section letter(s) representing the customer's connection must be downstream of the PCC. Otherwise an error message, requesting correction, will be displayed; similarly, if no entry has been made for the PCC.

B4.2.7 Approximate Guide to Motor Sizes

The approximate electrical sizes of motors, which may be expected to cause the maximum acceptable step-changes in voltage, may be read. Sizes (kWe) are given for direct starting and star-delta starting, frequently and infrequently.

B4.3 Stage 2 – Further Assessment

B4.3.1 Expected Starting Current

The expected starting current (assumed to be at 0.3 power factor) of the motor may be entered.

B4.3.2 Acceptable Interval between Starts

The least acceptable time interval between motor starts may be read. This value is derived from Figure 4 of ENA ER P28.

B5 Worksheet: Inputs and Results Extension

Operation of the Extension sheet matches that of Sheet 'Inputs and Results' for sections of the distributor in excess of 20. Common details such as those concerning the project, the substation, customer demands and services are copied from Sheet 'Inputs and Results'. Line sections are designated "ZA", "ZB" etc ("ZI" and "ZO" are not used) and the corresponding rows are used in the identical manner to those on Sheet 'Inputs and Results', as if the row for section "ZA" followed immediately below that for section "V".

B6 Worksheet: Unprotected Lengths

Where the rating of the existing fuses protecting a distributor is too great to afford full protection in accordance with CP331, it is useful for the designer to know how much of the distributor is unprotected. Also, it is necessary to check that all new or modified sections are fully protected. For these purposes, reference should be made to this 'Unprotected Lengths' sheet. For each section of the distributor, its maximum recommended fuse rating is shown, together with the part of its length (m) which would not be fully protected by each rating of fuse.

NOTE: A thermally limited section will be either entirely protected or entirely unprotected.

Where it is called for, the protection provided by sub-fusing, either in a LB or on an overhead line support, may also be checked. The whole distributor from the substation should first be modelled. This would be expected to show that the sub-fused section(s) were not fully protected. However, the 'Unprotected Lengths' sheet provides a check of the extent to which the sub-fused section(s) would be protected by the smaller-rated sub-fuses.

B7 Worksheet: Loadings and Ratings

Where the given ratings do not apply (i.e. where cables are laid in ducts, in groups or with a load pattern, which is not a winter-peaking cyclic pattern), reference shall be made to this 'Loadings and Ratings' sheet. For each section of the distributor, its loading is shown, together with ratings for continuous loading (laid direct), for cables laid in ducts (cyclic and continuous loading) and in groups (cyclic loading; laid direct and in ducts).

NOTE: Where any line section is connected via a distribution fuseboard, FP or LB, it might be necessary to reduce the rating of the section to that of the appropriate link- or fuse-way.

B8 Worksheet: Slow Fault Clearance

This sheet is similar in layout to the 'Unprotected Lengths' sheet. However, no account is taken of any thermal limitation, or of the risk of thermal damage caused by the passage of fault current. The purpose of the sheet is to provide indication of any improvement in fault clearance times, when substation refurbishment or re-arrangement of LV circuits from a substation is being proposed, and where the existing arrangement is not fully protected and the change to full protection (as CP331) is not justified.

For each section and for each fuse rating, the length of the section, for which maximum fault clearance time (100s for underground cable; 10s for overhead line) is exceeded, is shown. Such lengths have implications for the safety of personnel or third parties, working on or near the Network. However, on the 'Unprotected Lengths' sheet, they are often masked by the additional requirement to protect the Network from thermal damage.

The sheet shall NOT be used to indicate the compliance of new Network extensions.

B9 Worksheet: Microgeneration

Calculation of the maximum and minimum voltages expected to arise from the operation of small single-phase and three-phase generating units, in accordance with CP221, is provided via this worksheet. Trials suggest that this method is most suited to dense urban networks, rather than sparse rural ones. Alternative models, such as DiNIS, may be more suitable for use in sparsely populated networks.

The distributor being considered and to which the generation is connected, should first be modelled using the 'Inputs and Results' and 'Inputs and Results Extension' Sheets, as described above. It is necessary to include all information including the normal (admd) loads.

B9.1 Project Basic Details

The project name, the designer's name and the date are copied automatically from the 'Input and Results' sheet.

B9.2 HV System

B9.2.1 Nominal, and Actual High and Low Voltage

The normal (neglecting extreme short-lived peaks and troughs) high and low values of the voltage (kV) on the primary substation busbar, as recorded by Feeder Load Analysis, shall be entered from the keyboard. The values are expected to lie within ±6% of the nominal. The nominal voltage (11 or 6.6kV) of the HV system is automatically deduced from these entries.

B9.2.2 HV Voltage Drop

The voltage drop (%) on the HV circuit (from primary busbar to distribution substation) for both low load and high load conditions, based on a DiNIS study, shall be entered from the keyboard. The values are not expected to exceed 6%.

B9.3 Distribution Substation and Network

B9.3.1 Transformer Tap Number

The setting of the distribution transformer tapping switch (1, 2, 3, 4 or 5) shall be entered from a drop-down list. No other entry is acceptable.

NOTE: Some small pole-mounted transformers have only three tappings at -5%, 0 and +5% (of nominal LV terminal voltage). The correct numbers to enter to represent these tappings are 1, 3 and 5 respectively.

B9.3.2 Power factor of Transformer Power Flow

An estimate of the power factor of the power flow through the transformer, depending on the type of generation connected, may be entered from the keyboard. The default value is 1 and the entered value is not expected to be less than 0.7.

B9.3.3 Unbalance Factor

Where there are small numbers of single-phase generating units and the power flow direction is upstream, out-of-balance neutral currents can be expected to be significant. This factor is applied to the neutral current of any residual output (not absorbed by load) from generation connected downstream. Input may be from a drop-down list (0.0, 0.2, 0.4, 0.6, 0.8, 1) or from the keyboard. It is suggested that for one single-phase generating unit, connected to a three-phase distributor, the factor should be 1, reducing by 0.2 for each additional single-phase unit, down to zero for six or more. Further consideration may be necessary, to assess the relative size of the neutral current in split-phase distributors. The setting of this factor has no effect on the result for a single-phase section, or a two-phase section of a three-phase distributor, in which the neutral current is assumed to match the current in the phase(s).

B9.4 Single-Phase Connections

B9.4.1 Single-Phase Service MAD

For each single-phase service type, as defined and shown connected on the 'Input and Results' sheet, the MAD (kW) shall be entered, either from a drop-down list or from the keyboard. The values listed are those included in Table A1 of CP221.

B9.4.2 Single-Phase Service Generation

The output rating of single-phase generating units (kW) shall be entered according to the service types to which they are connected. It is assumed that generation connections are sparse. This allows up to three generating units to be modelled in this way; generation output is not multiplied by the numbers of customers (unlike the treatment of loads). Where more generation units than can be modelled in this way are connected to the distributor, their outputs need to be aggregated at end nodes (either single-phase or three-phase).

B9.4.3 Other Customers Connected to Substation

The customers' loads (MAD and admd) connected to the present distributor are automatically included. It is, however, necessary to enter the numbers of customers connected to other distributors from the same distribution substation, according to their types, since these affect the transformer LV terminal voltage.

B9.5 Point Loads and Point Generation

Non-domestic customers, connected at nodes also have MAD and may have generation. Three-phase and single-phase MAD and generation (kW) may be entered against each section (downstream end). If entries of three-phase quantities are made against single-phase or two-phase sections, the legend "ϕ mismatch" appears in the 'End Node MAD' column.

B9.6 MAD

Distributed and end-node MAD per phase (kW) on each section may be read.

B9.7 High Voltage at End Node

The high value of voltage (with generation and MAD) at the end node of each section may be read. Values in excess of 253 (V) appear in white on a red background.

B9.8 Service Voltages

Against each (connected) service type, the high (with generation and MAD) and low (with ADMD and no generation) values of voltage may be read. High values in excess of 253 (V) and low values less than 216 (V) appear in red. Low values in the range 216 to 220 appear in orange. A correspondingly coloured pass/fail indicator is also provided.

> **NOTE:** Where generation connected only to polyphase services is being considered, it is necessary to enter a dummy (zero length) single-phase service in the 'Inputs and Results' sheet, connected to the polyphase service downstream end. It is sufficient to enter only the section letter of the polyphase service against one of the single-phase service types, just as for reading total loop impedance. (See B2.7.1.)

Appendix C - % Voltage Drops for Distributor and Service Cables

The % voltage drops are quoted per kVA per metre and are based on:

- 415/240V busbar voltage
- Impedance data taken from CP204 - Network Component Impedance Data unless otherwise stated
- Impedance values are at an operating temperature of 20°C for the conductor
- Balanced 3 phase loads for 3 and 4 core cables

C1 Electricity North West Standards Cable Types & Sizes

C1.1 Electricity North West Standard LV Mains (Distributor) Cables

CABLE TYPE	SIZE (MM^2)	% VOLTAGE DROP PER KVA PER M 415V BALANCED 3 PHASE LOAD
BS 7870 - 3-40 Three-core XLPE-insulated solid-aluminium phase conductors & copper Waveform CNE conductor	95	0.000 191
	185	0.000 105
	300	0.000 073

C1.2 Electricity North West Standard LV Service Cables

CABLE TYPE	SIZE	% VOLTAGE DROP PER KVA PER M	
	(mm^2)	415V balanced 3 phase load	240V single phase load
3-phase CNE Solid aluminium phase conductors. XLPE insulated. BS 7870-3-11	25	0.000 697	- -
3-phase split concentric Solid aluminium phase conductors. XLPE insulated. BS 7870-3-21	25	0.000 699	- -
Single-phase CNE Solid aluminium phase conductors. XLPE insulated. BS 7870-3-11	35	-	0.003 098

Single-phase split concentric Solid aluminium phase conductors. XLPE insulated. BS 7870-3-21	35	-	0.002 844*
Single-phase CNE Stranded copper phase conductors. XLPE insulated. BS 7870-3-11	4	-	0.016 339
Single-phase split concentric Stranded copper phase conductors. XLPE insulated. BS 7870-3-21	4	-	0.016 340

* Neutral resistance is lower for the split concentric.

C2 Electricity North West Standard Overhead Conductor Types & Sizes

C2.1 Electricity North West Standard LV Mains Overhead Conductors

CONDUCTOR TYPE	SIZE (MM^2)	% VOLTAGE DROP PER KVA PER M 415V BALANCED 3 PHASE LOAD
4-core Aerial Bundled Conductor (ABC)	35	0.000 506
	95	0.000 191

C3 Historic Cable Types

C3.1 Historic LV Mains (Distributor) Cables

CABLE TYPE	SIZE	% VOLTAGE DROP PER KVA PER M
	(in^2)	**415V balanced 3 phase load**
BS 480 **Four-core paper**-insulated, stranded-**copper** conductor, lead-sheathed, steel-tape armoured (BEBS C2 (CES) 1955). (**Imperial**)	0.04	0.000 413
	0.06	0.000 275
	0.075*	0.000 233
* Not included in BS 480. Values calculated from the interpolated impedance values in CP204.	0.10	0.000 165
	0.12*	0.000146
	0.15	0.000 120
	0.20	0.000 096
	0.25	0.000 082
	0.30	0.000 073

	0.40	0.000 057
	0.50	0.000 052
	(in²)	
BS 480 Four-core paper- insulated, solid-aluminium conductor, lead-sheathed, steel-tape armoured. (Imperial)	0.10	0.000 265
	0.20	0.000 139
	0.30	0.000 095
	0.50	0.000 068
	(mm²)	
BS 6480 Four-core paper-insulated, solid-aluminium conductor, lead-sheathed, steel-tape armoured. (Metric)	70	0.000 262
	120	0.000 153
	185	0.000 104
	300	0.000 071
	(mm²)	
ENA TS 09-8 Impregnated-paper insulated with three solid-aluminium phase conductors and aluminium sheath neutral conductor (CONSAC)	95	0.000 191
	185	0.000 104
	240	0.000 084
	300	0.000 071
	(mm²)	
BS 7870 - 3-40 Three-core XLPE-insulated solid-aluminium phase conductors & copper Waveform CNE conductor	240	0.000 085
	(in²)	
BS 480 Stranded-copper single-core paper insulated lead-sheathed (laid in trefoil)	0.40	0.000 066
	0.50	0.000 060
	0.60	0.000 055
	0.75	0.000 052
	1.00	0.000 049

C3.2 Historic LV Service Cables

CABLE TYPE	SIZE	% VOLTAGE DROP PER KVA PER M	
	(mm²)	**415V balanced 3 phase load**	
3-phase CNE Solid aluminium phase conductors. PVC insulated. BS 7870-3-10	25	0.000 697	
3-phase split concentric Solid aluminium phase conductors. PVC insulated.	25	0.000 699*	
3-phase CNE Stranded copper phase conductors. PVC insulated. BS 7870-3-10	16	0.000 668	
3-phase split concentric Stranded copper phase conductors. PVC insulated.	16	0.000 674**	
	(in²)		
BS 480 Four-core copper conductor, paper insulated, lead sheath, steel tape armoured (CES C2 1955)	0.014 5	0.001 104	
	0.022 5	0.000 730	
	(in²)	**240V single phase load**	
BS 480 twin-core copper conductor, paper insulated, lead sheath, steel tape armoured (CES C2 1955)	0.007	0.013 775	
	0.014 5	0.006 615	
	0.022 5	0.004 375	
		240V single phase load	
	(mm²)	**Stranded copper conductor**	**Solid aluminium conductor**
Single-phase CNE XLPE insulated. BS 7870-3-11	25		0.004 349
Single-phase split concentric XLPE insulated. BS 7870-3-21	25		0.004 177
Single-phase CNE PVC insulated. BS 7870-3-10	4	0.016 339	
	16	0.004 086	

	25	0.002 591	0.004 350
Single-phase split concentric PVC insulated. BS 7870-3-20	4	0.016 340	
	16	0.004 093	
	25	0.002 603	0.004 178

* Not included in BS 7870. Value taken to be the same as that of the XLPE split-concentric equivalent cable.

** Not included in BS 7870. Value extrapolated from those of similar cables (PVC/CNE and XLPE).

C4 Historic Overhead Conductor Types

C4.1 Historic LV Overhead Conductors

CONDUCTOR TYPE	SIZE	% VOLTAGE DROP PER KVA PER M
	(in^2)	**415V balanced 3 phase load**
4-wire bare solid Copper ENA TS 43-30 open wire construction	0.025	0.000 669
	0.050	0.000 368
	(in^2)	
4-wire bare stranded Copper ENA TS 43-30 open wire construction	0.025	0.000 659
	0.040	0.000 449
	0.050	0.000 362
	0.060	0.000 323
	0.075	0.000 288
	0.100	0.000 231
	0.150	0.000 192
	(mm^2)	
4-core Aerial Bundled Conductor (ABC)	25	0.000 697
	50	0.000 375
	70	0.000 261
	(mm^2)	
	50	0.000 358

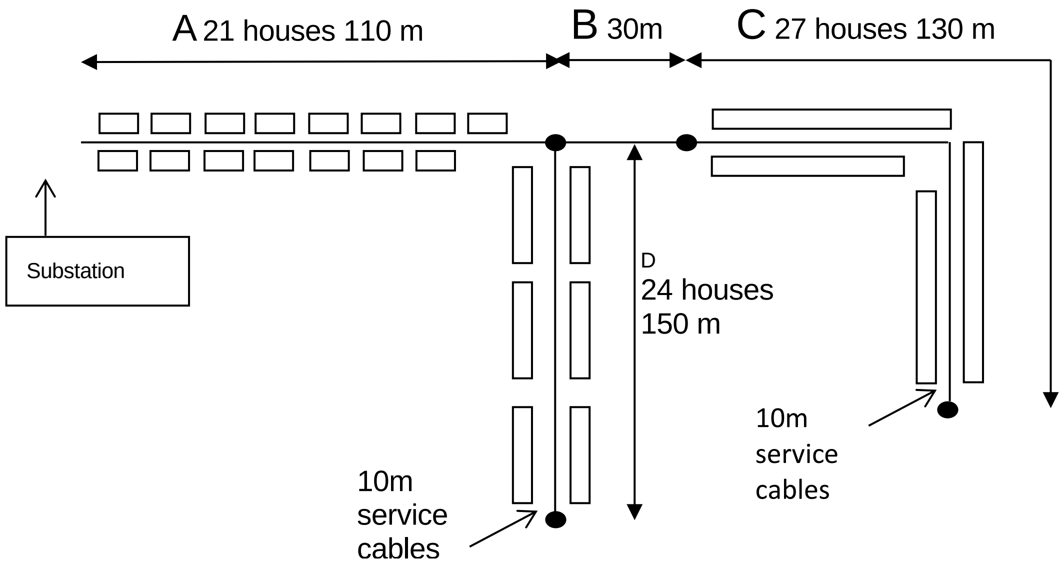
4-wire bare stranded Aluminium - metric - ENA TS 43-30 open wire construction	100	0.000 223
	(in²)	
4-wire bare stranded Aluminium - imperial - (Copper equivalent sizes) ENA TS 43-30 open wire construction	0.025	0.000 656
	0.040	0.000 426
	0.050	0.000 360
	0.060	0.000 312
	0.100	0.000 224
	0.150	0.000 185

C4.2 Historic LV Service Overhead Conductors

CONDUCTOR TYPE	SIZE (MM²)	% VOLTAGE DROP PER KVA PER M 240V SINGLE PHASE LOAD
2-core Aerial Bundled Conductor (ABC)	25	0.004 18
	35	0.003 03
	(mm²)	
2-wire bare stranded Aluminium - metric	22	0.004 39
	50	0.002 12
	(in²)	
2-wire bare stranded Aluminium - copper equivalent imperial	0.025	0.003 92
	0.040	0.002 53
	(in²)	
2-wire bare Copper (solid)	0.025	0.003 99
(stranded)	0.025	0.003 93
(stranded)	0.040	0.002 67

Appendix D – Manual Calculation of Voltage Drop

D1 Sample Network 1 – All Customers Same Type



All 72 houses have electric heating on an unrestricted tariff and so the ADMD is 3.4kW for each property. Distributed loads are considered as concentrated at the mid-point of the section to which they are attached.

The normal maximum load on the distributor is (72×3.4) + 8 = 253kW. Using the (continuous) cable ratings data in CP203 the minimum cable size for section A is 185mm^2 aluminium while 95mm^2 would carry the load on sections B, C and D.

The % voltage drop in the distributors is separated into sections and each section dealt with in turn. For the network above, 4 sections have been identified. The % voltage drop on the distributor and service cables is calculated using the expressions below, which assume balanced loads on the three-phase distributor:

(a) % Voltage Drop on the distributor for 415/240V busbar voltage is given by:

% Distributor Voltage Drop = $((D/2 + M) \times a + P) \times \Delta V \times L$
Where D = number of distributed customers on distributor M = number of through customers fed by distributor a = average ADMD (kW) per customer (3.4kW in this example) P = load allowance (kW) for loss of diversity (8kW in this example) ΔV = % voltage drop per kVA per metre from Appendix C for the selected distributor cable for a balanced 3 phase load L = Length of distributor (m)

(b) % Voltage Drop on the service cable for 415/240V busbar voltage is given by:

% Service Voltage Drop = (Service load) $\times$ ΔV $\times$ L
where ΔV = % voltage drop per kVA per metre from Appendix C for the CNE cable for a single phase load L = Length of service (m) For Economy 7 customers with space heating load: Service load = (X + 4) kW Where X is the installed space and water heating load For all other customers: Service load = (2aN + 8) kW where a is the ADMD (kW) for the customer (3.4kW in this example)

Calculating the % Voltage Drop for each distributor section in this example, using the Electricity North West standard cable sizes in Appendix D gives:

% VOLTAGE DROP FOR CABLE SIZE					
Section	D	M	L	185mm^2	95mm^2
Distributor ABC					
A	21	51	110m	**2.51%**	-
B	0	27	30m	0.31%	**0.57%**
C	27	0	130m	0.74%	**1.34%**
Distributor AD					
A	21	51	110m	**2.51%**	-
D	24	0	150m	0.77%	**1.40%**

Calculating the % Voltage Drop for a 10m service cable assumed for services at the ends of the distributor sections gives 0.46% for 35mm^2 SAC CNE cables, based on a service load of 14.8kW.

Taking account of the service cable % voltage drop, the economical design, within the constraints of the standard cable sizes, including fusing constraints, would be with the values indicated in **bold** in the above table giving an overall voltage drop at the ends of sections:

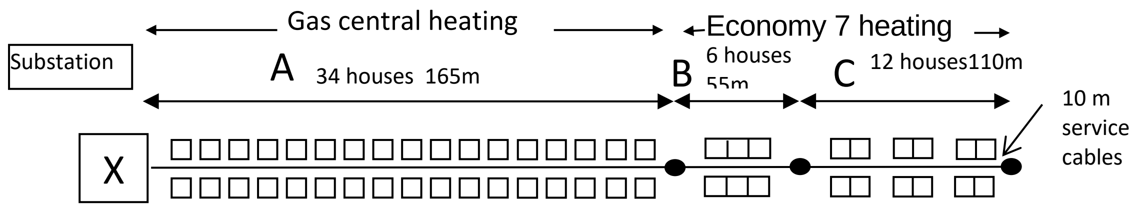
(a) C = (2.51% + 0.57% + 1.34% + 0.46%) = 4.88%
using 185mm^2 cable for section A, and 95mm^2 for sections B and C;

(b) D = (2.51% + 1.40% + 0.46%) = 4.37%
using 185mm^2 cable for section A and 95mm^2 for section D.

NOTE: The calculated voltage drops are valid only for balanced loads on three-phase distributors.

Figure D1 shows the Inputs and Results Sheet of LV AFFIRM for this Sample Network 1.

D2 Sample Network 2 – Mixed Customers, Off-Peak and Non-Electric



For the 34 detached houses having gas central heating the day time ADMD is 1.4kW with a night time ADMD of 0.6kW

The 18 Economy 7 houses have 12kW Electricaire units and 3kW restricted hour water heating and so the night time ADMD is 0.8 $\times$ 15 + 0.5 = 12.5kW with a day time ADMD of 1.5kW.

The maximum load will either be a day time or night time peak.

Night-time = (22 $\times$ 12.5) + (34 $\times$ 0.6) + 4 = 299kW

Day-time = (22 $\times$ 1.5) + (34 $\times$ 1.4) + 8 = 89kW

The design is thus based on the night time loading. Using the (continuous) cable ratings data in CP203 the minimum cable size for section A is 300mm^2 aluminium. The sections B and C can be considered for tapering with load on B being low enough for section B to be sized at 185mm^2 and for section C at 95mm^2.

Calculating the % Voltage Drop for each distributor section, again using the standard cables in Appendix D and the equations in example 1 above, gives:

				VOLTAGE DROP FOR ALUMINIUM PVC CABLE SIZE		
Section	D	M	L	300mm^2	185mm^2	95mm^2
A[1]	34	18	165m	**2.86%**	**-**	-
B	12	6	55m	0.76%	**1.11%**	-
C	8	0	110m	0.63%	0.91%	**1.66%**

[1] The load on section A is made up of 2 components: distributed load of 34 non-electric heated houses with an ADMD of 0.6kW plus through load of 18 Economy 7 houses with an ADMD of 12.5kW

Calculating the % Voltage Drop for a 10m service cable assumed for services at the end of the distributor section gives 0.59% for 35mm^2 SAC CNE cables, based on an Economy 7 service load of 19kW.D2.4

Taking account of the service cable voltage drop, the economical design would be with the cable sizes indicated in **bold** in the above table giving an overall voltage drop at the end of the distributor:

(2.86% + 1.11% + 1.66% + 0.59%) = 6.22%

using 300mm^2 cable for section A, 185mm^2 cable for section B and 95mm^2 cable for section C.

NOTE: the calculated voltage drops are valid only for balanced loads on three-phase distributors.

Figure D2 shows the Inputs and Results Sheet of LV AFFIRM for this Sample Network 2.

Figure D1 – LV AFFIRM, Inputs and Results Sheet for Sample Network 1

LV AFFIRM - Network Design Calculator - For detailed instructions, see CP226. Version 6.4

Project Name/Number Sample Network 1 - all customers of the same type | Designer | Date 10 August 2018

Substation Details - Name X | HV 3-φ Fault Level 200 MVA | Transformer Description **3φ 800kVA**

Loss of Diversity 8 kW | **House ADMD** - TypeA 3.4 kW | Type B kW | Type C kW

Line Sect'n	Up-stream Section	Length (m)	Description	Sect φs	No of φs	Dist'd Houses Type A	End Houses Type A	Dist'd Houses Type B	End Houses Type B	Dist'd Houses Type C	End Houses Type C	Polyφ End Load (kVA)	1φ End Load (kVA)	Cumulative Results: Volt Drop at End Node (%)	Mains only Impedance (Ω)	S/S + Mains Impedance (Ω)
A	X	110	3c 185 Waveform		3	21								2.51	0.040	0.0460
B	a	30	3c 95 Waveform		3									3.08	0.060	0.0659
C	b	130	3c 95 Waveform		3	27								4.42	0.150	0.1546
D	a	150	3c 95 Waveform		3	24								3.91	0.143	0.1477
E																0.0108
F																0.0108
U																0.0108
V																0.0108

Total Distributor Load (A) 351

Services	Section	(m)	Description	Total Volt Drop (%)	Total Loop Impedance (incl S/S) (Ω)
Type A	c	10	35 SAC XC	4.88	0.173
Type B					
Type C					

Substation Fuses	(A)
Max Fuse for Transformer	630
Fuse for Section A Rating	500
Max Fuse for Mains Protection	355
Min Fuse for Load	355

Figure D2 – LV AFFIRM, Inputs and Results Sheet for Sample Network 2

LV AFFIRM - Network Design Calculator - For detailed instructions, see CP226. Version 6.4

Project Name/Number Sample Network 2 - mixed customers - off-peak and non-electric | Designer | Date 10 August 2018

Substation Details - Name X | HV 3-φ Fault Level 200 MVA | Transformer Description **3φ 1000kVA**

Loss of Diversity 4 kW | **House ADMD** - TypeA 0.6 kW | Type B 12.5 kW | Type C kW

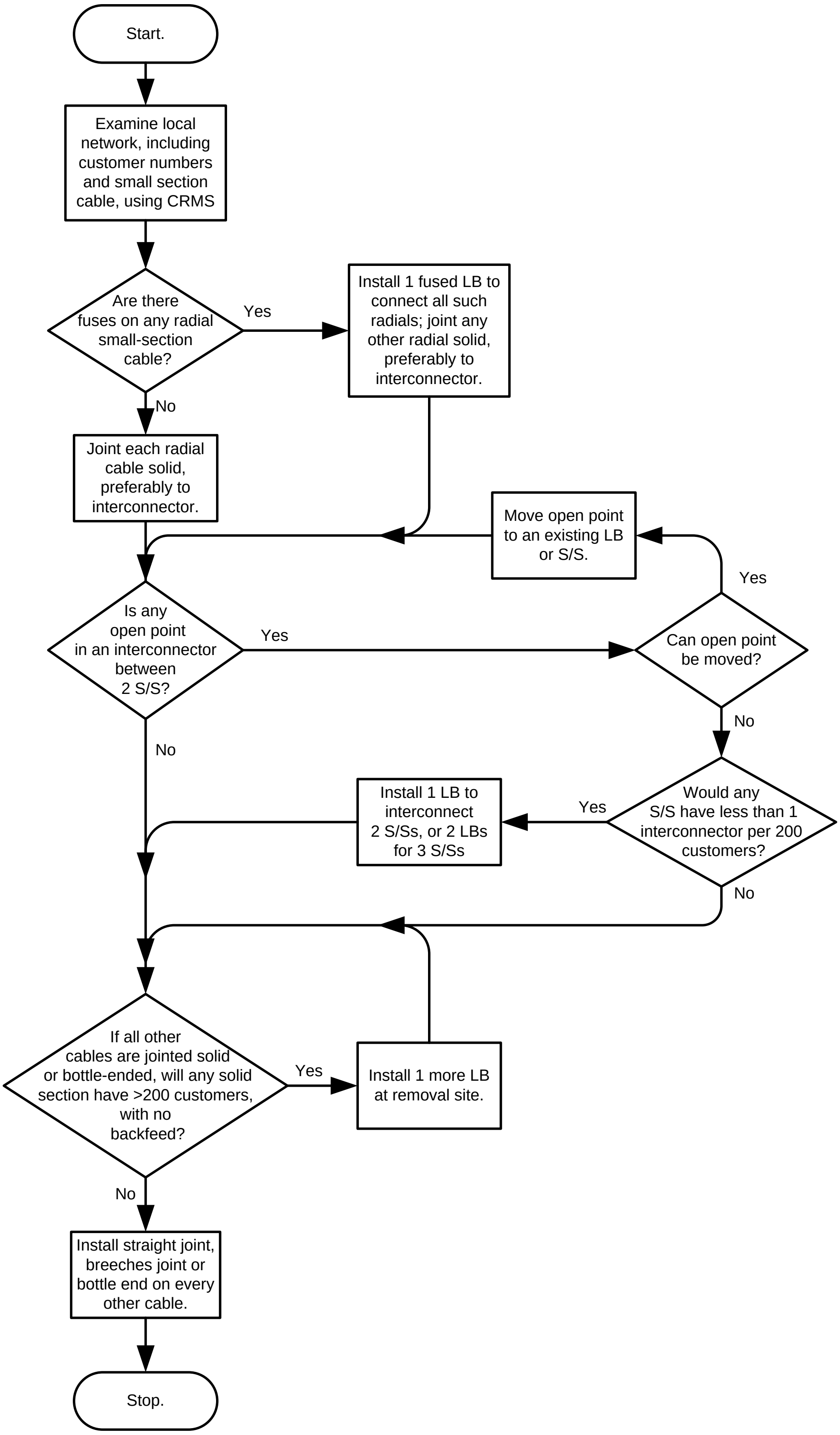
Line Sect'n	Up-stream Section	Length (m)	Description	Sect φs	No of φs	Dist'd Houses Type A	End Houses Type A	Dist'd Houses Type B	End Houses Type B	Dist'd Houses Type C	End Houses Type C	Polyφ End Load (kVA)	1φ End Load (kVA)	Cumulative Results: Volt Drop at End Node (%)	Mains only Impedance (Ω)	S/S + Mains Impedance (Ω)
A	X	165	3c 300 Waveform		3	34								2.86	0.048	0.0532
B	a	55	3c 185 Waveform		3			6						3.97	0.068	0.0728
C	b	110	3c 95 Waveform		3			12						5.63	0.144	0.1475
D																0.0088
E																0.0088
V																0.0088

Total Distributor Load (A) 346

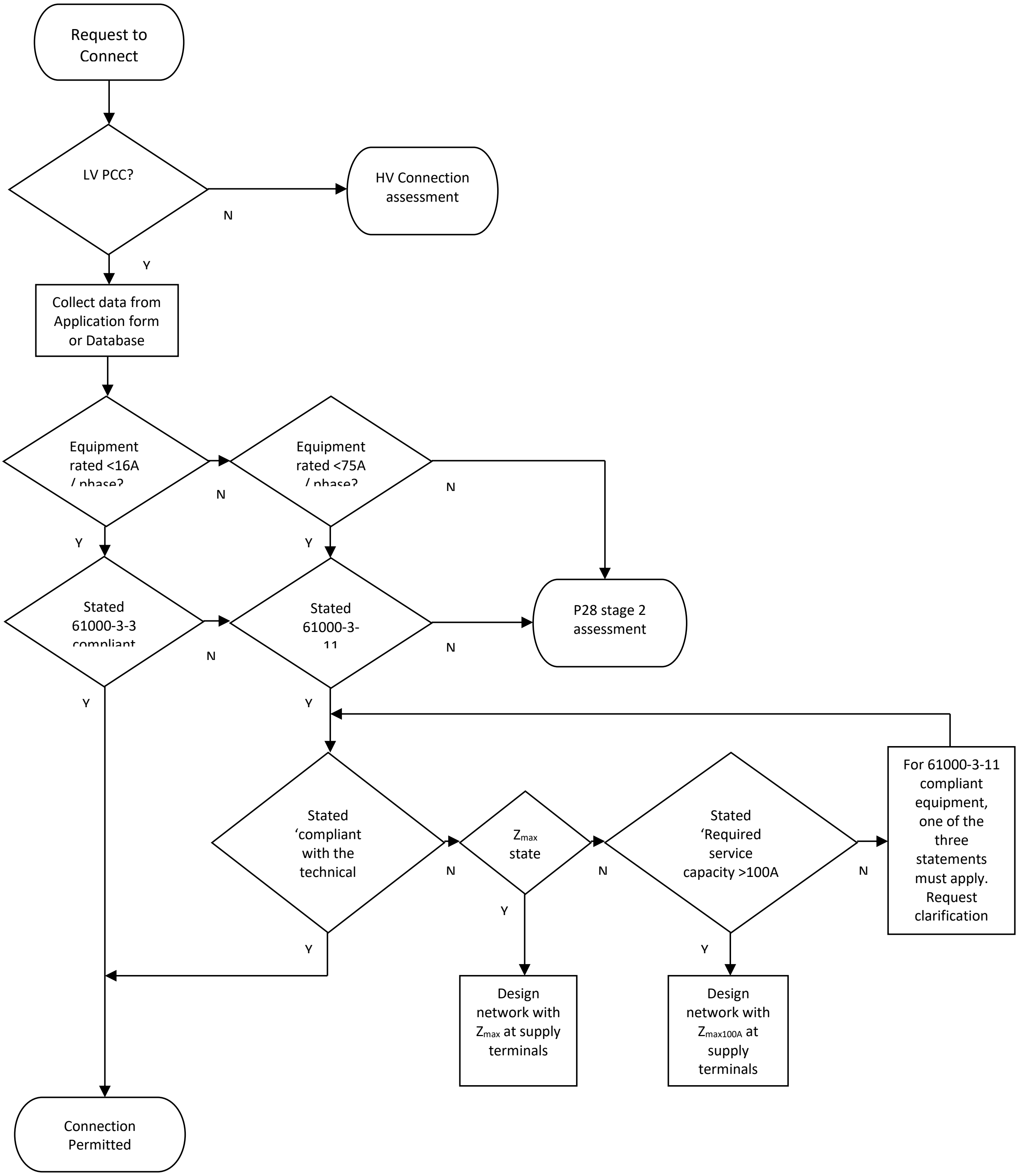
Services	Section	(m)	Description	Total Volt Drop (%)	Total Loop Impedance (incl S/S) (Ω)
Type A	a	10	35 SAC XC	2.99	0.071
Type B	c	10	35 SAC XC	6.22	0.166
Type C					

Substation Fuses	(A)
Max Fuse for Transformer	630
Fuse for Section A Rating	630
Max Fuse for Mains Protection	355
Min Fuse for Load	355

Appendix E - Decision Chart - Decommissioning of Street Pillars and Link-Boxes



Appendix F - Heat Pump Connection Process – Voltage Fluctuation and Flicker



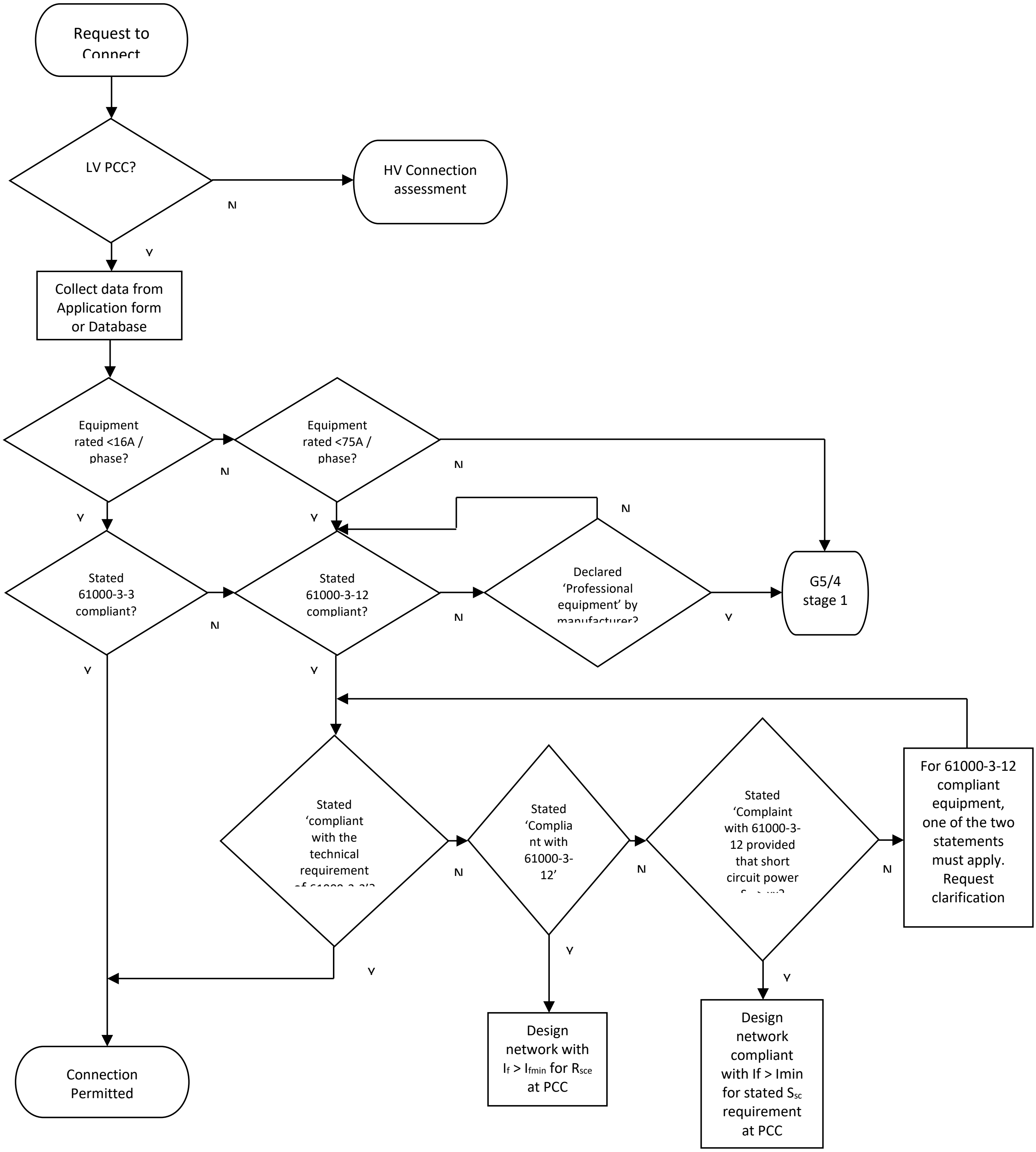
F1 Abbreviations

Z_{max} Maximum permissible source impedance declared by the manufacturer in accordance with BS EN 61000-3-11 clause 4(a).

$Z_{max\ 100A}$ Source impedance defined in BS EN 61000-3-11 associated with the statement that the equipment is intended for use only in premises having a service current capacity >100 A per phase as per BS EN 61000-3-11 clause 4(a).

Appendix G

G1 Harmonic Control Procedure



G2 Procedure to Determine I_{fmin} from I_{equ}

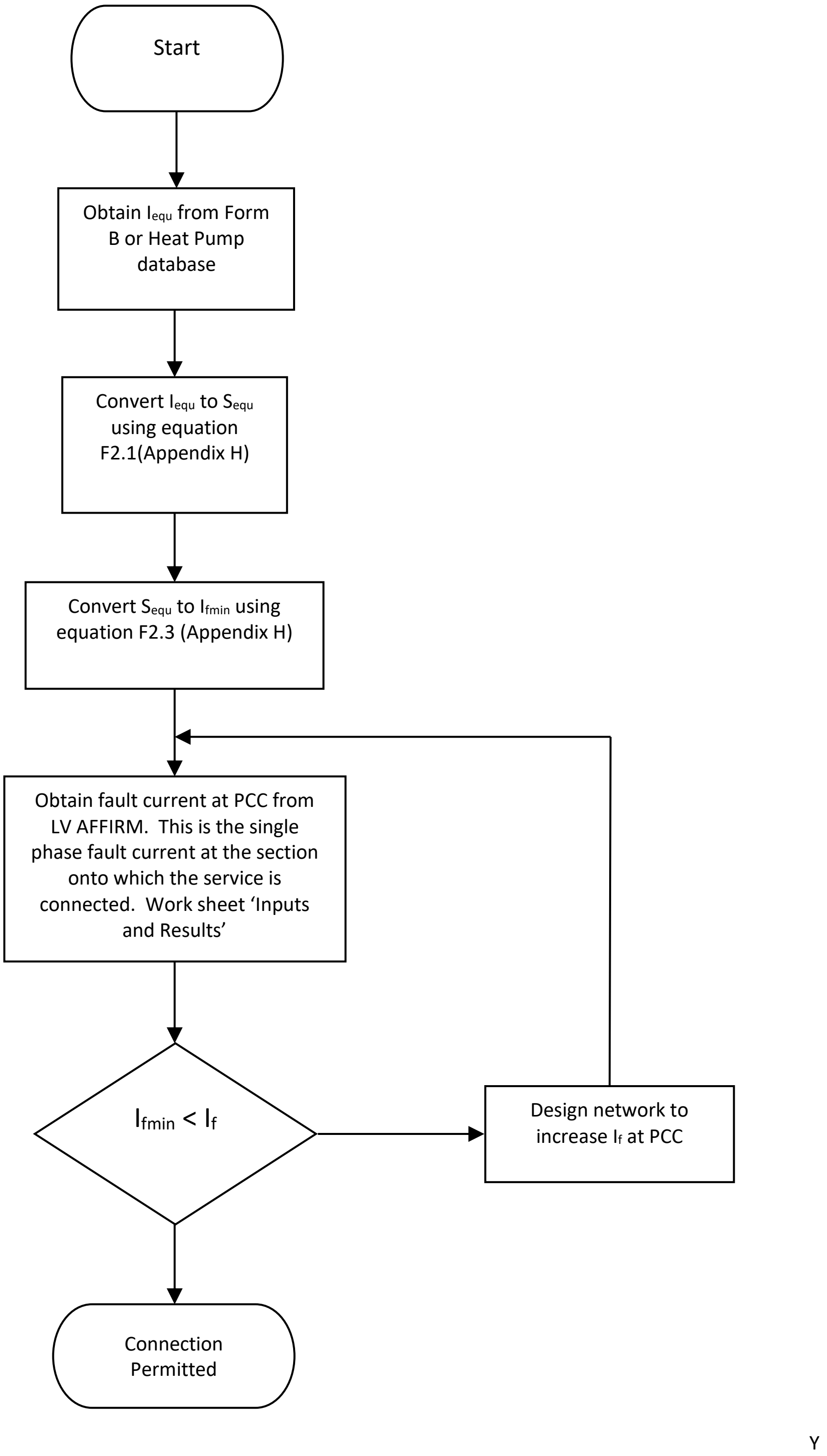


Table G1 Minimum Fault Current by Heat Pump Size

Heat Pump Input current Iequ (A)	Equipment rated apparaent power Sequ (kVA)			Minimum 3 Ph short circuit power (kVA)			Minimum fault current (kA)			Maximum permitted source impedance (?)		
	230V 1ph Sequ	400V Ph-Ph Sequ	400V 3-Ph Sequ	230V 1ph Sequ	400V Ph-Ph Sequ	400V 3-Ph Sequ	230V 1ph Sequ	400V Ph-Ph Sequ	400V 3-Ph Sequ	Zph - n	Zp - p	Z Line
16	3.68	6.40	11.09	364.32	422.40	365.81	0.5259	0.6097	0.5280	0.4374	0.7576	0.4374
17	3.91	6.80	11.78	387.09	448.80	388.67	0.5587	0.6478	0.5610	0.4117	0.7130	0.4117
18	4.14	7.20	12.47	409.86	475.20	411.54	0.5916	0.6859	0.5940	0.3888	0.6734	0.3888
19	4.37	7.60	13.16	432.63	501.60	434.40	0.6244	0.7240	0.6270	0.3683	0.6380	0.3683
20	4.60	8.00	13.86	455.40	528.00	457.26	0.6573	0.7621	0.6600	0.3499	0.6061	0.3499
21	4.83	8.40	14.55	478.17	554.40	480.12	0.6902	0.8002	0.6930	0.3332	0.5772	0.3332
22	5.06	8.80	15.24	500.94	580.80	502.99	0.7230	0.8383	0.7260	0.3181	0.5510	0.3181
23	5.29	9.20	15.93	523.71	607.20	525.85	0.7559	0.8764	0.7590	0.3043	0.5270	0.3043
24	5.52	9.60	16.63	546.48	633.60	548.71	0.7888	0.9145	0.7920	0.2916	0.5051	0.2916
25	5.75	10.00	17.32	569.25	660.00	571.58	0.8216	0.9526	0.8250	0.2799	0.4848	0.2799
26	5.98	10.40	18.01	592.02	686.40	594.44	0.8545	0.9907	0.8580	0.2692	0.4662	0.2692
27	6.21	10.80	18.71	614.79	712.80	617.30	0.8874	1.0288	0.8910	0.2592	0.4489	0.2592
28	6.44	11.20	19.40	637.56	739.20	640.17	0.9202	1.0669	0.9240	0.2499	0.4329	0.2499
29	6.67	11.60	20.09	660.33	765.60	663.03	0.9531	1.1050	0.9570	0.2413	0.4180	0.2413
30	6.90	12.00	20.78	683.10	792.00	685.89	0.9860	1.1432	0.9900	0.2333	0.4040	0.2333
31	7.13	12.40	21.48	705.87	818.40	708.76	1.0188	1.1813	1.0230	0.2257	0.3910	0.2257
32	7.36	12.80	22.17	728.64	844.80	731.62	1.0517	1.2194	1.0560	0.2187	0.3788	0.2187
33	7.59	13.20	22.86	751.41	871.20	754.48	1.0846	1.2575	1.0890	0.2121	0.3673	0.2121
34	7.82	13.60	23.56	774.18	897.60	777.34	1.1174	1.2956	1.1220	0.2058	0.3565	0.2058
35	8.05	14.00	24.25	796.95	924.00	800.21	1.1503	1.3337	1.1550	0.1999	0.3463	0.1999
36	8.28	14.40	24.94	819.72	950.40	823.07	1.1832	1.3718	1.1880	0.1944	0.3367	0.1944
37	8.51	14.80	25.63	842.49	976.80	845.93	1.2160	1.4099	1.2210	0.1891	0.3276	0.1891
38	8.74	15.20	26.33	865.26	1003.20	868.80	1.2489	1.4480	1.2540	0.1842	0.3190	0.1842
39	8.97	15.60	27.02	888.03	1029.60	891.66	1.2818	1.4861	1.2870	0.1794	0.3108	0.1794
40	9.20	16.00	27.71	910.80	1056.00	914.52	1.3146	1.5242	1.3200	0.1750	0.3030	0.1750
41	9.43	16.40	28.41	933.57	1082.40	937.39	1.3475	1.5623	1.3530	0.1707	0.2956	0.1707
42	9.66	16.80	29.10	956.34	1108.80	960.25	1.3804	1.6004	1.3860	0.1666	0.2886	0.1666
43	9.89	17.20	29.79	979.11	1135.20	983.11	1.4132	1.6385	1.4190	0.1627	0.2819	0.1627
44	10.12	17.60	30.48	1001.88	1161.60	1005.98	1.4461	1.6766	1.4520	0.1590	0.2755	0.1590
45	10.35	18.00	31.18	1024.65	1188.00	1028.84	1.4790	1.7147	1.4850	0.1555	0.2694	0.1555
46	10.58	18.40	31.87	1047.42	1214.40	1051.70	1.5118	1.7528	1.5180	0.1521	0.2635	0.1521
47	10.81	18.80	32.56	1070.19	1240.80	1074.56	1.5447	1.7909	1.5510	0.1489	0.2579	0.1489
48	11.04	19.20	33.26	1092.96	1267.20	1097.43	1.5776	1.8290	1.5840	0.1458	0.2525	0.1458
49	11.27	19.60	33.95	1115.73	1293.60	1120.29	1.6104	1.8672	1.6170	0.1428	0.2474	0.1428
50	11.50	20.00	34.64	1138.50	1320.00	1143.15	1.6433	1.9053	1.6500	0.1400	0.2424	0.1400
51	11.73	20.40	35.33	1161.27	1346.40	1166.02	1.6761	1.9434	1.6830	0.1372	0.2377	0.1372
52	11.96	20.80	36.03	1184.04	1372.80	1188.88	1.7090	1.9815	1.7160	0.1346	0.2331	0.1346
53	12.19	21.20	36.72	1206.81	1399.20	1211.74	1.7419	2.0196	1.7490	0.1320	0.2287	0.1320
54	12.42	21.60	37.41	1229.58	1425.60	1234.61	1.7747	2.0577	1.7820	0.1296	0.2245	0.1296
55	12.65	22.00	38.11	1252.35	1452.00	1257.47	1.8076	2.0958	1.8150	0.1272	0.2204	0.1272
56	12.88	22.40	38.80	1275.12	1478.40	1280.33	1.8405	2.1339	1.8480	0.1250	0.2165	0.1250
57	13.11	22.80	39.49	1297.89	1504.80	1303.20	1.8733	2.1720	1.8810	0.1228	0.2127	0.1228
58	13.34	23.20	40.18	1320.66	1531.20	1326.06	1.9062	2.2101	1.9140	0.1207	0.2090	0.1207
59	13.57	23.60	40.88	1343.43	1557.60	1348.92	1.9391	2.2482	1.9470	0.1186	0.2054	0.1186
60	13.80	24.00	41.57	1366.20	1584.00	1371.78	1.9719	2.2863	1.9800	0.1166	0.2020	0.1166
61	14.03	24.40	42.26	1388.97	1610.40	1394.65	2.0048	2.3244	2.0130	0.1147	0.1987	0.1147
62	14.26	24.80	42.95	1411.74	1636.80	1417.51	2.0377	2.3625	2.0460	0.1129	0.1955	0.1129
63	14.49	25.20	43.65	1434.51	1663.20	1440.37	2.0705	2.4006	2.0790	0.1111	0.1924	0.1111
64	14.72	25.60	44.34	1457.28	1689.60	1463.24	2.1034	2.4387	2.1120	0.1093	0.1894	0.1093
65	14.95	26.00	45.03	1480.05	1716.00	1486.10	2.1363	2.4768	2.1450	0.1077	0.1865	0.1077
66	15.18	26.40	45.73	1502.82	1742.40	1508.96	2.1691	2.5149	2.1780	0.1060	0.1837	0.1060
67	15.41	26.80	46.42	1525.59	1768.80	1531.83	2.2020	2.5530	2.2110	0.1045	0.1809	0.1045
68	15.64	27.20	47.11	1548.36	1795.20	1554.69	2.2349	2.5911	2.2440	0.1029	0.1783	0.1029
69	15.87	27.60	47.80	1571.13	1821.60	1577.55	2.2677	2.6293	2.2770	0.1014	0.1757	0.1014
70	16.10	28.00	48.50	1593.90	1848.00	1600.41	2.3006	2.6674	2.3100	0.1000	0.1732	0.1000
71	16.33	28.40	49.19	1616.67	1874.40	1623.28	2.3335	2.7055	2.3430	0.0986	0.1707	0.0986
72	16.56	28.80	49.88	1639.44	1900.80	1646.14	2.3663	2.7436	2.3760	0.0972	0.1684	0.0972
73	16.79	29.20	50.58	1662.21	1927.20	1669.00	2.3992	2.7817	2.4090	0.0959	0.1660	0.0959
74	17.02	29.60	51.27	1684.98	1953.60	1691.87	2.4321	2.8198	2.4420	0.0946	0.1638	0.0946
75	17.25	30.00	51.96	1707.75	1980.00	1714.73	2.4649	2.8579	2.4750	0.0933	0.1616	0.0933

Appendix H – Detailed Calculations

H1 Abbreviations

I_f	Actual fault current at point of connection. Calculated from LV Affirm
I_{fmin}	Minimum fault current value. Determined from S_{sc} using equation
I_{equ}	Current rating of heat pump. Obtained from application form or database.
S_{equ}	Apparent power rating of heat pump. Obtained from Iequ using equation
S_{sc}	Three phase short circuit power. Determined from S_{equ} using R_{sce} which is assumed to be 33.
R_{sce}	Short circuit ratio

H2 Calculations, Derivations and Formulae

H2.1 Rated Apparent Power S_{equ}

EQUIPMENT	S_{EQU}
Single phase 230V	230V x I_{equ}
Phase – Phase 400V	400V x I_{equ}
Three Phase 400V	√3 x 400V x I_{equ}

H2.2 Short Circuit Ratio R_{sce}

EQUIPMENT	R_{SCE}
Single phase 230V	$S_{sc}/3S_{equ}$
Phase – Phase 400V	$S_{sc}/2S_{equ}$
Three Phase 400V	S_{sc}/S_{equ}

NOTE: minimum value of R_{sce} = 33

H2.3 Minimum Short Circuit Current

Ifmin = $S_{sc}/(\sqrt{3} \times 400V)$

H2.4 Process to Derive I_{fmin} from I_{equ}

Appendix I – Standard Technical Information Forms

NOTE: The manufacturer may need to be consulted to complete this technical data.

Device details	**Manufacturer**	
	Type reference	

EC Declaration of Conformity	Attach the manufacturer's EC Declaration of Conformity as produced in association with the EMC Directive	Attached?
		Yes/No?

Part 1 - Harmonic compliance against BS EN 61000-3-3 / 61000-3-12

Power Quality. Harmonics. This information should be provided by the manufacturer of a Device whose tests should be carried out as specified in BS EN 61000-3-12. Note that this is equivalent to IEC 61000-3-12.					
Manufacturer states Device meets technical requirements of EN/IEC 61000-3-2? Note: Where the Device meets the technical requirements of BS EN/IEC 61000-3-2 then there is no need to complete the rest of this table.				Yes/No	
Manufacturer states Device complying with EN/IEC 61000-3-12?				Yes/No	
Manufacturer states Device complies with EN/IEC 61000-3-12 provided that the short-circuit power Ssc is greater than or equal to xx. If yes then complete S_{sc} value below.				Yes/No	
State minimum 3-phase supply short circuit level, S_{sc}, required to allow connection under EN 61000-3-12					kVA
Rated Current, I_{equ}			A	Limit in EN 61000-3-12	
Reference Current, I_{ref}			A		
Operating Voltage (V):			V		
Phases			1 or 3		
Harmonic	Measured current (A)	Current as % of I_{ref}		1 phase (Ih/I_{ref})	3 phase balanced (Ih/I_{ref})
2				8%	8%
3				21.6%	Not stated
4				4%	4%
5				10.7%	10.7%
6				2.67%	2.67%
7				7.2%	7.2%
8				2%	2%
9				3.8%	8%
10				1.6%	1.6%
11				3.1%	3.1%
12				1.33%	1.33%
13				2%	2%
THC				23% of I_{ref}	13% of I_{ref}
PWHC				23% of I_{ref}	22% of I_{ref}

Part 2 – Harmonic Compliance against EREC G5

Harmonic Emissions (Complete When BS EN 61000-3-2 Do Not Apply)					
Rated Current (A)			....		
Operating Voltage[1] (V):			....		
Maximum Value Of Harmonic Currents For Each Harmonic Order					
Harmonic Order 'H'	Emission Current (A)	Harmonic Order 'H'	Emission Current (A)	Harmonic Order 'H'	Emission Current (A)
2	....	20	....	38	....
3	....	21	....	39	....
4	....	22	....	40	....
5	....	23	....	41	....
6	....	24	....	42	....
7	....	25	....	43	....
8	....	26	....	44	....
9	....	27	....	45	....
10	....	28	....	46	....
11	....	29	....	47	....
12	....	30	....	48	....
13	....	31	....	49	....
14	....	32	....	50	....
15	....	33	....		
16	....	34	....		
17	....	35	....		
18	....	36	....		

19	………………..	37	………………..	

[1] Note that where the customer has a Point of Common Coupling (PCC) above LV then the quoted currents should relate to the voltage at the PCC. In such a case, where the equipment is a source of DC injection then it may be necessary to determine the values at a PCC after modelling to allow for effect of transformer saturation with elevated harmonic currents. NB PCC is defined as the point in the public electricity distribution system electrically nearest to the Customer's installation at which other customers are, or may be, connected.

Part 3 – Voltage Flicker against BS EN 61000-3-3 / 61000-3-11

Power Quality. Voltage fluctuations and Flicker. The tests/calculations should be carried out by the heat pump manufacturer or their designate, with typical worst case cycling on and off. The results should be normalised to the standard source impedance Zref, if this results in figures above the limits set in EN 61000-3-3 then a suitable Maximum source Impedance Zmax should be identified as required by EN 61000-3-11.	
Manufacturer states Device meets technical requirements of EN/IEC 61000-3-3? Note: Where the Device meets the technical requirements of BS EN/IEC 61000-3-3 then there is no need to complete the rest of this table.	Yes/No
Manufacturer states Device complying with EN/IEC 61000-3-11 provided that the source impedance is no more than Z_{max}?	Yes/No
Manufacturer states Device complying with BS EN/IEC 61000-3-11 provided that service current capacity ≥100A per phase?	Yes/No

	d_{max}	d_c	d(t)	T_{max} (8 new)	P_{st}	P_{lt} 2 hours
Measured Values at test impedance						
Normalised to standard impedance						
Normalised to required maximum impedance						
Limits set under BS EN 61000-3-11 & 61000-3-3	4%	3.3%	3.3%	500ms	1.0	0.65
Z test	R		ohms	X		ohms
Z ref	R	0.24 * 0.4 ^ 0.48 #	ohms	X	0.15 * 0.25 ^ 0.3 #	ohms
Z max	R		ohms	X		ohms

8 T max applied to comply with new revision

* Applies to three phase Devices

^ Applies to single phase Devices

Applies to interphase connected Devices using two phases on a three phase system

NOTE: Z_{max} must take account of multiple devices using the scaling down detailed in EN 61000-3-11 Section 6.2.2.

Appendix J – Not used

Appendix K – Heat Pump and Electric Vehicle Connection Process

Nov 22

K1 Device Power Quality Data (when required by connect & manage policy)

Note: The manufacturer may need to be consulted to complete this technical data.

Device details	Manufacturer	
	Type reference	

EC Declaration of Conformity	Attach the manufacturer's EC Declaration of Conformity as produced in association with the EMC Directive	Attached?
		Yes/No?

Power Quality. Harmonics. This information should be provided by the manufacturer of a Device whose tests should be carried out as specified in BS EN 61000-3-12. Note that this is equivalent to IEC 61000-3-12.					
Manufacturer states Device meets technical requirements of EN/IEC 61000-3-2? Note: Where the Device meets the technical requirements of BS EN/IEC 61000-3-2 then there is no need to complete the rest of this table.					Yes/No
Manufacturer states Device complying with EN/IEC 61000-3-12?					Yes/No
Manufacturer states Device complies with EN/IEC 61000-3-12 provided that the short-circuit power Ssc is greater than or equal to xx. If yes then complete S_{sc} value below.					Yes/No
State minimum 3-phase supply short circuit level, S_{sc}, required to allow connection under EN 61000-3-12					kVA
Rated Current, I_{equ}			A	Limit in EN 61000-3-12	
Reference Current, I_{ref}			A		
Operating Voltage (V):			V		
Phases			1 or 3		
Harmonic	Measured current (A)	Current as % of I_{ref}		1 phase (Ih/I_{ref})	3 phase balanced (Ih/I_{ref})
2				8%	8%
3				21.6%	Not stated
4				4%	4%
5				10.7%	10.7%
6				2.67%	2.67%

7				7.2%	7.2%
8				2%	2%
9				3.8%	8%
10				1.6%	1.6%
11				3.1%	3.1%
12				1.33%	1.33%
13				2%	2%
THC				23% of I_{ref}	13% of I_{ref}
				23% of I_{ref}	22% of I_{ref}

Harmonic Emissions (Complete When BS EN 61000-3-12 Or -2 Do Not Apply)					
Rated Current (A)	………………………………………………				
Operating Voltage[2] (V)	………………………………………………				
Maximum Value Of Harmonic Currents For Each Harmonic Order					
Harmonic Order 'H'	Emission Current (A)	Harmonic Order 'H'	Emission Current (A)	Harmonic Order 'H'	Emission Current (A)
2	……………	20	……………	38	……………
3	……………	21	……………	39	……………
4	……………	22	……………	40	……………
5	……………	23	……………	41	……………
6	……………	24	……………	42	……………
7	……………	25	……………	43	……………
8	……………	26	……………	44	……………

[2] Note that where the customer has a Point of Common Coupling (PCC) above LV then the quoted currents should relate to the voltage at the PCC. In such a case, where the equipment is a source of DC injection then it may be necessary to determine the values at a PCC after modelling to allow for effect of transformer saturation with elevated harmonic currents. NB PCC is defined as the point in the public electricity distribution system electrically nearest to the Customer's installation at which other customers are, or may be, connected.

9	....	27	....	45	....
10	....	28	....	46	....
11	....	29	....	47	....
12	....	30	....	48	....
13	....	31	....	49	....
14	....	32	....	50	....
15	....	33	....		
16	....	34	....		
17	....	35	....		
18	....	36	....		
19	....	37	....		

Power Quality. Voltage fluctuations and Flicker. The tests/calculations should be carried out by the heat pump manufacturer or their designate, with typical worst case cycling on and off.

The results should be normalised to the standard source impedance Zref, if this results in figures above the limits set in EN 61000-3-3 then a suitable Maximum source Impedance Zmax should be identified as required by EN 61000-3-11.	
Manufacturer states Device meets technical requirements of EN/IEC 61000-3-3? Note: Where the Device meets the technical requirements of BS EN/IEC 61000-3-3 then there is no need to complete the rest of this table.	Yes/No
Manufacturer states Device complying with EN/IEC 61000-3-11 provided that the source impedance is no more than Z_{max}?	Yes/No
Manufacturer states Device complying with BS EN/IEC 61000-3-11 provided that service current capacity ≥100A per phase?	Yes/No

	d_{max}	d_c	d(t)	T_{max} (8 new)	P_{st}	P_{lt} 2 hours
Measured Values at test impedance						
Normalised to standard impedance						
Normalised to required maximum impedance						
Limits set under BS EN 61000-3-11 & 61000-3-3	4%	3.3%	3.3%	500ms	1.0	0.65
Z test	R		ohms	X		ohms
Z ref	R	0.24 * 0.4 ^ 0.48 #	ohms	X	0.15 * 0.25 ^ 0.3 #	ohms
Z max	R		ohms	X		ohms

8 T max applied to comply with new revision

* Applies to three phase Devices

^ Applies to single phase Devices

Applies to interphase connected Devices using two phases on a three phase system

Note: Z_{max} must take account of multiple devices using the scaling down detailed in EN 61000-3-11 Section 6.2.2.

K2 Combined Generation and Storage Application (Formerly G59 Fast Track)

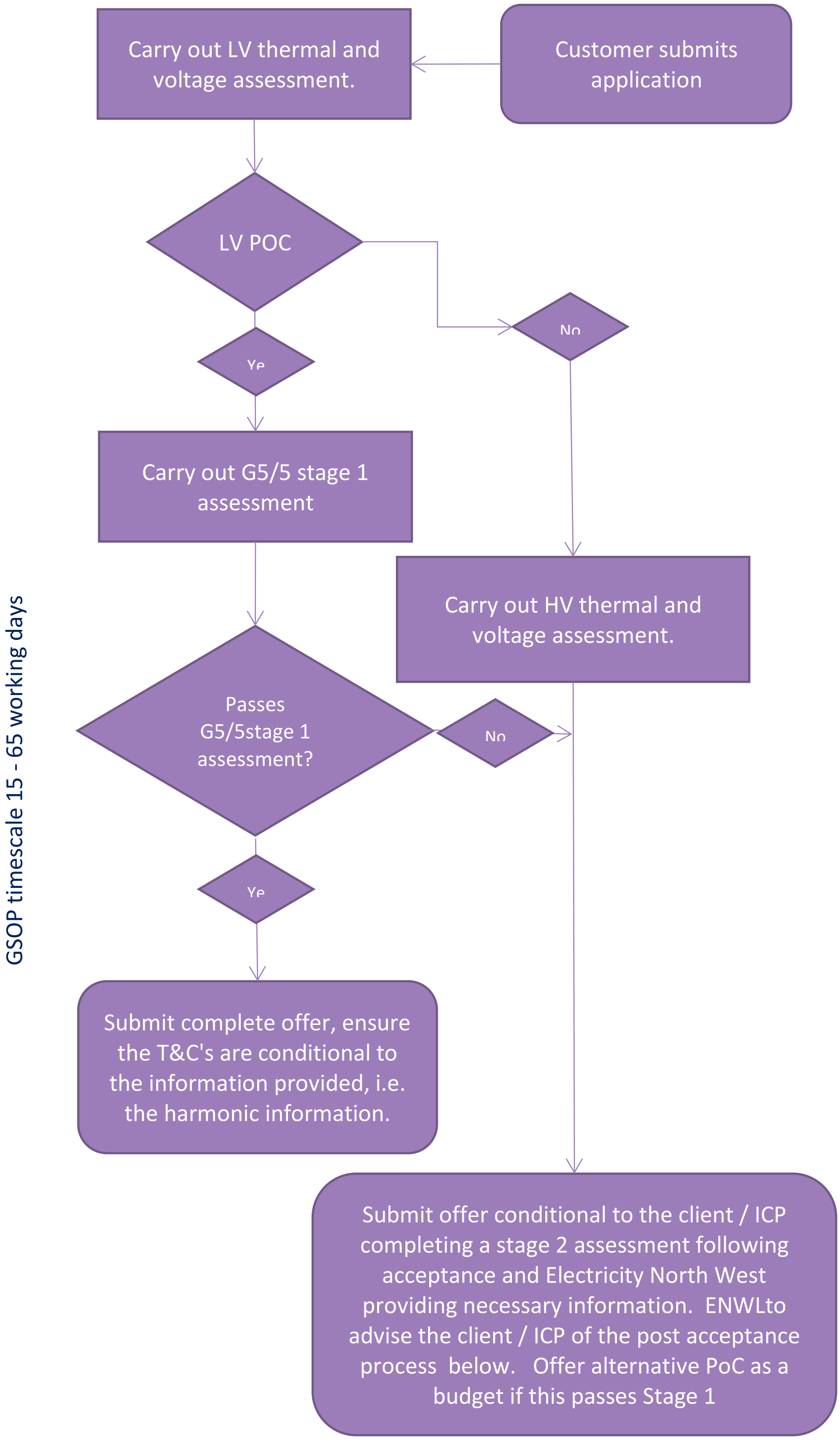
Contact Details		
Site MPAN		
Installer contact and qualification details	Generation unit:-	
	Storage Unit:-	
Generation owner details (if different)		
How many sites are you applying for?	1	More than 1

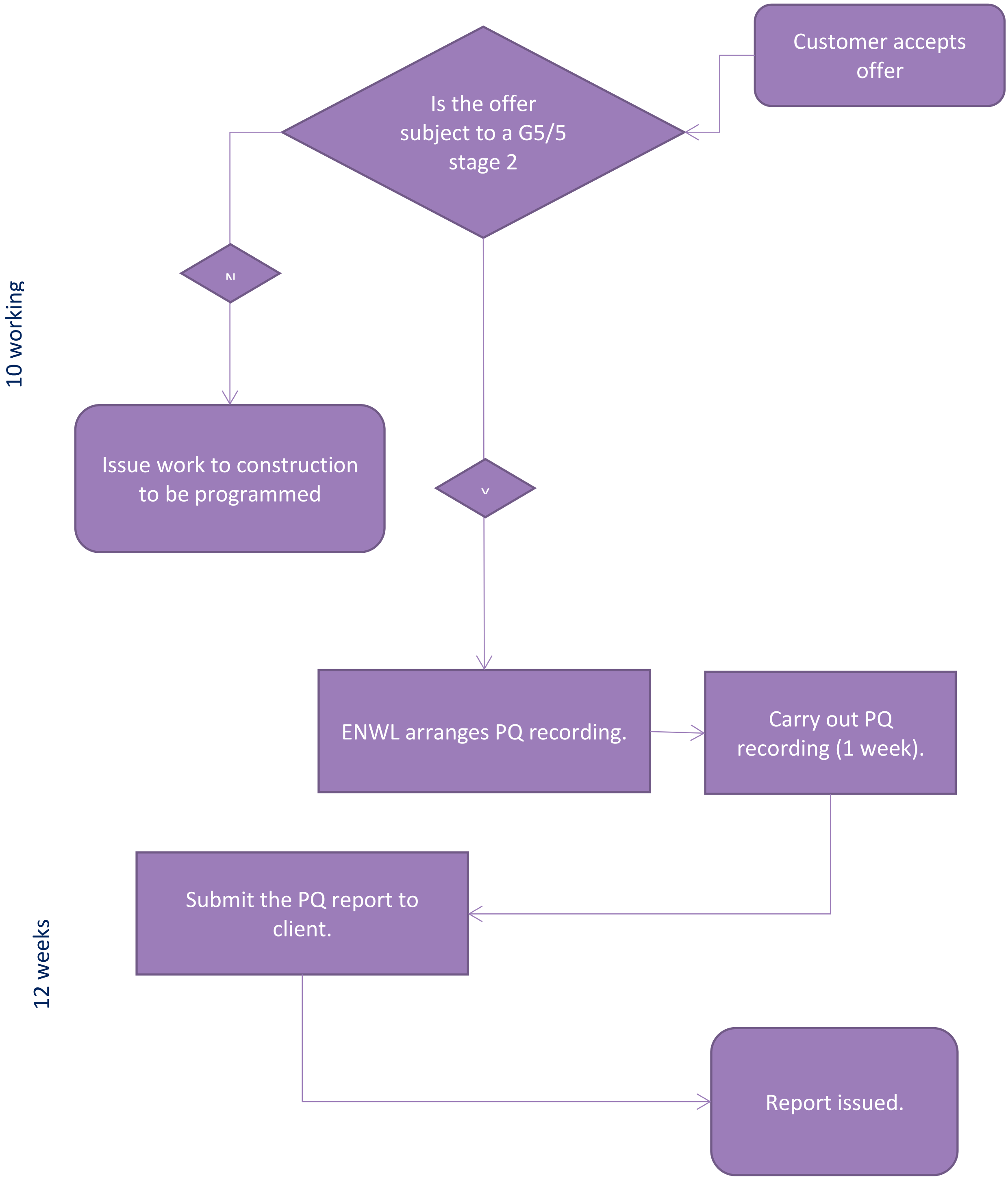
Total aggregated capacity of units including the capacity of the storage unit	Between 16A and 32A	Higher than 32A
Are you installing the equipment to limit your export capacity to 16A / phase (3.66kW)?	Yes	No
Will you be installing a G100 compliant export limiting scheme?	Yes	No
Will all your generating units (including storage units) be connected via G83 type tested inverters?	Yes	No
Will generator operate in island mode	No	Yes
Please provide the following: • Distributed Energy Resources (DER) technology / primary energy source • DER Capacity by technology • Inverter capacity by technology • G83 type test inverter reference number	Total DER capacity (limited by inverter where appropriate) ≤ 32A / phase and all units G83 type tested (upload type test certificates) where this is provided proceed...where not follow G59 route	
Please provide details of your export limiting scheme: • G100 compliance declaration • Maximum export setting	Provided	Not provided
Please provide schematic diagram for the proposed scheme	Provided	Not provided
Connection route	**Use G59 Fast Track**	**Use standard G59**

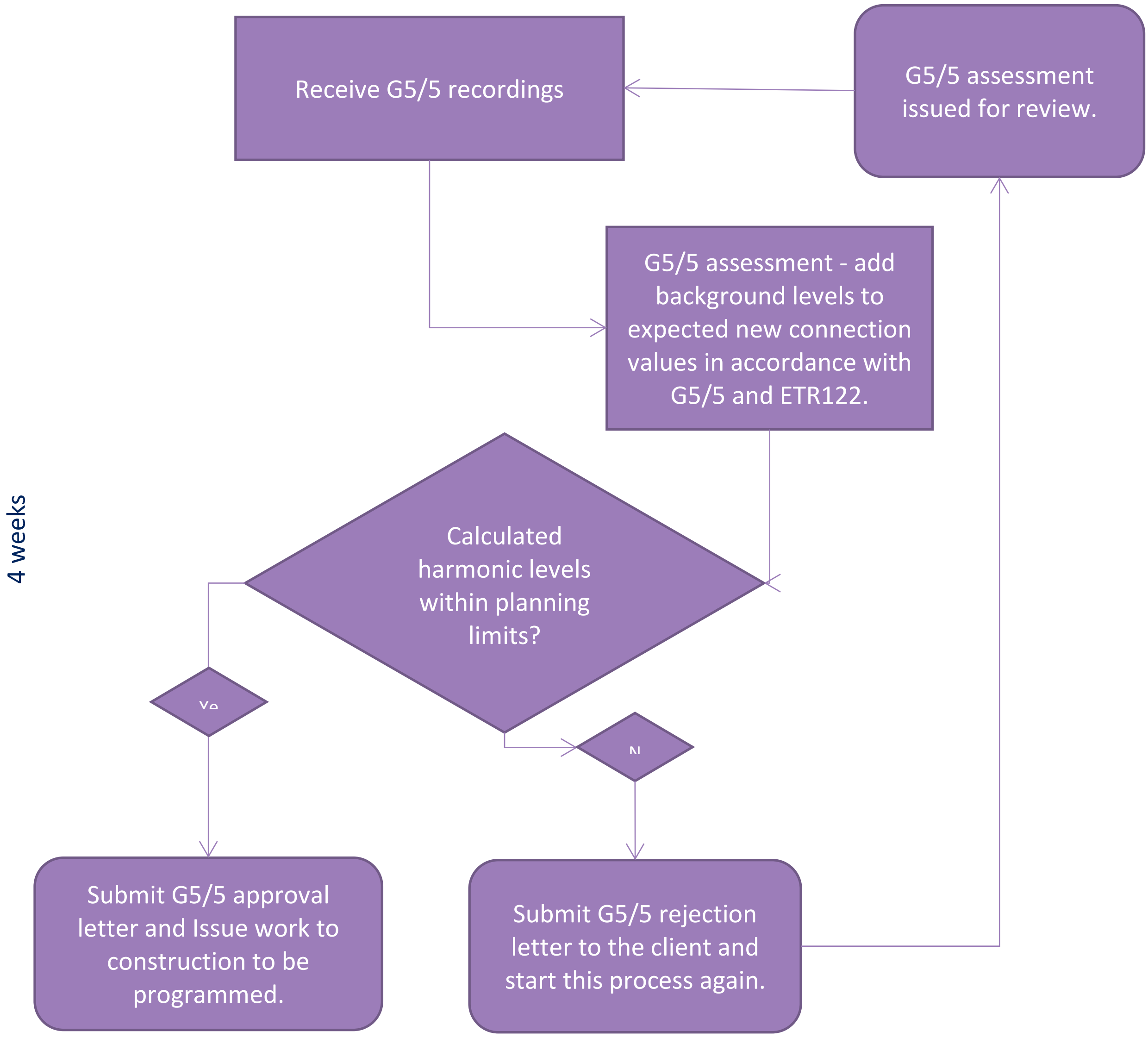
What is your planned commissioning date?	Must be at least 10 working days[1] from date of application but not more than 3 months in advance (our connection offers are only valid for 3 months) Applicants must return commissioning sheets within 28 days of commissioning

K3 Large EVCP Connection Procedure

Nov 22




Customer accepts offer
Is the offer subject to a G5/5 stage 2
10 working
Issue work to construction to be programmed
ENWL arranges PQ recording.
Carry out PQ recording (1 week).
Submit the PQ report to client.
12 weeks
Report issued.


Receive G5/5 recordings
G5/5 assessment issued for review.
G5/5 assessment - add background levels to expected new connection values in accordance with G5/5 and ETR122.
4 weeks
Calculated harmonic levels within planning limits?
Submit G5/5 approval letter and Issue work to construction to be programmed.
Submit G5/5 rejection letter to the client and start this process again.

Appendix L – Form A Outline of Works

FORM A - OUTLINE PLAN OF WORKS (FRONT)

This form is to be completed in accordance with Electricity North West Engineering Specification 210 and forwarded to:

The General Manager, Connections
Electricity North West Limited,
Oakland House,
PO Box 9, Talbot Road,
Old Trafford
Manchester, M16 0QF

The following additional items shall be attached:

- A description of the main features of the proposed works, including construction phases, in order that non-contestable works can be identified accurately for inclusion in the Joint Construction and Adoption Contract.
- A plan of the proposed works based on the most recent edition of the Ordnance Survey map at 1/500 scale with any relevant detail shown on 1/250 enlargements.
- A substation building plan at not less than 1/50 scale (if a substation is included in the proposed works).
- Details of proposed plant
- A Certificate of Registered Design reference number or a Design Proposal.

Scheme Reference Number	
Name of Owner of the proposed works.	
Name of Installer of the proposed Owner's Works and the telephone number for routine and emergency communication.	
* Name(s) of the User(s).	
Location of the proposed Owner's Works.	
* The electrical loading of the individual parts of the Owner's Works.	

*Use additional sheets of paper if required.

FORM A - OUTLINE PLAN OF WORKS (REVERSE)

*Total electrical load (define if connected in stages).	
*Power factor(s) (if appropriate at each stage).	
* Voltage drop(s) at maximum loading to the Exit point(s) to the User(s) calculated to include the voltage drop at the point of connection to Electricity North West' existing system with the new load connected.	
* Details of tests to be performed prior to commissioning of the Owner's Works and the proposed limiting values for the works to be acceptable. Tests are to be specified for insulation resistance, loop impedances or substation neutral earth value demonstrating the correct operation of protective equipment and adequate discrimination.	
Date on which it is proposed that the connection to Electricity North West' system shall be made.	

*Use additional sheets of paper if required.

Appendix M – Notification of Acceptance/Rejection

FORM B - NOTIFICATION OF ACCEPTANCE OR REJECTION OF OUTLINE PLAN OF WORKS

From: **The General Manager, Connections,**
Electricity North West Limited,
Oakland House,
PO Box 9, Talbot Road,
Old Trafford
Manchester, M16 0QF.

Name of Owner of the proposed works.	
Name of Installer of the proposed works.	
Location of the proposed works.	
Electricity North West Reference Number (please use in any future correspondence).	

THE PROPOSED WORKS ARE ACCEPTED.

Signed: Date:

Subject to:

THE PROPOSED WORKS ARE REJECTED FOR THE FOLLOWING REASONS:

Signed: Date:

IF CALLING PLEASE ASK FOR:

DIRECT DIAL NUMBER:

Appendix N – Installation Details Prior to Commissioning

FORM C - INSTALLATION DETAILS PRIOR TO COMMISSIONING OF OWNER'S WORKS

To:- **The General Manager, Connections**
Electricity North West Limited,
Oakland House,
PO Box 9, Talbot Road,
Old Trafford
Manchester, M16 0QF.

Name of Owner of the proposed works.	
Name of Installer of the Owner's Works.	
Location of the Owner's Works.	
Electricity North West Reference Number (please use in any future correspondence).	

*Results of commissioning tests performed.

*Specify here for each cable, joint, termination, overhead line and plant item its location on the Owner's Works and its date of installation. A cross referenced 1/500 scale plan with any relevant detail shown 1/250 enlargements, shall be attached, marked in accordance with **Electricity North West** Code of Practice 012 on the most recent edition Ordnance Survey map for the area.

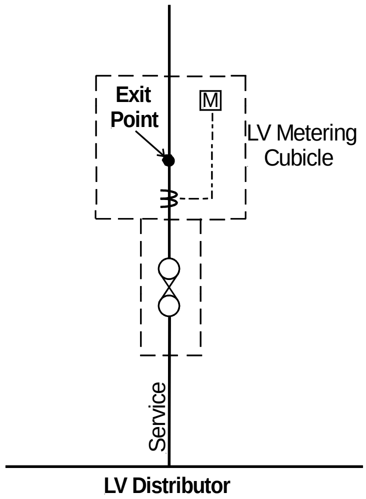
*Use additional sheets of paper if required.

SUBMISSION OF THIS DOCUMENT DOES NOT IMPLY AGREEMENT BY ELECTRICITY NORTH WEST LIMITED TO COMMISSION THE WORKS.

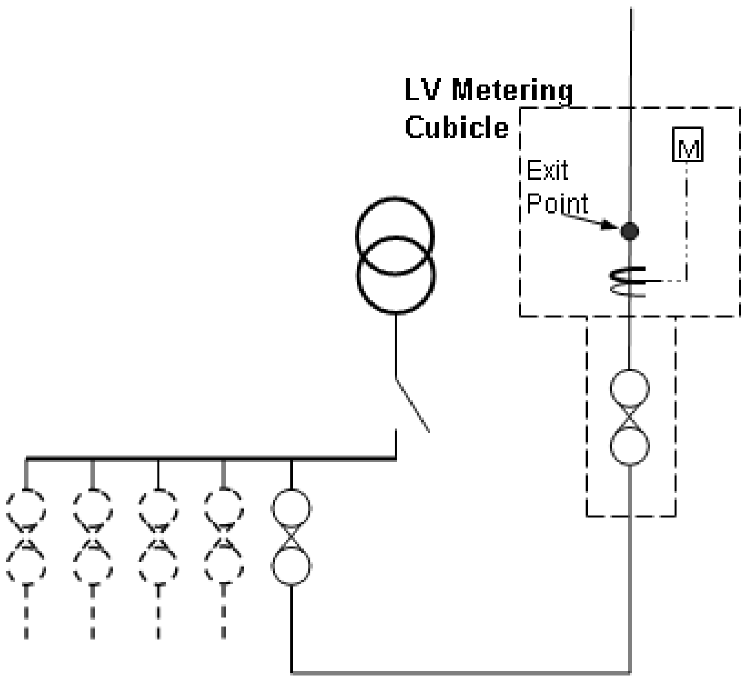
Appendix O – Arrangement of Termination Equipment

DRAWING NO.	TITLE
900000-53-068	Single Phase Termination
900000-53-071	Single Phase Termination Using Meter with Integral Disconnector
900000-53-072	Single-Phase Termination without Earth Terminal (for Caravans, Boats, Building Sites)
900000-53-067	Three Phase Termination (Multi-Rate Tariff)
900000-53-066	Three Phase Termination (Single Rate Tariff)
A3 - 018/02/E	Standard Meter Cupboard (Small) for External Reading and External Cable for Conventional Brick Structures with Cavity

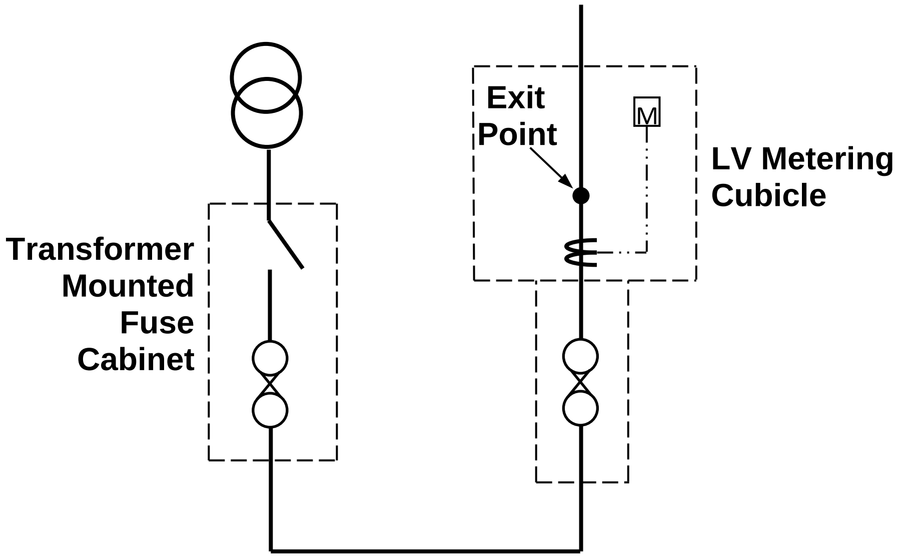
Appendix P – Typical Connection Arrangements for Loads above 60kVA and up to 300kVA



61kVA to 300kVA Connection to LV Network



Up to 300kVA Connected Directly to a Substation with Provision for LV Network Connections



61kVA to 300kVA Connection where LV Network Provision is Not Required or where the Load would Cause Unacceptable Interference to the Quality of Supply to other Customers

Appendix Q – Cut-out Fuses, Metering CTs and Meter Trails

MAXIMUM IMPORT CAPACITY RANGE (KVA)	FUSES PER PHASE	METERING CT RATIO	METER TAILS (MM^2)
61- 80	1 x 100A	400/5	35
81 – 120	1 x 160A		70
121 – 150	1 x 200A		95
151 – 190	1 x 250A		150
191 – 230	1 x 315A		185
231 – 260	1 x 355A		240
261 – 300	1 x 400A		300

Appendix R - LV Connections up to 1500kVA

Figure 1 – Distribution Substation Connection

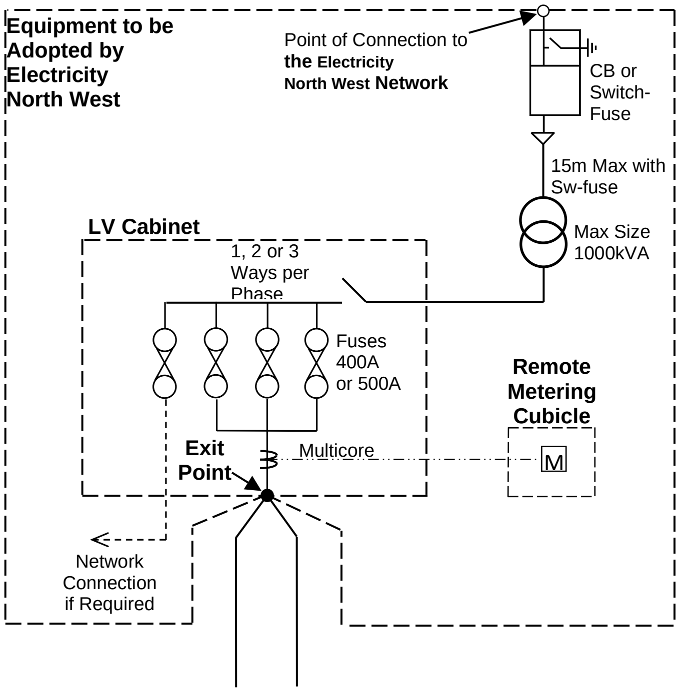


Figure 2 – Connection with NO Provision for LV Network

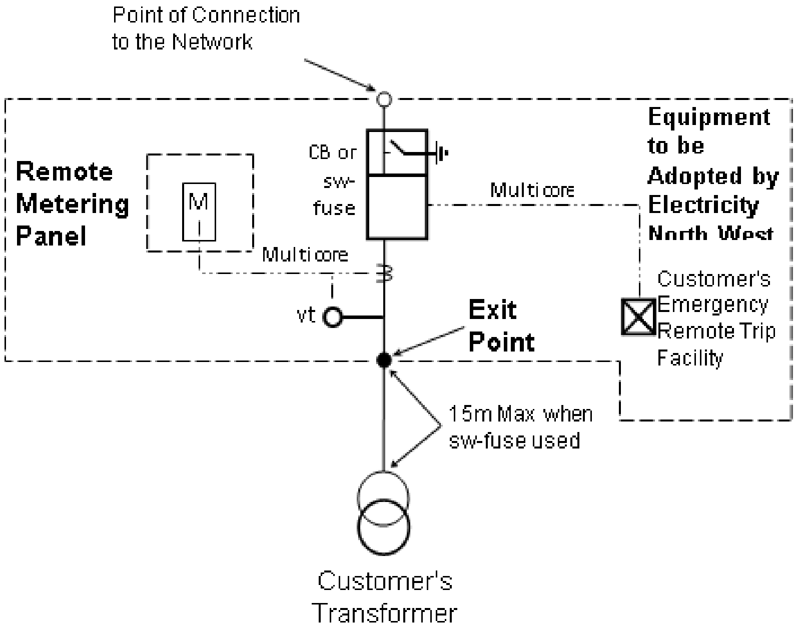


Figure 2 Connection with NO Provision for LV Network

Figure 3 – RMU Connection

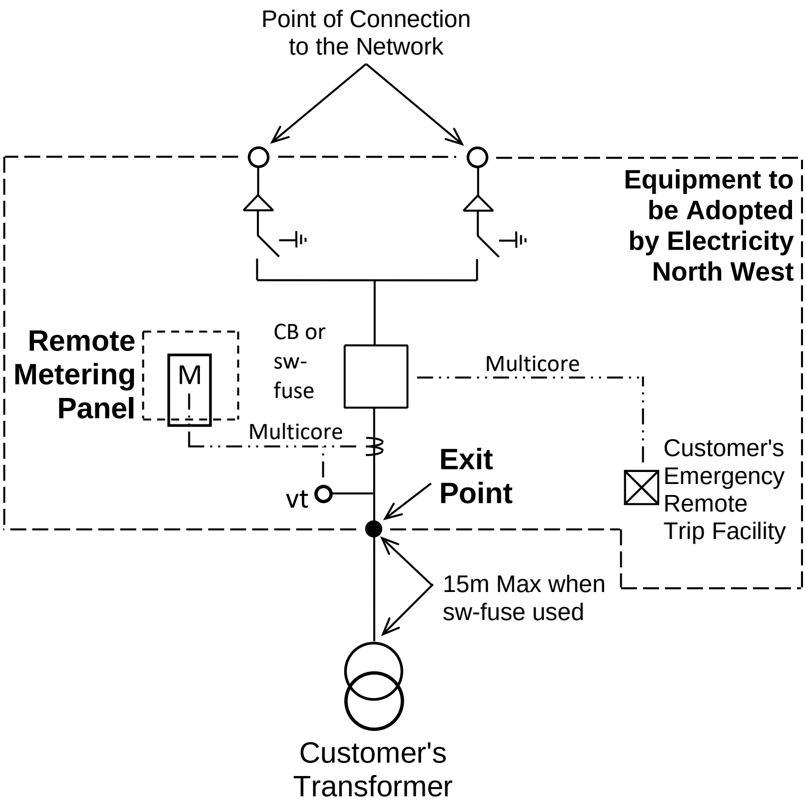


Fig 3 RMU Connection

Appendix S – Fuses, Metering CTs and Connection Types

MAXIMUM IMPORT CAPACITY RANGE (KVA)	FUSES PER PHASE	METERING CT RATIO	CONNECTION TYPE
301 - 360	1 x 500A	500/5	Single way with metering cts at Electricity North West's LV Board.
361 - 453	2 x 315A	800/5	2 parallel 'consumer ways' with metering cts at Electricity North West's LV Board..
454 – 575	2 x 400A		
576 – 680	3 x 315A	1500/5	3 parallel 'consumer ways' with metering cts at Electricity North West's LV Board.
681 – 864	3 x 400A		
865 - 1000	3 x 500A		

Appendix T – Calculating Maximum Distributor Loop Impedance

T1 – Fuse-Link Operating Current

For the fuse-link rating use the fuse characteristics to determine the current (I_{fuse}) required to operate the fuse-link in a time not to exceed (i) 100s for a cable distributor; (ii) 10s for an OHL distributor; and (iii) normally 10s for a mixed distributor.

HRC fuse-links in accordance with ENA TS 12-8 and BS 88 Part 5 (1988) have been used for the tables in this CP using the +10% limit on the BS 88 time/current curves to ensure operation for all fuse-link characteristic within the BS 88 envelope. No additional allowance is made for fuse-link operation outside the BS 88 time/current zones.

Changes in the Standards, such as the replacement of BS 88 by BS-HD 60269: 2010 / BS 88-2: 2010, "Low-voltage fuses. Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application). Examples of standardized systems of fuses A to J", has not necessarily changed the fuse characteristics. The compatibility of the characteristics of fuses purchased in accordance with current standards is checked at the time of contract renewal and on the publication of standards revisions against the BS 88 Part 5 (1988).

T2 – Adiabatic Thermal Limit

To determine whether the thermal limit of the cable/conductor would be reached with the value of fuse-link current (I_{fuse}) and duration (100s or 10s as appropriate) use the method in Appendix A of CP203 for cables or section 6 of CP206 for conductors. If the temperature is below the allowed thermal limit then this value of fuse-link current is used as the value for I_{fuse} in calculating the maximum loop impedance.

If the temperature is above the allowed thermal limit then it is necessary to use the current/time curve of the rated fuse-link (using the +10% limit) to establish the value of fuse-link current and duration at which the cable/conductor will just reach its thermal limit.

A suitable method is to create a table of the current and time values from the current/time curve of the fuse-link using the +10% limit at a suitable time interval. For each entry, calculate the cable/conductor temperature that would be reached. Interpolate between results to find the current/time value that will cause the temperature to just reach the cable/conductor thermal limit.

This value of fuse-link current shall be used as the value for I_{fuse} in calculating the maximum loop impedance.

NOTE:

The required current will be larger than the 10s or 100s value and so the operating time will meet the requirement that the fuse-link operating time shall not exceed 10s or 100s

Example Calculation – Cable Protection – Fuse-link Operating Time is not to Exceed 100s

CABLE TYPE	FUSE-LINK = 400A		CONDUCTOR TEMP AT FUSE OPERATION	COMMENT
	Operating time (s)	Current (A)		
185mm2 Al PILC	100	1300	120°C	Thermal limit not exceeded I_{fuse} = 1300A
120mm2 Al PILC	100	1300	245°C	Thermal limit exceeded
	80	1400	227	
	70	1425	207	By interpolation
	60	1450	186	I_{fuse} = 1430A
	45	1500	155	

T3 – Maximum Distributor Loop Impedance

The maximum impedance (Z_{tot}) that will allow the fuse-link to operate is the summation of the impedance of the source, transformer & distributor loop:

$Z_{tot} = Z_s + Z_t + aZ_c$ [Equation 1]

Where:

Z_s = Source impedance = $R_s + jX_{s\#}$

NOTE:

(a) A source impedance of 50MVA (purely inductive) is assumed for cable fed transformers = 0 + j0.0034Ω

(b) A source impedance of 10MVA (purely inductive) is assumed for OHL fed transformers = 0 + j0.0172Ω (the resistive component has an insignificant effect for an OHL of typical X/R ratio)

(c) These values need to be converted to the equivalent impedance on the LV side of the transformer (see ENA TS P28, Appendix C, Table C1)

Z_t = Transformer impedance = $R_t + jX_t$

a = Maximum length (km) of distributor that will ensure fuse-link will operate

Z_c = Cable/OHL conductor loop impedance per km = $R_c + jX_c$

Immediately prior to fault the conductor/sheath temperature is assumed to be 50°C. The calculation assumes Z_c remains constant during the time it takes the fuse-link to operate.

The maximum impedance (Z_{tot}) that will allow the fuse/protection to operate is calculated as follows:

The appropriate value current (I_{fuse}) to operate the fuse-link is obtained using the methods in T.1 and T.2.

A factor of 0.85 is used to allow for the fault impedance and the driving voltage (240) is reduced to 0.85 x 240 = 204. This implies that a fixed 36V is dropped across the fault.

Therefore $Z_{tot} = 204/ I_{fuse}$

Equation 1 can be re-written:

$I_{fuse} \cdot \sqrt{((R_s + R_t + aR_{c@50°C})^2 + (X_s + X_t + aX_{c@50°C})^2)} = 204$ [Equation 2]

Equation 2 is solved for 'a' to give the allowable maximum length of cable for the fuse-link to operate.

The corresponding maximum cable loop impedance is then be calculated = aZ_c

Appendix U – References & Publications – PME & Substation Earthing

U1 References and Associated Publications – PME & Substation Earthing

For convenience of reference, a range of documents not referred to within CP332, but relevant to PME and substation earthing in general are listed below. Some of these documents may be pertinent to non standard or unusual circumstances requiring individual engineering design:

(a) ENA ER P22 - Procedure for advising customers on the unsuitability of water pipes for use as earth electrodes.

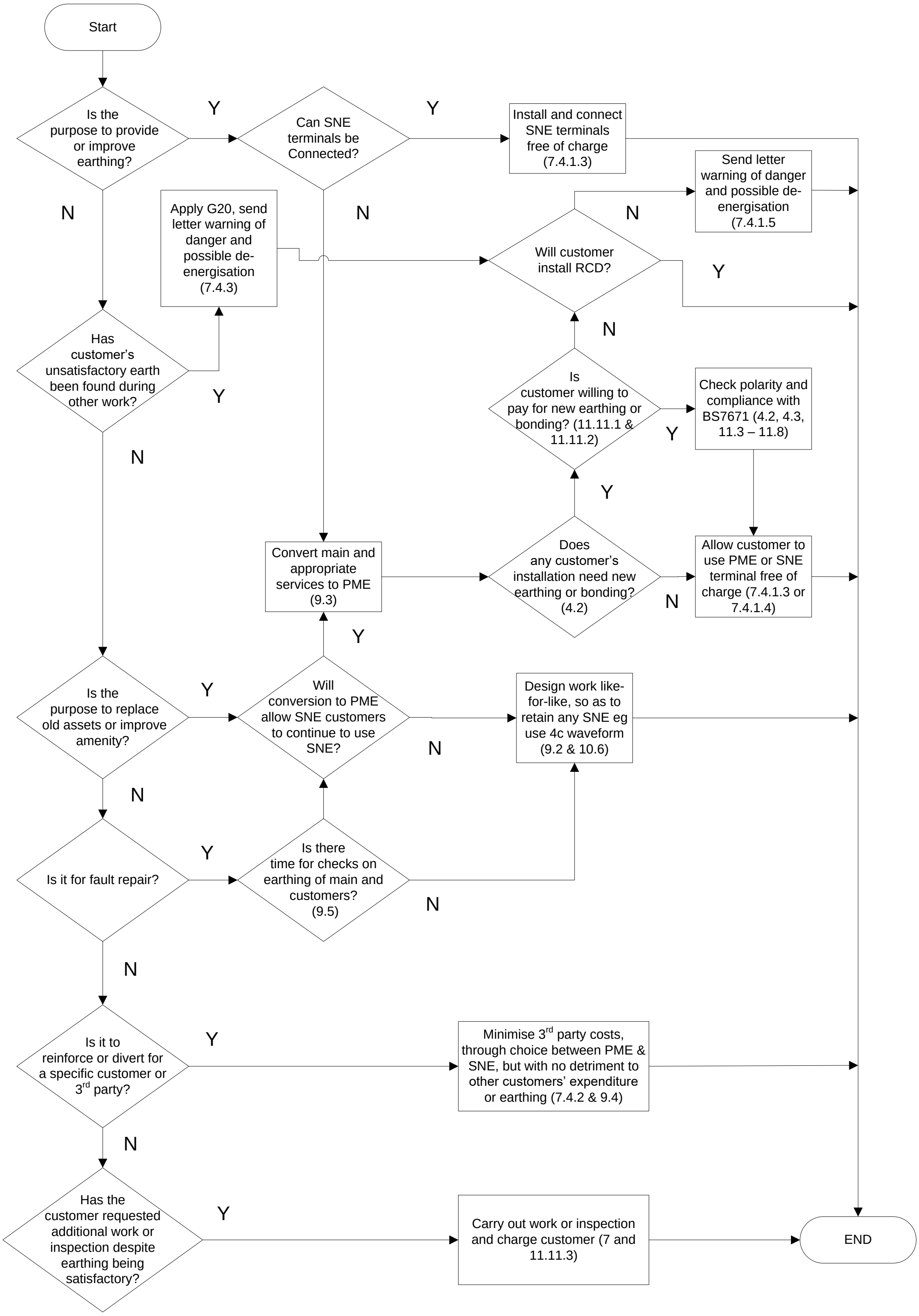
(b) ENA ER P23/1 - Customers' earth fault protection for compliance with the BS7671.

(c) ENA ER S34 - A guide for assessing the rise of earth fault potential at substation sites.

(d) ENA Technical Specification 41-24 - Guidelines for the design, installation, testing and maintenance of earthing systems in substations (replaces ER S5/1).

(e) ENA Technical Specification 43-94 - Earth rods and their connectors.

Appendix V – Network Change and/or Improvement to Customers' Unsatisfactory Earthing



Appendix W – LV AFFIRM – Network Design Workbook – Documentation

15.1 General Description

LV AFFIRM, available in the form of a Microsoft Excel Template (.xlt), comprises nine worksheets entitled:

- Inputs and Results
- Motors and Flicker
- Detailed Calculation
- Data
- Inputs and Results Extension
- Unprotected Lengths
- Loadings and Ratings
- Slow Fault Clearance
- Microgeneration

Although users have access to view all parts of all these worksheets, it is the first two, in which they can enter design parameters and from which they can read the results, to which they will need frequent access. As issued, the five Sheets, 'Detailed Calculation', 'Data', 'Inputs and Results Extension', 'Slow Fault Clearance' and 'Microgeneration', will be hidden, but available for the users to "unhide". (Use the 'Format' menu and then click on 'Sheet' and then on 'Unhide'.) All parts of the workbook are locked, except for the white entry cells on the first two worksheets and 'Inputs and Results Extension'.

LV AFFIRM is capable of calculating voltage drop, loop impedance, fuse ratings and the largest acceptable step-changes in current, for most network conditions, and also voltage rise caused by the operation of microgeneration. Modern and historical line types, three-phase, split-phase and single-phase transformers and circuits, and distributed and point loads can be accommodated.

15.2 Detailed Description of Functionality

15.2.1 'Data' Sheet

The 'Data' Sheet contains various ranges of numerical data, generally used by the other worksheets in the form of drop-down lists and look-up tables. The contents of these lists and tables are described below. The layout of the sheet is shown in Figures 1.1, 1.2, 1.3 and 1.4, where the cells and ranges described below are highlighted with bold outlines.

15.2.2 Sheet 'Data': Range A3:A9; HVFL (MVA)

This contains typical values of fault level at the HV side of distribution transformers. It forms a drop-down list, named "HVFL", called for by Sheet 'Inputs and Results' (L6). The range includes a blank cell (A9), the presence of which enables the user, as an alternative to selecting one of these values, to insert a value from the keyboard.

15.2.3 Sheet 'Data': Range C13:C35; Transformer

All transformer types (three-phase, single-phase and split-phase; ground-mounted and pole-mounted) and ratings (historically and currently purchased) are listed, forming a drop-down list, named "Transformer", called for by the 'Inputs and Results' Sheet (Q6). Input is restricted to one of the descriptions listed.

15.2.4 Sheet 'Data': Range D13:D35; Transformer Phases

Together with Range C13:C35, this forms a look-up table, used to populate the 'Number of Phases' cell (F2) of Sheet 'Detailed Calculation', according to the transformer selected.

15.2.5 Sheet 'Data': Range E13:F35; Transformer Impedance (Ω)

Impedance values (resistance and reactance in ohm at 415/240V) are taken from CP204 - Network Component Impedance Data, except for those for a 3ϕ 1 500, 1 250 and 250kVA transformers, which are derived by logarithmic extrapolation and interpolation, and for a 1ϕ 100kVA transformer. They form a look-up table, used to populate the 'Transformer Equivalent Resistance' and 'Transformer Equivalent Reactance' cells (H2 and I2) of Sheet 'Detailed Calculation', according to the transformer selected.

15.2.6 Sheet 'Data': Range G13:G35; Max Fuse for Transformer (A)

Maximum LV fuse ratings to allow discrimination with HV protection are taken from CP331. They form a look-up table, used to populate the 'Max Fuse for Transformer' cell (Q35) of Sheet 'Inputs and Results', according to the transformer selected.

15.2.7 Sheet 'Data': Range H33:I35; Transformer Impedance (Ω) - Split-phase

As E13:F35, but for the 480V windings of split-phase transformers. Values are taken from CP204. They form a look-up table to populate the 'Substation Equivalent Resistance (Flicker)' and Substation Equivalent Reactance (Flicker)' cells (AX2, AY2) of Sheet 'Detailed Calculation', as alternative values for flicker calculations on 2-phase loads connected to split-phase transformers.

15.2.8 Sheet 'Data': Range J15:J22; ADMD (kW)

The ADMD values included in the table in CP226, sub-section 4.2.2 are listed to form a drop-down list, the list being named 'ADMD', for the input to Cells J8, M8 and P8 of Sheet 'Inputs and Results'. The range includes a blank cell (J22), the presence of which enables the user, as an alternative to selecting one of these values, to insert a value from the keyboard.

15.2.9 Sheet 'Data': Range L15:L16; Loss of Diversity Allowance (kW)

Two values of Loss of Diversity Allowance (See CP226, sub-section 4.2.1.) are listed to form a drop-down list, named "LoD", for the population of Cell D8 of Sheet 'Inputs and Results'. Input is restricted to one of the two values listed.

15.2.10 Sheet 'Data': Range L20:L24; Tap

A list (1, 2, 3, 4, 5) named "Tap" forms a drop-down list, for the population of Cell L7 of Sheet 'Microgeneration'. Input is restricted to one of the five numbers given.

15.2.11 ‘Data’: Range L29:L30; Bond

A list (“SNE)”, “Bond)”), named ‘Bond’, is used for data validation, in conjunction with the entries of ‘Line Description’, according to whether SNE (neutral core) type cables have a neutral-earth bond applied downstream.

15.2.12 Sheet ‘Data’: Range O15:O21; Unbalance

Selected values (0.0, 0.2, 0.4, 0.6, 0.8, 1) are used to form a drop-down list, named “Unbalance”, for the population of Cell L10 of Sheet ‘Microgeneration’. The range includes a blank cell (O21), the presence of which enables the user, as an alternative to selecting one of these values, to insert a value from the keyboard.

15.2.13 Sheet ‘Data’: Range O25:O30; MAD

The values of Minimum Average Demand (MAD) tabulated in CP221, Table A1 for domestic microgeneration are used to form a drop-down list, named “MAD”, for the population of Range O8:O10 of Sheet ‘Microgeneration’. The range includes a blank cell (O30), the presence of which enables the user, as an alternative to selecting one of these values, to insert a value from the keyboard.

15.2.14 Sheet ‘Data’: Range O33:O34; HV

Two values (11 and 6.6) of nominal HV system voltage are used for data validation in the population of Cell E6 of Sheet ‘Microgeneration’. Input is restricted to one of the two values listed.

15.2.15 Sheet ‘Data’: Range Q15:R28; P28

Time intervals from “1 minute” to “12 minute” are listed against voltage dips, expressed as percent to form a look-up table used by Cell M44 of Sheet ‘Motors and Flicker’. The legend “No restriction” is placed against 0% and “Not acceptable” against 3%. The values listed have been computed from an equation empirically derived from Figure 4 in ENA ER P28:

$$\log v = (0.31 \log t) - 0.4$$

where v is voltage dip in percent and t is time in second.

(A straight line on the log/log graph was assumed between points (20, 1) and (700, 3).)

(Because the function VLOOKUP always finds the highest value that is <u>less</u> than the target, and the required result is the next <u>longer</u> time interval, the time intervals appear displaced vertically by one cell, to the next lower value of voltage dip.)

15.2.16 Sheet ‘Data’: Range E41:N41; Fuse Ratings - Descending

Fuse ratings are listed in descending order, preceded by a dummy value “99999”. These are used by Sheet ‘Inputs and Results’ (Q38) to determine the minimum fuse to cater for the load and to identify an overloaded fuseway.

15.2.17 Sheet ‘Data’: Range N41:V41; Fuse Ratings - Ascending

Fuse ratings are listed in ascending order. These are used by Sheet ‘Detailed Calculation’ (Column AU) to determine the maximum fuse to protect the distributor.

15.2.18 Sheet 'Data': Range A42:B141; Line Type and Size

Indicates for each line type and size, whether it is underground (UG), overhead (OH) or service and what its aluminium equivalent cross-section (mm^2) is. Used only as an aid, when viewing this sheet.

15.2.19 Sheet 'Data': Range C42:C141; Line Description

All line types and sizes, including underground cables, overhead lines, three-phase and single-phase services are listed. Strictly, the values listed for copper-cored PILC cables are for 4-core cables; similarly, those for open-wire overhead lines are for 4- or 5-wire lines. However, the same values may be assumed for 2- and 3-core PILC mains cables and for 2- and 3-wire lines. Cables with neutral cores (not concentric) each have two entries for 'SNE' operation and for bonded neutral and sheath. ABC each have two entries for 10s and 30s fault clearance times. (See CP331, 4.2.) The Range C128:C141 forms a drop-down list, named "Services" of single-phase services, used to populate the Service Description cells (Sheet 'Inputs and Results', E35:E37). Input is restricted to one of the descriptions listed.

15.2.20 Sheet 'Data': Range D42:D141; Line Ratings (A)

Underground cable ratings are based on CRATER, a software tool developed by EA Technology, assuming cyclic (8 hour at 1.0pu and 16 hour at 0.75pu) loading and typical UK (soil thermal resistivity 0.9KmW^{-1}) winter (soil temperature 10°C) conditions. Overhead line ratings are based on CP206. The ratings are used to identify any overloaded section. Identical rating figures for mains appear also in Column X.

15.2.21 Sheet 'Data': Range E42:H141; Line Normal Impedances (Ω/km)

Line impedances (Ω/km) for normal service are listed for each line type and size. Values are taken from CP204. However, for cables with concentric neutrals, neutral reactance values are derived from CP204, using the formula $X_n = (X_0 - X_1)/3$. The values form a look-up table for the population of the corresponding cells in Sheet 'Detailed Calculation' (Columns G:J) for the calculation of voltage-drops and flicker.

15.2.22 Sheet 'Data': Range I42:L141; Line Fault Impedances (Ω/km)

Line impedances (Ω/km) for fault currents are listed for each line type and size. Phase resistance values are derived from CP204 and adjusted to 50°C. Earth-return/neutral resistance values are derived from CP204, using the formula $R_e = (R_0 - R_1)/3$ where appropriate, resistances for overhead lines being adjusted to 50°C. For underground cables, phase reactance values are taken from CP204 and earth-return/neutral reactance values are derived from CP204, using the formula $X_e = (X_0 - X_1)/3$, For overhead lines, reactance values are calculated for the largest phase-neutral spacing, for 4-wire open wire lines or for 4-core ABC. (See CP205.) Alternative values are included for 4-core cables, for operation as SNE and with neutral and sheath bonded. The values form a look-up table for the population of the corresponding cells in Sheet 'Detailed Calculation' (Columns K:N) for the calculation of loop impedances and fault currents.

NOTE:

Fault-impedance values for 4c cables are based on the following assumptions:

(a) a cable operating as SNE, ie with no CNE branch, extension or insert, will have its armour bonded to its sheath at all joints (plumbed joints); and

(b) where a CNE cable has been jointed to a 4c cable, the neutral will have been bonded to the sheath, but the armour will not have been bonded (resin joints). (This ignores the reality that early Consac jointing systems used plumbed joints.)

15.2.23 Sheet 'Data': Range M42:M127; Largest Fuse Ratings (A)

The largest acceptable fuse rating to protect against overload is listed for each line type and size, except services. Values are taken from CP331. They are used to populate 'Fuse for Section A Rating' cells, Q36 in Sheet 'Inputs and Results and E10:E49 in Sheet 'Unprotected Lengths'.

15.2.24 Sheet 'Data': Range N42:V127; Minimum Fault Currents (A)

Minimum fault currents are listed for each fuse rating and for each line type and size, except service cables. The values are those used in the formulation of the maximum protected lengths listed in CP331. They form a look-up table, used to populate the 'Max Fuse for LV Main Protection' cell (Q37) of Sheet 'Inputs and Results', according to the line type and size selected. Alternative values are given for ABC, according to whether a 10s (preferred) or 30s fault clearance is required. Against service cables, an increasing series of small dummy values is entered. This is to avoid "divide by zero" errors in Sheet 'Unprotected Lengths' and ensures that the fuse size allocated to service cables is always 630A and that, therefore, service cables have no influence on the size of the maximum fuse to protect the distributor.

15.2.25 Sheet 'Data': Range W42:W127; Fault Clearance Times (s)

Maximum fault clearance times are listed for each line type (cables: 100s; overhead lines: 10s; alternative for ABC: 30s). These are used in Sheet 'Detailed Calculation' (Columns BR:BZ) to determine whether sections are thermally limited.

15.2.26 Sheet 'Data': Range X42:AA127; Ratings (A)

Ratings are listed for each line type. Four ratings are given for mains cables: laid-direct, both cyclic (Column X) and sustained (Column Y); and in a single-way duct, both cyclic (Column Z) and sustained (Column AA). Cable ratings have been derived from CRATER and overhead line ratings taken from CP206.

15.2.27 Sheet 'Data': Range AB42:AB103; Line Description

Line types and sizes, including underground cables, overhead lines, three-phase and single-phase services are listed. The Range AB42:AB103 forms a drop-down list, named "LinesShort", which, in conjunction with the list 'Bond' (See 5.1.10.), is used to populate the Line Description cells (E12:F31) of Sheets 'Inputs and Results' and 'Inputs and Results Extension'. Input is restricted to one of the descriptions listed.

15.2.28 Sheet 'Data': Range AC42:AH127; Grouped Ratings

Ratings are listed for groups of each cable type. Six cyclic ratings are given for mains cables in groups of 2, 3 and 4 cables: laid-direct at 150mm spacing (Columns AC to AE) and in touching ducts (Columns AF to AH). Ratings have been derived from CRATER. (See 15.3.19)

15.2.29 Sheet 'Data': Range M150:V151; Fuse Operating Currents

Fuse operating currents are listed according to fuse rating (Columns N to V), against maximum fault clearance times (Rows 150 to 151). These are used as a look-up table by Sheet 'Detailed Calculation' (Columns BR:BZ), to identify thermally limited sections.

Figure 1.1 – Data Sheet Rows 1 to 35

	A	B	C	D	E	F	G	H	I
1	[HV FAULT LEVEL]			LV AFFIRM - Network Design Calculator - Data					Version 6.2
2	MVA								
3	200								
4	150								
5	100								
6	50								
7	25								
8	10								
9									
10	[TRANSFORMER]				Impedance (Ω) -				
11					415/240V				
12			Description	Phases	Resistance	Reactance	Max Fuse (A)		
13			3φ 1500kVA	3	0.0012	0.0062	630		
14			3φ 1250kVA	3	0.0015	0.0067	630		
15			3φ 1000kVA	3	0.00202	0.00795	630		
16			3φ 800kVA	3	0.00268	0.00986	630		
17			3φ 750kVA	3	0.00288	0.0106	630		
18			3φ 500kVA	3	0.00469	0.01576	400		
19			3φ 315kVA	3	0.0083	0.0247	315		
20			3φ 300kVA	3	0.00874	0.0259	315		
21			3φ 250kVA	3	0.011	0.0306	315		
22			3φ 200kVA	3	0.01456	0.0374	200		
23			3φ 100kVA	3	0.0342	0.0746	200		
24			3φ 50kVA	3	0.0807	0.1327	160		
25			3φ 25kVA	3	0.1917	0.245	100		
26			1φ 100kVA	1	0.0149	0.023	200		
27			1φ 50kVA	1	0.0245	0.0457	200		
28			1φ 25kVA	1	0.0564	0.087	160		
29			1φ 16kVA	1	0.0995	0.1281	100		
30			1φ 15kVA	1	0.1087	0.1346	100		
31			1φ 10kVA	1	0.176	0.1898	100	Impedance (Ω) - 480V	
32			1φ 5kVA	1	0.396	0.334	100	Resistance	Reactance
33			Split φ 100kVA	2	0.01521	0.0235	200	0.041	0.094
34			Split φ 50kVA	2	0.0362	0.0473	160	0.1005	0.1797
35			Split φ 25kVA	2	0.0786	0.0869	100	0.215	0.336

	J	K	L	M	N	O	P	Q	R	S
13	[ADMD]		[LOSS OF DIVERSITY]			[UNBALANCE]		[P28]		
15	0.4		4			1		0	No restriction	
16	0.6		8			0.8		1	1 minute	
17	1					0.6		1.41	2 minute	
18	1.4		[TAP]			0.4		1.76	3 minute	
19	1.5					0.2		1.99	4 minute	
20	2.4		1			0.0		2.17	5 minute	
21	3.4		2					2.33	6 minute	
22			3					2.47	7 minute	
23			4			[MAD]		2.59	8 minute	
24			5					2.7	9 minute	
25						0.16		2.8	10 minute	
26						0.17		2.89	11 minute	
27			[Bond]			0.23		2.98	12 minute	
28						0.31		3	Not acceptable	
29			SNE)			0.45				
30			Bond)							
32						[HV]				
33						11				
34						6.6				

Figure 1.2 – Data Sheet – Columns A to L

	A	B	C	D	E	F	G	H	I	J	K	L
36	[LINE DATA]											
37					Impedances (Ω)							
38					Normal				Fault			
39				RATING	Phase		Neutral		Phase		Earth Return	
40	TYPE	SIZE (mm²)	NAME	A	Resistance	Reactance	Resistance	Reactance	Resistance	Reactance	Resistance	Reactance
41	(UG or OH)	Al equiv.		[Fuses →	99999	630	500	400	355	315	250	200
42	UG	300	3c 300 Waveform	580	0.102	0.073	0.166	0.011	0.114	0.073	0.166	0.011
43	UG	240	3c 240 Waveform	515	0.127	0.073	0.166	0.012	0.142	0.073	0.166	0.012
44	UG	185	3c 185 Waveform	440	0.166	0.074	0.166	0.013	0.186	0.074	0.166	0.013
45	UG	95	3c 95 Waveform	300	0.322	0.074	0.322	0.017	0.361	0.074	0.322	0.017
46	Service	25	3c 25 SAC XC Service	145	1.200	0.077	1.300	0.013	1.345	0.077	1.300	0.013
47	Service	25	3c 25 SAC XSC Service	150	1.200	0.077	1.200	0.014	1.345	0.077	1.200	0.014
48	UG	300	4c 300 Waveform (SNE)	580	0.102	0.072	0.102	0.072	0.114	0.072	0.166	0.010
49	UG	240	4c 240 Waveform (SNE)	515	0.127	0.072	0.127	0.072	0.142	0.072	0.166	0.011
50	UG	185	4c 185 Waveform (SNE)	440	0.166	0.073	0.166	0.073	0.186	0.073	0.166	0.013
51	UG	95	4c 95 Waveform (SNE)	300	0.322	0.074	0.322	0.074	0.361	0.074	0.322	0.013
52	UG	300	3c 300 Consac	545	0.102	0.068	0.094	0.006	0.114	0.068	0.094	0.006
53	UG	185	3c 185 Consac	405	0.166	0.069	0.153	0.006	0.186	0.069	0.153	0.006
54	UG	95	3c 95 Consac	280	0.322	0.069	0.293	0.009	0.361	0.069	0.293	0.009
55	UG	300	4c 300 SAC (SNE)	560	0.102	0.067	0.102	0.067	0.114	0.067	0.234	0.005
56	UG	185	4c 185 SAC (SNE)	420	0.166	0.068	0.166	0.068	0.186	0.068	0.338	0.005
57	UG	120	4c 120 SAC (SNE)	325	0.255	0.068	0.255	0.068	0.286	0.068	0.489	0.006
58	UG	70	4c 70 SAC (SNE)	230	0.446	0.071	0.446	0.071	0.500	0.071	0.698	0.007
59	UG	323	4c 0.5 SAC (SNE)	585	0.097	0.067	0.097	0.067	0.109	0.067	0.182	0.007
60	UG	194	4c 0.3 SAC (SNE)	430	0.150	0.068	0.150	0.068	0.168	0.068	0.282	0.008
61	UG	129	4c 0.2 SAC (SNE)	340	0.230	0.069	0.230	0.069	0.258	0.069	0.378	0.008
62	UG	65	4c 0.1 SAC (SNE)	215	0.451	0.073	0.451	0.073	0.506	0.073	0.610	0.011
63	UG	532	0.5 Cu PILC (SNE)	745	0.059	0.067	0.059	0.067	0.066	0.067	0.167	0.003
64	UG	319	0.3 Cu PILC (SNE)	565	0.106	0.068	0.106	0.068	0.118	0.068	0.257	0.003
65	UG	266	0.25 Cu PILC (SNE)	500	0.124	0.069	0.124	0.069	0.139	0.069	0.296	0.004
66	UG	213	0.2 Cu PILC (SNE)	440	0.150	0.069	0.150	0.069	0.168	0.069	0.346	0.004
67	UG	160	0.15 Cu PILC (SNE)	375	0.195	0.070	0.195	0.070	0.218	0.07	0.445	0.004
68	UG	128	0.12 Cu PILC (SNE)	325	0.242	0.072	0.242	0.072	0.271	0.072	0.513	0.004
69	UG	106	0.1 Cu PILC (SNE)	290	0.274	0.073	0.274	0.073	0.306	0.073	0.557	0.003
70	UG	80	0.075 Cu PILC (SNE)	240	0.396	0.074	0.396	0.074	0.443	0.074	0.664	0.006
71	UG	64	0.06 Cu PILC (SNE)	215	0.469	0.075	0.469	0.075	0.524	0.075	0.727	0.009
72	UG	53	0.05 Cu PILC (SNE)	190	0.589	0.077	0.589	0.077	0.658	0.077	0.821	0.008
73	UG	43	0.04 Cu PILC (SNE)	170	0.708	0.079	0.708	0.079	0.791	0.079	0.914	0.008
74	UG	24	0.0225 Cu PILC MAIN (SN	120	1.257	0.086	1.257	0.086	1.405	0.086	1.118	0.009
75	Service	26	4c 16 Cu PILC Service	125	1.149	0.080	1.149	0.080	1.284	0.080	1.037	0.004
76	Service	24	4c 0.0225 SERVICE	120	1.257	0.086	1.257	0.086	1.405	0.086	1.118	0.009
77	Service	15	4c 0.0145 Service	90	1.903	0.089	1.903	0.089	2.13	0.089	1.116	0.020
78	OH	95	95 ABC (10s clearance)	228	0.320	0.080	0.320	0.080	0.359	0.098	0.359	0.098
79	OH	70	70 ABC (10s clearance)	183	0.443	0.080	0.443	0.080	0.497	0.099	0.497	0.099
80	OH	50	50 ABC (10s clearance)	143	0.641	0.083	0.641	0.083	0.718	0.102	0.718	0.102
81	OH	35	35 ABC (10s clearance)	117	0.868	0.086	0.868	0.086	0.973	0.104	0.973	0.104
82	OH	25	25 ABC (10s clearance)	95	1.200	0.088	1.200	0.088	1.345	0.107	1.345	0.107
83	OH	95	95 ABC (30s clearance)	228	0.320	0.080	0.320	0.080	0.359	0.098	0.359	0.098
84	OH	70	70 ABC (30s clearance)	183	0.443	0.080	0.443	0.080	0.497	0.099	0.497	0.099
85	OH	50	50 ABC (30s clearance)	143	0.641	0.083	0.641	0.083	0.718	0.102	0.718	0.102
86	OH	35	35 ABC (30s clearance)	117	0.868	0.086	0.868	0.086	0.973	0.104	0.973	0.104
87	OH	25	25 ABC (30s clearance)	95	1.200	0.088	1.200	0.088	1.345	0.107	1.345	0.107
88	OH	100	100 Al open wire	390	0.270	0.275	0.270	0.275	0.303	0.329	0.303	0.329
89	OH	50	50 Al open wire	250	0.542	0.297	0.542	0.297	0.608	0.351	0.608	0.351
90	OH	160	0.15 Al (Cu Eq) open w	395	0.182	0.262	0.182	0.262	0.204	0.317	0.204	0.317
91	OH	106	0.1 Al (Cu Eq) open w	360	0.271	0.275	0.271	0.275	0.304	0.329	0.304	0.329
92	OH	64	0.05 Al (Cu Eq) open w	260	0.545	0.297	0.545	0.297	0.611	0.351	0.611	0.351
93	OH	43	0.04 Al (Cu Eq) open w	205	0.670	0.303	0.670	0.303	0.751	0.358	0.751	0.358
94	OH	27	0.025 Al (Cu Eq) open w	155	1.088	0.312	1.088	0.312	1.220	0.367	1.220	0.367
95	OH	160	0.15 Cu (strand) open w	395	0.182	0.277	0.182	0.277	0.203	0.332	0.203	0.332
96	OH	106	0.1 Cu (strand) open w	360	0.272	0.290	0.272	0.290	0.303	0.344	0.303	0.344
97	OH	80	0.075 Cu (strand) open w	310	0.375	0.300	0.375	0.300	0.418	0.354	0.418	0.354
98	OH	64	0.06 Cu (strand) open w	260	0.466	0.307	0.466	0.307	0.519	0.361	0.519	0.361
99	OH	53	0.05 Cu (strand) open w	230	0.543	0.308	0.543	0.308	0.605	0.362	0.605	0.362
100	OH	43	0.04 Cu (strand) open w	205	0.705	0.320	0.705	0.320	0.786	0.374	0.786	0.374
101	OH	27	0.025 Cu (strand) open w	160	1.087	0.330	1.087	0.330	1.211	0.384	1.211	0.384
102	OH	53	0.05 Cu (solid) open w	230	0.550	0.316	0.550	0.316	0.613	0.37	0.613	0.370
103	OH	27	0.025 Cu (solid) open w	160	1.129	0.338	1.129	0.338	1.258	0.392	1.258	0.392
104	UG	300	4c 300 Waveform (Bond)	580	0.102	0.072	0.102	0.072	0.114	0.072	0.063	0.005
105	UG	240	4c 240 Waveform (Bond)	515	0.127	0.072	0.127	0.072	0.142	0.072	0.072	0.006
106	UG	185	4c 185 Waveform (Bond)	440	0.166	0.073	0.166	0.073	0.186	0.073	0.082	0.007
107	UG	95	4c 95 Waveform (Bond)	300	0.322	0.074	0.322	0.074	0.361	0.074	0.161	0.006
108	UG	300	4c 300 SAC (Bond)	560	0.102	0.067	0.102	0.067	0.114	0.067	0.086	0.003
109	UG	185	4c 185 SAC (Bond)	420	0.166	0.068	0.166	0.068	0.186	0.068	0.138	0.003
110	UG	120	4c 120 SAC (Bond)	325	0.255	0.068	0.255	0.068	0.286	0.068	0.210	0.004
111	UG	70	4c 70 SAC (Bond)	230	0.446	0.071	0.446	0.071	0.500	0.071	0.353	0.004
112	UG	323	4c 0.5 SAC (Bond)	585	0.097	0.067	0.097	0.067	0.109	0.067	0.080	0.005
113	UG	194	4c 0.3 SAC (Bond)	430	0.150	0.068	0.150	0.068	0.168	0.068	0.124	0.005
114	UG	129	4c 0.2 SAC (Bond)	340	0.230	0.069	0.230	0.069	0.258	0.069	0.184	0.005
115	UG	65	4c 0.1 SAC (Bond)	215	0.451	0.073	0.451	0.073	0.506	0.073	0.346	0.006
116	UG	532	0.5 Cu PILC (Bond)	745	0.059	0.067	0.059	0.067	0.066	0.067	0.052	0.002
117	UG	319	0.3 Cu PILC (Bond)	565	0.106	0.068	0.106	0.068	0.118	0.068	0.091	0.003
118	UG	266	0.25 Cu PILC (Bond)	500	0.124	0.069	0.124	0.069	0.139	0.069	0.106	0.003
119	UG	213	0.2 Cu PILC (Bond)	440	0.150	0.069	0.150	0.069	0.168	0.069	0.128	0.003
120	UG	160	0.15 Cu PILC (Bond)	375	0.195	0.070	0.195	0.070	0.218	0.07	0.165	0.003
121	UG	128	0.12 Cu PILC (Bond)	325	0.242	0.072	0.242	0.072	0.271	0.072	0.203	0.002
122	UG	106	0.1 Cu PILC (Bond)	290	0.274	0.073	0.274	0.073	0.306	0.073	0.228	0.002
123	UG	80	0.075 Cu PILC (Bond)	240	0.396	0.074	0.396	0.074	0.443	0.074	0.317	0.004
124	UG	64	0.06 Cu PILC (Bond)	215	0.469	0.075	0.469	0.075	0.524	0.075	0.371	0.005
125	UG	53	0.05 Cu PILC (Bond)	190	0.589	0.077	0.589	0.077	0.658	0.077	0.454	0.005
126	UG	43	0.04 Cu PILC (Bond)	170	0.708	0.079	0.708	0.079	0.791	0.079	0.537	0.005
127	UG	24	0.0225 Cu PILC MAIN (Bo	120	1.257	0.086	1.257	0.086	1.405	0.086	0.859	0.005
128	Service	35	35 SAC XC	132	0.868	0.077	0.910	0.077	0.973	0.077	0.910	0.077
129	Service	35	35 SAC XSC	132	0.868	0.092	0.760	0.092	0.973	0.092	1.200	0.095
130	Service	25	25 SAC XC	107	1.200	0.079	1.300	0.079	1.345	0.079	1.300	0.079
131	Service	25	25 SAC XSC	107	1.200	0.085	1.200	0.085	1.345	0.088	1.200	0.088
132	Service	25	25 SAC PC	94	1.200	0.084	1.300	0.084	1.345	0.084	1.300	0.084
133	Service	25	25 SAC PSC	94	1.200	0.088	1.200	0.088	1.345	0.091	1.200	0.091
134	Service	25	25 PC	121	0.727	0.081	0.760	0.081	0.813	0.081	0.760	0.081
135	Service	25	25 PSC	121	0.727	0.092	0.760	0.092	0.813	0.094	1.200	0.094
136	Service	16	16 PC	94	1.150	0.083	1.200	0.083	1.286	0.083	1.200	0.083
137	Service	16	16 PSC	94	1.150	0.088	1.200	0.088	1.286	0.092	1.200	0.092
138	Service	7	4 polymeric	50	4.61	0.091	4.80	0.091	5.15	0.091	4.80	0.091
139	Service	43	2c 0.04	170	0.708	0.080	0.708	0.080	0.791	0.080	2.00	0.008
140	Service	24	2c 0.0225	120	1.257	0.085	1.257	0.085	1.405	0.085	2.24	0.009
141	Service	15	2c 0.0145	93	1.903	0.090	1.903	0.090	2.13	0.09	2.44	0.020
142	Service	7	2c 0.007	54	3.97	0.099	3.97	0.099	4.44	0.099	2.87	0.029

Figure 1.3 – Data Sheet – Columns M to W

	M	N	O	P	Q	R	S	T	U	V	W
36											
37											
38		Minimum Fault Currents									
39	Recommended										Maximum
40	Max Fuse	Min Current	Min Current	Min Current	Min Current	Min Current	Min Current	Min Current	Min Current	Min Current	Clearance
41	160	100	160	200	250	315	355	400	500	630	Time (s)
42	630	270	450	600	760	925	1125	1300	1700	2100	100
43	500	270	450	600	760	925	1125	1300	1700	2100	100
44	500	270	450	600	760	925	1125	1300	1700	2275	100
45	315	270	450	600	760	925	1275	1600	2400	4000	100
46	100	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	100
47	100	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	100
48	630	270	450	600	760	925	1125	1300	1700	2100	100
49	500	270	450	600	760	925	1125	1300	1700	2100	100
50	500	270	450	600	760	925	1125	1300	1700	2275	100
51	315	270	450	600	760	925	1275	1600	2400	4000	100
52	630	270	450	600	760	925	1125	1300	1700	2100	100
53	400	270	450	600	760	925	1125	1300	1700	2275	100
54	315	270	450	600	760	925	1275	1600	2400	4000	100
55	630	270	450	600	760	925	1125	1300	1700	2100	100
56	400	270	450	600	760	925	1125	1300	1700	2275	100
57	355	270	450	600	760	925	1125	1425	2100	3150	100
58	250	270	450	600	810	1050	1500	1875	3000	5000	100
59	630	270	450	600	760	925	1125	1300	1700	2100	100
60	500	270	450	600	760	925	1125	1300	1700	2250	100
61	355	270	450	600	760	925	1125	1350	2000	3000	100
62	250	270	450	600	825	1100	1600	2100	3100	5300	100
63	630	270	450	600	760	925	1125	1300	1700	2100	100
64	630	270	450	600	760	925	1125	1300	1700	2100	100
65	500	270	450	600	760	925	1125	1300	1700	2100	100
66	500	270	450	600	760	925	1125	1300	1700	2175	100
67	400	270	450	600	760	925	1125	1300	1750	2750	100
68	355	270	450	600	760	925	1125	1425	2200	3100	100
69	315	270	450	600	760	925	1175	1500	2300	3450	100
70	250	270	450	600	760	1050	1400	1800	2850	4250	100
71	250	270	450	600	825	1100	1605	2100	3450	6000	100
72	200	270	450	640	950	1375	1800	2450	4050	6900	100
73	200	270	480	710	1050	1725	2050	2750	5050	9000	100
74	160	290	670	985	1655	2500	3750	4250			100
75	100	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	100
76	100	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	100
77	100	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	100
78	315	383	700	905	1175	1600	1750	2050	2650		10
79	200	383	700	905	1175	1600	1750	2050	3000		10
80	160	383	700	905	1175	1675	1950	2500	4000		10
81	160	383	700	905	1200	1750	2475	3050	6550		10
82	100	383	700	1000	1550	2120	3450	4025	9100		10
83	315	325	560	725	950	1245	1455	1670	2500		30
84	200	325	560	725	950	1245	1620	2035	3000		30
85	160	325	560	725	975	1675	1950	2500	4000		30
86	160	325	560	800	1200	1750	2475	3050	6550		30
87	100	325	615	1000	1550	2120	3450	4025	9100		30
88	400	383	700	905	1175	1600	1750	2050	2650		10
89	315	383	700	905	1175	1675	1950	2500	4000		10
90	400	383	700	905	1175	1600	1750	2050	2650		10
91	400	383	700	905	1175	1600	1750	2050	2650		10
92	315	383	700	905	1175	1675	1950	2500	4000		10
93	250	383	700	905	1175	1725	2050	2750	5050		10
94	200	383	700	1000	1550	2125	3450	4025	9100		10
95	400	383	700	905	1175	1600	1750	2050	2650		10
96	400	383	700	905	1175	1600	1750	2050	2650		10
97	355	383	700	905	1175	1600	1750	2050	2850		10
98	315	383	700	905	1175	1600	1750	2100	3450		10
99	315	383	700	905	1175	1600	1800	2450	4050		10
100	200	383	700	905	1175	1725	2050	2750	5050		10
101	160	383	700	975	1525	2100	3250	3950	9000		10
102	315	383	700	905	1175	1725	2050	2750	5050		10
103	160	383	700	975	1525	2100	3250	3950	9000		10
104	630	270	450	600	760	925	1125	1300	1700	2100	100
105	500	270	450	600	760	925	1125	1300	1700	2100	100
106	500	270	450	600	760	925	1125	1300	1700	2275	100
107	315	270	450	600	760	925	1275	1600	2400	4000	100
108	630	270	450	600	760	925	1125	1300	1700	2100	100
109	400	270	450	600	760	925	1125	1300	1700	2275	100
110	355	270	450	600	760	925	1125	1425	2100	3150	100
111	250	270	450	600	810	1050	1500	1875	3000	5000	100
112	630	270	450	600	760	925	1125	1300	1700	2100	100
113	500	270	450	600	760	925	1125	1300	1700	2250	100
114	355	270	450	600	760	925	1125	1350	2000	3000	100
115	250	270	450	600	825	1100	1600	2100	3100	5300	100
116	630	270	450	600	760	925	1125	1300	1700	2100	100
117	630	270	450	600	760	925	1125	1300	1700	2100	100
118	500	270	450	600	760	925	1125	1300	1700	2100	100
119	500	270	450	600	760	925	1125	1300	1700	2175	100
120	400	270	450	600	760	925	1125	1300	1750	2750	100
121	355	270	450	600	760	925	1125	1425	2200	3100	100
122	315	270	450	600	760	925	1175	1500	2300	3450	100
123	250	270	450	600	760	1050	1400	1800	2850	4250	100
124	250	270	450	600	825	1100	1605	2100	3450	6000	100
125	200	270	450	640	950	1375	1800	2450	4050	6900	100
126	200	270	480	710	1050	1725	2050	2750	5050	9000	100
127	160	290	670	985	1655	2500	3750	4250			100

	M	N	O	P	Q	R	S	T	U	V	W
150	100	270	450	600	760	925	1125	1300	1700	2100	100
151	30	325	560	725	950	1245	1455	1670	2150		30
152	10	383	700	905	1175	1600	1750	2050	2650		10

Figure 1.4 – Data Sheet – Columns X to AH

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
38	Ratings					Cyclic Ratings					
39	Laid Direct		In Single-Way Duct			Grouped Cables					
40	Cyc Rating	Cont Rating	Cyc Rating	Cont Rating	NAME	Laid Direct - 150mm Spacing			In Single-Way Ducts Touching		
41					No N-E	2	3	4	2	3	4
42	580	510	430	400	3c 300 Waveform	555	545	535	420	410	410
43	515	450	380	355	3c 240 Waveform	495	485	475	370	365	360
44	440	390	325	305	3c 185 Waveform	425	415	405	320	310	310
45	300	270	220	205	3c 95 Waveform	290	280	280	215	210	210
46	145	135	105	100	3c 25 SAC XC Service	140	135	135	105	100	100
47	150	135	110	105	3c 25 SAC XSC Service	145	140	140	110	105	105
48	580	510	430	400	4c 300 Waveform (	555	545	535	420	410	410
49	515	450	380	355	4c 240 Waveform (	495	485	475	370	365	360
50	440	390	325	305	4c 185 Waveform (	425	415	405	320	310	310
51	300	270	220	205	4c 95 Waveform (	290	280	280	215	210	210
52	545	485	410	385	3c 300 Consac	525	510	505	400	395	390
53	405	365	305	290	3c 185 Consac	390	380	375	300	290	290
54	280	255	205	195	3c 95 Consac	270	265	260	200	195	195
55	560	495	420	395	4c 300 SAC (	540	525	520	410	405	400
56	420	375	315	295	4c 185 SAC (	405	395	390	310	300	300
57	325	295	240	230	4c 120 SAC (	310	305	300	235	230	230
58	230	210	175	165	4c 70 SAC (	220	215	215	170	170	165
59	585	520	440	410	4c 0.5 SAC (	560	550	540	430	420	420
60	430	390	325	305	4c 0.3 SAC (	415	405	400	320	310	310
61	340	305	250	240	4c 0.2 SAC (	325	320	315	245	240	240
62	215	195	165	155	4c 0.1 SAC (	205	200	200	160	160	155
63	745	655	565	525	0.5 Cu PILC (	715	700	690	555	540	535
64	565	500	430	400	0.3 Cu PILC (	545	530	525	420	410	410
65	500	450	380	355	0.25 Cu PILC (	480	470	465	370	365	360
66	440	395	335	310	0.2 Cu PILC (	425	415	405	330	320	320
67	375	340	285	260	0.15 Cu PILC (	360	350	345	280	275	270
68	325	295	250	230	0.12 Cu PILC (	310	305	300	245	240	240
69	290	265	225	200	0.1 Cu PILC (	280	270	270	220	215	215
70	240	220	185	170	0.075 Cu PILC (	230	225	220	180	175	175
71	215	200	165	150	0.06 Cu PILC (	205	200	200	160	160	155
72	190	175	140	130	0.05 Cu PILC (	185	180	175	135	135	135
73	170	155	125	115	0.04 Cu PILC (	165	160	155	125	120	120
74	120	115	95	90	0.0225 Cu PILC MAIN	115	115	110	95	90	90
75	125	115	95	95	4c 16 Cu PILC Service	120	115	115	95	90	90
76	120	115	95	90	4c 0.0225 SERVICE	115	115	110	95	90	90
77	90	80	65	55	4c 0.0145 Service	85	85	85	65	60	60
78	228	228			95 ABC (10s clearance)						
79	183	183			70 ABC (10s clearance)						
80	143	143			50 ABC (10s clearance)						
81	117	117			35 ABC (10s clearance)						
82	95	95			25 ABC (10s clearance)						
83	228	228			95 ABC (30s clearance)						
84	183	183			70 ABC (30s clearance)						
85	143	143			50 ABC (30s clearance)						
86	117	117			35 ABC (30s clearance)						
87	95	95			25 ABC (30s clearance)						
88	390	390			100 Al open wire						
89	250	250			50 Al open wire						
90	395	395			0.15 Al (Cu Eq) open w						
91	360	360			0.1 Al (Cu Eq) open w						
92	260	260			0.05 Al (Cu Eq) open w						
93	205	205			0.04 Al (Cu Eq) open w						
94	155	155			0.025 Al (Cu Eq) open w						
95	395	395			0.15 Cu (strand) open w						
96	360	360			0.1 Cu (strand) open w						
97	310	310			0.075 Cu (strand) open w						
98	260	260			0.06 Cu (strand) open w						
99	230	230			0.05 Cu (strand) open w						
100	205	205			0.04 Cu (strand) open w						
101	160	160			0.025 Cu (strand) open w						
102	230	230			0.05 Cu (solid) open w						
103	160	160			0.025 Cu (solid) open w						
104	580	510	430	400		555	545	535	420	410	410
105	515	450	380	355		495	485	475	370	365	360
106	440	390	325	305		425	415	405	320	310	310
107	300	270	220	205		290	280	280	215	210	210
108	560	495	420	395		540	525	520	410	405	400
109	420	375	315	295		405	395	390	310	300	300
110	325	295	240	230		310	305	300	235	230	230
111	230	210	175	165		220	215	215	170	170	165
112	585	520	440	410		560	550	540	430	420	420
113	430	390	325	305		415	405	400	320	310	310
114	340	305	250	240		325	320	315	245	240	240
115	215	195	165	155		205	200	200	160	160	155
116	745	655	565	525		715	700	690	555	540	535
117	565	500	430	400		545	530	525	420	410	410
118	500	450	380	355		480	470	465	370	365	360
119	440	395	335	310		425	415	405	330	320	320
120	375	340	285	260		360	350	345	280	275	270
121	325	295	250	230		310	305	300	245	240	240
122	290	265	225	200		280	270	270	220	215	215
123	240	220	185	170		230	225	220	180	175	175
124	215	200	165	150		205	200	200	160	160	155
125	190	175	140	130		185	180	175	135	135	135
126	170	155	125	115		165	160	155	125	120	120
127	120	115	95	90		115	115	110	95	90	90

15.3 Detailed Calculation' Sheet

The 'Detailed Calculation' Sheet contains the particular elements of data pertinent to the current model network, together with the functions and formulae by which they are processed, in order to produce the results. The layout of the sheet is shown in Figures 2.1, 2.2, 2.3, 2.4 and 2.5, where the cells and ranges described below are highlighted with bold outlines.

15.3.1 Sheet 'Detailed Calculation': Cell B2; Substation HV 3-phase Fault Level (MVA)

This cell contains the fault level (MVA) (three-phase symmetrical) at the HV side of the distribution transformer. It is copied from Sheet 'Inputs and Results' Cell L6 and used to derive an equivalent reactance in Cell D2.

15.3.2 Sheet 'Detailed Calculation': Cell D2; Substation HV Equivalent Reactance (Ω)

This cell calculates the equivalent ohmic reactance for a single-phase to earth fault (or load) at 240V, corresponding to the HV fault level, using the formula (0.1152/B2). The derived value is used in compiling total impedance values for the calculation of loop impedance, fault current and flicker.

NOTE:

When considering three-phase symmetrical faults, the equivalent numerator in this expression is given by:

$$\frac{415.7 \times 415.7}{10^6} = 0.1728$$

For single-phase to neutral faults, with which this workbook is mostly concerned, this is adjusted by the factor:

$$\frac{2}{\left(\sqrt{3}\right)^2}$$

(See ENA ER P28 - Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom, Table C1.)

15.3.3 Sheet 'Detailed Calculation': Cell F2; No of ϕs

This cell contains the number of phases of the LV winding of the transformer. The value is taken from Sheet 'Data' in the Range D13:D35 (column D in the look-up Range C13:F35). It is used in part to determine the load per phase within the network.

15.3.4 Sheet 'Detailed Calculation': Cell G2; Transformer Description

This cell contains the description of the transformer. The value is taken from Sheet 'Inputs and Results' Cell Q6. It is used as a look-up reference within this sheet.

15.3.5 Sheet 'Detailed Calculation': Range H2:I2; Transformer Equivalent Resistance and Reactance (Ω).

The transformer resistance and reactance values are taken from Sheet 'Data' Range E12:F35 (columns E and F in the look-up Range C13:F33) according to the selected transformer type and size.

15.3.6 Sheet 'Detailed Calculation': Cell P2; Loss of Diversity Allowance (kW)

This cell contains the Loss of Diversity Allowance, taken from Sheet 'Inputs and Results' Cell D8. Its value must be either 4 or 8(kW), unless no houses are connected. (See CP226, sub-section 4.2.1.) The allowance is included in the form of a load at the downstream end node of each section, which has houses connected to it (either distributed or at the end-node), or has houses connected downstream of it. The allowance is applied only once to each such section; it is not added into the load imposed upstream.

15.3.7 Sheet 'Detailed Calculation': Cells S2, U2 and W2; ADMD (kW)

These cells contain the ADMD values for up to three different house types. The values are taken from Sheet 'Inputs and Results' Cells J8, M8 and P8.

15.3.8 Sheet 'Detailed Calculation': Cell AC2; Houses Y/N

Set to 1, if any downstream section has houses connected directly to it; otherwise 0. This is used to determine whether a Loss of Diversity allowance is appropriate to the total distributor load. See 15.3.38 and 15.3.43.

15.3.9 Sheet 'Detailed Calculation': Cells AF2; Total load (kW)

This cell totals all downstream loads, but does not include any Loss of Diversity Allowance. This is used to calculate the total load in ampere in Cell AG2. See 15.3.41.

15.3.10 Sheet 'Detailed Calculation': Cells AG2; Total load (A)

This cell calculates the total current in the distributor, using the value in Cell AF2 and including, where appropriate, the Loss of Diversity allowance. See 15.3.42.

15.3.11 Sheet 'Detailed Calculation': Cells AN2:AO2; Substation Equivalent Resistance and Reactance (1-phase Fault) (Ω)

The resistance value in Cell AN2 is copied from Cell H2 (transformer equivalent resistance). The reactance value in Cell AO2 is the sum of Cells D2 (HV equivalent reactance) and I2 (transformer equivalent reactance).

15.3.12 Sheet 'Detailed Calculation': Cell AW2; HV Equivalent Reactance (Flicker) (Ω)

The reactance value from Cell D2, which is the appropriate value for a LV single-phase to neutral/earth circuit, is adjusted, where necessary, according to the connection of the disturbing load. For a three-phase load, the multiplier is 3/2, thus reversing the correction made in Cell D2. (See the note at 15.3.2.) For a two-phase load connected to a three-phase distributor the multiplier is 3 and for a split-phase (480V) load the multiplier is 4.

15.3.13 Sheet 'Detailed Calculation': Cells AX2:AY2; Substation Equivalent Resistance and Reactance (flicker) (Ω)

The resistance value in Cell AX2 is copied from Cell H2 (transformer equivalent resistance). The reactance value in Cell AY2 is the sum of Cells AW2 (HV equivalent reactance) and I2 (transformer equivalent reactance). However, where the load is 2-phase (415V), the transformer impedance values are first multiplied by the voltage adjustment factor ($(\sqrt{3})^2 = 3$) and where the load is split-phase (480V), the transformer impedance values are taken directly from Sheet 'Data', Range H33:I35.

15.3.14 Sheet 'Detailed Calculation': Cell BF2; Disturbing Load Power Factor (cosϕ)

The power factor of the disturbing load is copied from Sheet 'Motors and Flicker', Cell I20.

15.3.15 Sheet 'Detailed Calculation': Cell BG2; Disturbing Load Reactive Factor (sinϕ)

Derived from Cell BF2, using the formula:

$$\sin\phi = \sqrt{1 - \cos^2\phi}$$

15.3.16 Sheet 'Detailed Calculation': Cell CL2; Substation High Voltage (V)

The high end of the normally expected voltage range at the substation LV busbars is calculated from the value taken from the FLA trace of the primary substation voltage (Sheet 'Microgeneration', Cell E7), the low load voltage drop on the HV feeder from a DiNIS study (Sheet 'Microgeneration', Cell E9) and the tapping number of the distribution transformer (Sheet 'Microgeneration', Cell L7). For this purpose the open circuit voltage of the transformer on tap 3 is taken to be 250V.

15.3.17 Sheet 'Detailed Calculation': Cell CM2; Substation Low Voltage (V)

The low end of the normally expected voltage range at the substation LV busbars is calculated from the value taken from the FLA trace of the primary substation voltage (Sheet 'Microgeneration', Cell E8), the high load voltage drop on the HV feeder from a DiNIS study (Sheet 'Microgeneration', Cell E10) and the tapping number of the distribution transformer (Sheet 'Microgeneration', Cell L7). For this purpose the open circuit voltage of the transformer on tap 3 is taken to be 250V.

15.3.18 Sheet 'Detailed Calculation': Range CN2:CP2; Minimum Average Demand (MAD) (kW)

For each customer type, the MAD is copied from Sheet 'Microgeneration', Range O8:O10.

15.3.19 Sheet 'Detailed Calculation': Range CQ2:CS2; Other Customers

For each customer type, the numbers of customers connected to other distributors from the same substation is copied from Sheet 'Microgeneration', Range Q8:Q10.

15.3.20 Sheet 'Detailed Calculation': Cell CT2; Distributor Load per Phase (kW)

The total distributor load per phase is calculated as the sum of the assumed present section load and the downstream load for any section directly connected to the substation (X). Since the connected equipment is expected to include generation, this total can be negative, i.e. energy flow is toward the substation.

15.3.21 Sheet 'Detailed Calculation': Cell CU2; Total Transformer Current (A)

The total MAD of customers connected to other distributors, calculated from Ranges CN2:CP2 and CQ2:CS2 and divided by the number of phases (Cell F2), less the total generation per phase connected to other distributors (Sheet 'Microgeneration', Cell L9) is added to the distributor Load per Phase (Cell CT2), and the total multiplied by 1000/240.

15.3.22 Sheet 'Detailed Calculation': Range CV2:CW2; Transformer Equivalent Impedance (Power Flow) (Ω)

Transformer resistance and reactance values are copied from Range H2:I2.

15.3.23 Sheet 'Detailed Calculation': Cell CX2; Transformer Power Factor

The power factor of the transformer load is copied from Sheet 'Microgeneration', Cell L8.

15.3.24 Sheet 'Detailed Calculation': Cell CY2; Transformer Voltage Drop (Generation plus MAD) (V)

The Transformer Voltage Drop is calculated from the Total Transformer Current (Cell CU2), the Transformer Impedance (Range CV2:CW2) and the Power Factor (Cell CX2).

15.3.25 Sheet 'Detailed Calculation': Cell CZ2; Transformer Voltage Drop (No Generation plus Full Load) (V)

As Cell CY2, but using the Total Transformer Current in Cell AG2.

15.3.26 Sheet 'Detailed Calculation': Range A5:A45; Line Section

Fixed values of the letters "A" to "V" (excluding "I" and "O") and similarly "ZA" to "ZV" are used to denote up to 40 sections of the network, each using only one line type and size. These match the letters in Sheets 'Inputs and Results' and 'Inputs and Results Extension' Ranges B12:B31. "X" (A5) denotes the substation.

15.3.27 Sheet 'Detailed Calculation': Range B6:B45; Upstream Section

For each present section, the letter(s) denoting the upstream section is inserted. The values are taken from Sheets 'Inputs and Results' and 'Inputs and Results Extension' Ranges C12:C31.

15.3.28 Sheet 'Detailed Calculation': Range C6:C45; Length (m)

The length (m) of each section is inserted. The values are taken from Sheets 'Inputs and Results' and 'Inputs and Results Extension' Ranges D12:D31.

15.3.29 Sheet 'Detailed Calculation': Range D6:D45; Line Description

The line description, including type and cross-section, of each section is inserted. The values are taken from Sheet 'Inputs and Results' and 'Inputs and Results Extension' Ranges E12:F31. Where the short Description in Column E is of an SNE cable (with a non-concentric neutral core), this Description ends in "(". In this case the contents of the corresponding cell in Column F (either "SNE)" or "Bond)") is added to (concatenated with) the Description.

15.3.30 Sheet 'Detailed Calculation': Range E6:E45; Section ϕs

For each single-phase section, the value "1" may be inserted and for each 2-phase section the value "2". Values are taken from Sheet 'Inputs and Results' and 'Inputs and Results Extension' (G12:G31). If the number of phases throughout the whole distributor matches the transformer, corresponding entries in this range are unnecessary, but have no effect on the results.

15.3.31 Sheet 'Detailed Calculation': Range F6:F45; No of ϕs

For each section, the number of available phases is calculated. This depends upon the number of LV phases of the transformer and upon the presence of any single-phase or two-phase sections upstream. The value is taken from Cell F2, but is changed to "1" or "2" depending on the connectivity (B6:B45) and the corresponding values of Range E6:E45.

15.3.32 Sheet 'Detailed Calculation': Range G6:N45; Resistance and Reactance: Phase, Neutral and Earth Return (Ω/km)

Resistance and reactance values (Ω/km) for phase and neutral conductors under normal conditions, and phase and earth return conductors under fault conditions of each section are taken from Sheet 'Data' Range E42:L127 (columns E, to L of the look-up Range C42:Y127) according to the line description (D6:D45).

15.3.33 Sheet 'Detailed Calculation': Range O6:P45; Phase and Phase-Neutral Impedance (Ω)

For each section the phase impedance and phase-neutral loop impedance are calculated from its length (C6:C45) and resistance and reactance values (G6:J45), using the basic formula: $Z^2 = R^2 + X^2$.

15.3.34 Sheet 'Detailed Calculation': Range Q6:R45; E/F Loop Resistance and Reactance (Ω)

For each section the earth-loop resistance and reactance are calculated from its length (C6:C45) and phase and earth return resistance and reactance values (K6:N45).

15.3.35 Sheet 'Detailed Calculation': Range S6:Z45; Houses and Point Loads

The numbers of distributed and terminal houses of each type and the sizes of any point loads, single-phase or polyphase, are inserted. The values are taken from Sheet 'Inputs and Results' and 'Inputs and Results Extension' Ranges I12:P31. Where the section is single-phase, the polyphase end-node load (Y6:Y45) is forced to be zero.

15.3.36 Sheet 'Detailed Calculation': Range AA6:AA45; Distributed Houses Load per Phase (kW)

The distributed loads (kW) imposed by the houses of each Type are separately calculated from the ADMDs (S2, U2 and W2) and the numbers of houses (S6:S45, U6:U45 and W6:W45). The results are divided by the number of available phases (F6:F45) to give distributed loads per phase. These totals do not include any Loss of Diversity Allowance.

15.3.37 Sheet 'Detailed Calculation': Range AB6:AB45; Section Houses

All houses from Columns S to X are totalled. The result is used to determine whether each section has houses connected directly to it or downstream of it.

15.3.38 Sheet 'Detailed Calculation': Range AC2:AC45; Houses Y/N

Set to 1, if the present section or any downstream section has houses connected directly to it; otherwise 0. This is used to determine whether a Loss of Diversity allowance is appropriate to the present section. See 15.3.43.

15.3.39 Sheet 'Detailed Calculation': Range AD6:AD45; End Node Houses and Polyphase Load per phase (kW)

The end-node loads (kW) imposed by the houses of each Type are separately calculated from the ADMDs (S2, U2 and W2) and the numbers of houses (T6:T45, V6:V45 and X6:X45) connected at the end node of the present section. To this result is added the end-node polyphase load (kW) (Y6:Y45). This total is then divided by the number of available phases (F6:F45) to give end-node loads per phase, excluding loads entered as "1ϕ End Load". These totals do not include any Loss of Diversity Allowance.

15.3.40 Sheet 'Detailed Calculation': Range AE6:AE45; Assumed Load per Phase as imposed Upstream (kW)

The effective assumed load per phase imposed on the upstream section is totalled. As all loads have been expressed per phase, these are simply added; Z6:Z45 + AA6:AA45 + AD6:AD45. (This effectively, for the purposes of the voltage-drop calculation, imposes the same single-phase load on each of the phases of the upstream section, where this is polyphase.) These totals do not include any Loss of Diversity Allowance. (For a further explanation of this computation, see CP226, Appendix A2.6.4.)

15.3.41 Sheet 'Detailed Calculation': Range AF2:AF45; Downstream Load per Phase (kW)

For each downstream section, its downstream loads (in sections further downstream) and its effective assumed load (AE6:AE45) (as described in 15.3.40) are totalled.

15.3.42 Sheet 'Detailed Calculation': Range AG2:AG45; Section Current (A)

The phase current in each section is calculated by adding the single-phase end-node load (Z6:Z45), the distributed houses load per phase (AA6:AA45), the polyphase end-node load per phase (AD6: AD45), the downstream load (AF6:AF45) per phase and, where applicable (cell in Column AC = 1), the loss of diversity allowance per phase and dividing the total by 0.24 (kV).

NOTE:

The value in Cell AG2 (the total load on the distributor) will differ from that in Cell AG6 (the load on Section A) only in rare cases, where there is more than one section connected immediately downstream of the substation.

15.3.43 Sheet 'Detailed Calculation': Range AH6:AH45; Section Volt Drop (V)

The voltage-drop in each section is calculated. This is **not** obtained directly from the current, previously calculated, and as described in 15.3.42. In single-phase sections, the single-phase end-node load (Z6:Z45), **half** the distributed houses load per phase (AA6:AA45), the end-node load per phase (AD6:AD45) and the downstream load per phase (AF6:AF45)) are totalled, divided by 0.24 (kV) and multiplied by the impedance of the phase-neutral loop (P6:P45). In three-phase and split-phase sections, any single-phase end-node loads are treated as above, but the multiplier for other loads is the phase impedance only (O6:O45). In two-phase sections of three-phase distributors, the multiplier for loads, other than single-phase loads is the mean of the phase impedance and the phase-neutral loop impedance. (By this means account is taken of the current in each phase conductor and an equal current in the neutral.) In each section, which connects any houses, the Loss of Diversity allowance (P2), divided by the number of phases (F6:F45), is added to the load.

15.3.44 Sheet 'Detailed Calculation': Range AI6:AJ45; Upstream and Cumulative Voltage Drop (V)

The cumulative voltage-drop to the end-node of each section is totalled. Whilst these results are listed in Column AJ, Column AI stores the appropriate upstream voltage-drops, copied back from Column AJ, to be added into each downstream total.

15.3.45 Sheet 'Detailed Calculation': Range AK6:AK45; Cumulative Volt Drop (%)

Absolute values of voltage-drop (AJ6:AJ45) are converted to percentage values (multiplied by 100/240).

15.3.46 Sheet 'Detailed Calculation': Range AL6:AO45; Mains only Upstream and Cumulative E/F Loop Resistance and Reactance (Ω)

Cumulative earth-fault loop resistances and reactances to the end-node of each section are totalled. Values for each individual section are taken from Columns Q and R. Whilst the totals are listed in Columns AN and AO, Columns AL and AM store the appropriate upstream resistances and reactances, copied back from Column AN and AO, to be added into each downstream total. These values are for mains and three-phase services only, not including the equivalent resistance and reactance of the substation.

15.3.47 Sheet 'Detailed Calculation': Range AP6:AP45; Mains Only Cumulative E/F Loop Impedance (Ω)

Cumulative earth-fault loop impedances are calculated from Range AN6:AO45, using the formula: $Z^2 = R^2 + X^2$.

15.3.48 Sheet 'Detailed Calculation': Range AQ6:AQ45; Total (S/S and Mains) Cumulative E/F Loop Impedance (Ω)

Total earth fault loop impedances are calculated from Cells AN2 and AO2 added to Range AN6:AO45, and then using the formula: $Z^2 = R^2 + X^2$.

15.3.49 Sheet 'Detailed Calculation': Range AR6:AR45; Earth Fault Loop Current (A)

Earth-fault currents (for faults at end-nodes) are calculated (I = 204/Z). The reduced voltage of 204V (85%) is used here in accordance with CP331 (sections 3.4.3 and 4.4.4), in order to model the impedance of the fault arc. The value of Z here is taken as the appropriate values in Column AQ. Where the present section is a 3-phase small-section service cable, the fault current appropriate to the upstream section is inserted; this is to ensure that the fault current (and hence the fuse rating) appropriate to no upstream section is reduced, in order to take account of the service cable.

15.3.50 Sheet 'Detailed Calculation': Range AS6:AS25; (First Sheet) Least Downstream E/F Loop Current (A)

For each present section within the first 20 sections, which has a downstream section, the value of fault current in Column AR is reduced, in this column, to that of the least of any section downstream. Where there is no downstream section, the fault current for the present section is copied from Column AR.

Within this range, a match (between the present section Column A and any section Column B, indicating a downstream connection) is sought with any section within the first 20 sections. Wherever there is a match, the E/F Loop Currents (Column AR) for those downstream sections are compared with the Least Downstream E/F Loop Currents (Column AS) for those downstream sections. This comparison does also include the Least Downstream E/F Loop Currents in downstream sections within the second 20 sections, since the values in Column AT are also compared and the least value of all inserted. The resulting values in this range are used to determine the fuse ratings in the Range AU6:AU25.

15.3.51 Sheet 'Detailed Calculation': Range AT6:AT25; (Extension Sheet) Least Downstream E/F Loop Current (A)

This range deals with another part of the same process as described in 15.3.50. It deals with each present section within the first 20 sections, which has a downstream section within the second 20 sections. As described above the resulting values are also brought into the comparison made in Column AS.

15.3.52 Sheet 'Detailed Calculation': Range AT26:AT45; (Extension Sheet) Least Downstream E/F Loop Current (A)

This range also deals with another part of the same process as described in 15.3.50. It deals with each present section within the second 20 sections, which has a downstream section within the second 20 sections. The resulting values in this range are used to determine the fuse ratings in the Range AU26:AU45.

NOTE:

The process described in 15.3.50 to 15.3.52 is divided into these three parts, in order to avoid formulae within the Excel spreadsheet exceeding the limit of 1000 characters.

15.3.53 Sheet 'Detailed Calculation': Range AU6:AU47; Largest Fuse to Protect Section (A)

The maximum acceptable fuse rating, to protect each section is deduced. The data used in this search are on Sheet 'Data' (C42:V127). The line type and size (D6:D25) is used to select the range of minimum fusing currents, appropriate to that line type and size, according to the fuse rating used. This range of minimum fusing currents is used to seek a match for the least earth-fault current (AS6:AS25 and AT26:AT45), the value selected being the largest fusing current less than the earth-fault current. Dummy data entered against service cables ensure that service cables are always allocated 630A fuses. (See 15.2.23.) This value of least earth-fault current identifies the largest acceptable fuse rating for each section, using Sheet 'Data', Range N41:V41. The smallest fuse rating for all sections together is placed in Cell AU47. For more detail of this formula, see Appendix K2.

15.3.54 Sheet 'Detailed Calculation': Range AV6:BC45; Upstream and Cumulative Phase and Neutral Resistance and Reactance (Ω)

Cumulative phase and neutral resistances and reactances to the end-node of each section are totalled. Values for each individual section are taken from Columns G, H, I and J. Whilst the totals are listed in Columns AX, AY, BB and BC, Columns AV, AW, AZ and BA store the appropriate upstream resistances and reactances, copied back from Columns AX, AY, BB and BC, to be added into each downstream total.

15.3.55 Sheet 'Detailed Calculation': Cell BD5; Dirty Load Phases

This cell contains the number of phases of a disturbing load, selected to be connected at one end-node. The cell is populated from Sheet 'Motors and Flicker' Cell N18.

15.3.56 Sheet 'Detailed Calculation': Range BE5:BE45; Customer Connection Path

Set to 1, where the present section is part of the connection path from the substation to the customer (disturbing load); otherwise 0. The value of the cell corresponding to the customer's connection (Sheet 'Motors and Flicker', Cell N25) is set to 1. Also, the value of any cell is set to 1, where the cell representing the downstream section is set to 1. This provides a check, used by Sheet 'Motors and Flicker', Cell O24, that the customer is correctly connected downstream of the PCC.

15.3.57 Sheet 'Detailed Calculation': Range BF5:BF45; Volt Dip per Ampere (at PCC) (V/A)

The voltage-dip (flicker) per ampere is calculated from the values in Range AX2:AY45 for three-phase or the Ranges AX2:AY45, BB6:BC45 for single-phase loads, taking the power factor (cosϕ) of Cell BF2 and the reactive factor (sinϕ) value of Cell BG2. Cell BF5 calculates only the substation impedance, from Cells AX2 and AY2, while in Range BF6:BF45 the appropriate section impedance values are included.

15.3.58 Sheet 'Detailed Calculation': Cell BF47; Volt Dip (at PCC, for given step change in current) (%)

The voltage dip (%) at the PCC, caused by the given step change in current (Cell M42 of Sheet 'Motors and Flicker') is calculated by multiplying that value by the voltage dip per ampere at the PCC (looked up in the Range BF5:BF45) and dividing the result by 4.8 for split phase, 4.16 for two phase and 2.4 for other (single phase and three phase) loads.

15.3.59 Sheet ‘Detailed Calculation’: Range BG6:BH45; Greatest Starting Currents (A)

The incremental current, resulting in 1% (BG) and 3% (BH) flicker is calculated from the voltage-dip per ampere values in Range BF6:BF45, based on 240V (1% is 2.4V; 3% is 7.2V.), for 2-phase loads on 415V (1% is 4.16V, 3% is 12.48V) or, for split-phase loads, on 480V (1% is 4.8V; 3% is 14.4V.).5.2.60

15.3.60 Sheet ‘Detailed Calculation’: Range BI6:BJ45; Single-phase Service Total Resistance and Reactance (Ω)

Where details of services connected to a section have been entered (Sheet ‘Inputs and Results’, Range C35:E37), the total resistances and reactances (phase-neutral loop) are calculated. If more than one service type is listed against the same section, the calculation will be for that listed first (highest in the list).

15.3.61 Sheet ‘Detailed Calculation’: Range BK5:BK45; Volt Dip per Ampere (Customer) (V/A)

Where the number of phases of the disturbing load is entered as ‘1’ (Sheet ‘Motors and Flicker’, Cell N18) and details of a single-phase service are entered, the values from Range BF6:BF45 are modified, to take account of the impedance of the service.

15.3.62 Sheet ‘Detailed Calculation’: Range BL5:BM45; Voltage Dip at Customer, Frequent and Infrequent Start (%)

The Voltage Dip downstream of each section, including, where appropriate, a single-phase service, is calculated from the impedances in Range BK5:BK45 and the Greatest Starting Currents in the Range BG6:BH45 and expressed as a percentage of 240V (÷ 2.4), or, for split-phase, 480V (÷ 4.8).

NOTE: Columns BN to BQ are not used.

15.3.63 Sheet ‘Detailed Calculation’: Range BR6:BR45; 100A Fuse - Unprotected Length (m)

Each section is first checked to determine whether it is thermally limited. For this situation, two conditions must be satisfied:

- The minimum fusing current for the section, when protected by a 100A fuse (Sheet ‘Data’, Column N), exceeds the current required to blow a 100A fuse in the required maximum clearance time. This time is found in Sheet ‘Data’, Column W and is used to find the appropriate fuse clearance current in Rows 150:152 (Column N).

- The minimum fusing current for the section, when protected by a 100A fuse (Sheet ‘Data’, Column N), exceeds the current in a fault at or beyond the downstream end of the section (Column AS, for the first 20 sections, thereafter, Column AT).

If both of the above conditions are satisfied, the result is the entire length of the section (from Column C).

Otherwise, the difference between the actual cumulative earth-fault loop-impedance and the maximum impedance at which a 100A fuse would operate within the maximum time (See CP331.) is calculated. (This difference is calculated as the total actual cumulative earth-fault loop-impedance (Column AQ) minus the maximum impedance (204V divided by the minimum fusing current, as in Sheet 'Data, Column N).) This difference is then multiplied by the length of the section (Column C) and divided by the impedance of the section (Columns Q and R), to give a length, which might be negative, indicating total protection of the section, or might exceed the length of the section, indicating no protection of the section. This result is used in Sheet 'Unprotected Lengths' to give the actual length of the section, which is unprotected.

For more details of this formula, see Appendix K3.

15.3.64 Sheet 'Detailed Calculation': Range BS6:BZ45; 160A to 630A Fuse - Unprotected Length (m)

The computation in these columns follows the exactly corresponding pattern as in Column BR, as described in 15.3.63. In place of Sheet 'Data', Column N, the appropriate column in the range O:V is used.

15.3.65 Sheet 'Detailed Calculation': Range CA6:CA45; 100A Fuse - Slow Clearance

The difference between the actual cumulative earth-fault loop-impedance and the maximum impedance at which a 100A fuse would operate within the maximum time (See CP331.) is calculated. (This difference is calculated as the total actual cumulative earth-fault loop-impedance (Column AQ) minus the maximum impedance (204V divided by the minimum fusing current, as in Sheet 'Data, Column N).) This difference is then multiplied by the length of the section (Column C) and divided by the impedance of the section (Columns Q and R), to give a length, which might be negative, indicating that a fault anywhere in the section would be cleared within the maximum clearance time, or might exceed the length of the section, indicating that the clearance of any fault within the section would exceed the maximum time. This result is used in Sheet 'Slow Fault Clearance' to give the actual length of the section, in which the maximum fault clearance time is exceeded.

15.3.66 Sheet 'Detailed Calculation': Range CB6:CI45; 160A to 630A Fuse - Slow Clearance

The computation in these columns follows the exactly corresponding pattern as in Column CA, as described in 15.3.65. In place of Sheet 'Data', Column N, the appropriate column in the range O:V is used.

NOTE: Columns CJ and CK are not used.

15.3.67 Sheet 'Detailed Calculation': Range CM6:CM45; Polyphase Point MAD at End Node (kW)

For each polyphase section, the polyphase point MAD at the end node is copied from Sheet 'Microgeneration', Ranges C15:C34 and N15:N34.

15.3.68 Sheet 'Detailed Calculation': Range CN6:CN45; Polyphase Generation at End Node (kW)

For each polyphase section, the polyphase generation at the end node is copied from Sheet 'Microgeneration', Ranges D15:D34 and O15:O34, but is made negative.

15.3.69 Sheet 'Detailed Calculation': Range CO6:CO45; Single Phase Point MAD at End Node (kW)

Single phase point MAD at the end node is copied from Sheet 'Microgeneration', Ranges E15:E34 and P15:P34.

15.3.70 Sheet 'Detailed Calculation': Range CP6:CP45; Single Phase Generation at End Node (kW)

Single phase generation at the end node is copied from Sheet 'Microgeneration', Ranges F15:F34 and Q15:Q34, but is made negative.

15.3.71 Sheet 'Detailed Calculation': Range CQ6:CQ45; Distributed Houses MAD per Phase (kW)

The distributed MAD (kW) imposed by the houses of each Type is separately calculated from the MADs (Cells CN2, CO2 and CP2) and the numbers of houses (Ranges S6:S45, U6:U45 and W6:W45). The results are divided by the number of available phases (Range F6:F45) to give distributed MAD per phase.

15.3.72 Sheet 'Detailed Calculation': Range CR6:CR45; End Node Houses MAD per Phase (kW)

The end node MAD (kW) imposed by the houses of each Type are separately calculated from the MADs (Cells CN2, CO2 and CP2) and the numbers of houses (Ranges T6:T45, V6:V45 and X6:X45). The results are divided by the number of available phases (Range F6:F45) to give end node houses MAD per phase.

15.3.73 Sheet 'Detailed Calculation': Range CS6:CS45; Assumed Section Load per Phase as imposed Upstream (kW)

The polyphase point MAD at the end node (Column CM) and the polyphase generation at the end node (Column CN) are added (generation is negative) and divided by the number of phases (Column F); to this total are added the single phase point MAD at the end node (Column CO), the single phase generation at the end node (Column CP) (generation is negative), the distributed houses MAD per phase (Column CQ), the end node houses MAD per phase (Column CR) and, where there is a single-phase service connected, the single-phase generation on that service (the first applicable service in the list) (Range CP47:CP49).

15.3.74 Sheet 'Detailed Calculation': Range CT6:CT45; Downstream Load per Phase (kW)

For each downstream section, its downstream loads (in sections further downstream) and its effective assumed load (CS6:CS45) (as described in 15.3.73) are totalled.

15.3.75 Sheet 'Detailed Calculation': Range CU6:CU45; Section Phase Current (A)

The current flowing downstream into the upstream end of the section is calculated from the sum of the assumed section load (Column CS) and the downstream load (Column CT), multiplied by 1000/240. Where net energy flow is toward the substation, this value is negative.

15.3.76 Sheet 'Detailed Calculation': Range CV6:CV45; Unbalance Factor (pu)

For each section in which the downstream load (Column CT) is negative (generation exceeds load) the Unbalance Factor is copied from Sheet 'Microgeneration', Cell L10. This is to take account of the likelihood that generation will be single phase and in small numbers, thus, in polyphase sections not being balanced across the phases.

15.3.77 Sheet 'Detailed Calculation': Range CW6:CW45; Section Volt Drop (V)

The voltage drop in each section is calculated. In a single-phase section, or a two-phase section of a three-phase distributor, this is the phase/neutral loop impedance (Column P) divided by 0.24 (kV), multiplied by the sum of the single-phase point MAD (Column CO), the single-phase generation (Column CP), half the distributed houses MAD (Column CQ), the end-node houses MAD (Column CR), the downstream load (Column CT) and, where there is a single-phase service connected, the single-phase generation on that service (the first applicable service in the list) (Range CP47:CP49).

In a polyphase section, this is the sum of three components:

- the phase impedance (Column O) divided by 0.24 (kV), multiplied by the sum of a third of the three-phase point MAD (Column CM), a third of the three-phase generation (Column CN), half the distributed houses MAD (Column CQ), the end-node houses MAD (Column CR) and the downstream load (Column CT); plus

- the neutral impedance (derived from Columns C, I and J), multiplied by the unbalance factor and divided by 0.24 (kV), multiplied by the downstream load (Column CT); plus

- the phase/neutral loop impedance (Column P) divided by 0.24 (kV), multiplied by the sum of the single-phase point MAD (Column CO), the single-phase generation (Column CP) and, where there is a single-phase service connected, the single-phase generation on that service (the first applicable service in the list) (Range CP47:CP49).

NOTE:

In this context, "polyphase" may include split-phase. However, in such case the values of three-phase quantities must be zero.

15.3.78 Sheet 'Detailed Calculation': Range CX6:CY45; Upstream and Cumulative Voltage Drop (V)

The cumulative voltage-drop to the end-node of each section is totalled. Whilst these results are listed in Column CY, Column CX stores the appropriate upstream voltage-drops, copied back from Column CY, to be added into each downstream total.

15.3.79 Sheet 'Detailed Calculation': Range CZ6:CZ45; Voltage at End Node (High) (V)

The voltage at the end node of each section is calculated as the Substation High Voltage (Cell CL2) minus the Transformer Volt Drop (Generation plus MAD) (CellCY2) and minus the Total Volt Drop to the End Node (Column CY). (Voltage rise, caused by energy flow toward the substation, is negative.)

15.3.80 Sheet 'Detailed Calculation': Range B47:B49; Services: Upstream Section

For each service type, the letter denoting the section (in practice, the worst case), to which the service is connected, is inserted. The values are taken from Sheet 'Inputs and Results' Range C35:C37.

15.3.81 Sheet 'Detailed Calculation': Range C47:C49; Service Length (m)

The length of each service type (m) is inserted. The values are taken from Sheet 'Inputs and Results' Range D35:D37.

15.3.82 Sheet 'Detailed Calculation': Range D47:D49; Service Description

The service description, including type and cross-section, of each service type is inserted. The values are taken from Sheet 'Inputs and Results' Range E35:E37.

15.3.83 Sheet 'Detailed Calculation': Range G47:R49; Service Resistance, Reactance and Impedance (Ω/km, Ω)

The various resistance reactance and impedance values are derived, using corresponding formulae to those used above for main line sections. Refer to 15.3.32 to 15.3.34 above.

15.3.84 Sheet 'Detailed Calculation': Range AD47:AD49; Service Load (kW)

The maximum demand on each service type is calculated. Where the service cable is of a small section street-lighting type, no loss of diversity allowance is included. For domestic services, where the loss of diversity allowance is 4 (kW) the installed load is reverse calculated as 1.25 (ADMD - 0.5); the loss of diversity of 4 (kW) is then added, to arrive at the (night-time) service load. Otherwise the (day-time) service load is the loss of diversity allowance (8kW) plus twice the ADMD (S2, U2 or W2).

15.3.85 Sheet 'Detailed Calculation': Range AG47:AG49; Service Current (A)

The maximum current in each service type is derived from the maximum demand (AD47:AD49).

15.3.86 Sheet 'Detailed Calculation': Range AH47:AH49; Service Volt Drop (V)

The service voltage drop is calculated as the product of the maximum current (AG47:AG49) and the phase-neutral impedance (P47:P49).

15.3.87 Sheet 'Detailed Calculation': Range AI47:AI49; Mains Volt Drop (V)

The upstream (mains) voltage drop is derived from the Range AJ6:AJ45, according to the upstream section selected for each service type.

15.3.88 Sheet 'Detailed Calculation': Range AJ47:AJ49; Total Volt Drop (V)

The total voltage drop (V) is the sum of the service voltage drop (AH47:AH49) and the upstream (mains) voltage drop (AI47:AI49).

15.3.89 Sheet 'Detailed Calculation': Range AK47:AK49; Total Volt Drop (%)

The total voltage drop (%) is derived from the Range AJ47:AJ49.

15.3.90 Sheet 'Detailed Calculation': Range AO47:AO49; Service E/F Loop Impedance (Ω)

The service loop impedance is derived from the loop resistance (Q47:Q49) and reactance (R47:R49), using the basic formula: $Z^2 = R^2 + X^2$.

15.3.91 Sheet 'Detailed Calculation': Range AP47:AP49; Total E/F Loop Impedance (Ω)

The total loop impedance is calculated, using the formula $Z^2 = R^2 + X^2$, from the sums of the upstream loop resistance (AN6:AN45), the substation equivalent resistance (AN2) and the service loop resistance (Q47:Q49), and the upstream loop reactance (AO6:AO45) the substation equivalent reactance (AO2) and the service loop reactance (R47:R49).

15.3.92 Sheet 'Detailed Calculation': Range AQ47:AQ49; Loop impedance warnings

Conditional on the value of the total loop impedance (AP47:AP49): "Loop Z high for CNE network" for values over 0.35 (Ω), "Loop Z high; max c/o fuse 80A" for values over 0.54 (Ω) and "Loop Z excessive" for values over 0.8(Ω)

15.3.93 Sheet 'Detailed Calculation': Range CP47:CP49; Single-phase Service-connected Generation (kW)

The rating of generation connected to single-phase services are copied from Sheet 'Microgeneration' Range P8:P10 but is made negative.

15.3.94 Sheet 'Detailed Calculation': Range CR47:CR49; Single-phase Service MAD (kW)

The MAD for each service type is copied from the Range CN2:CP2.

15.3.95 Sheet 'Detailed Calculation': Range CS47:CS49; Service Load (kW)

The service load for each service type is calculated by adding the Generation (negative) (Column CP) and the MAD (Column CR).

15.3.96 Sheet 'Detailed Calculation': Range CU47:CU49; Service Current (A)

The service current is calculated from the service load (Column CS) by multiplying by 1000/240.

15.3.97 Sheet 'Detailed Calculation': Range CW47:CW49; Service Volt Drop (V)

The service volt drop is calculated as the product of the service phase and neutral impedance (Column P) and the service current (Column CU).

15.3.98 Sheet 'Detailed Calculation': Range CZ47:CZ49; Total Volt Drop (V)

The total voltage drop is calculated by subtracting the service voltage drop (Range CW47:CW49) from the voltage at the end node of the section (Range CZ6:CZ45), to which the service is connected.

Figure 2.1 – Detailed Calculations Sheet – Columns A to Z

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	Substation	HV 3-phase Fault Level (MVA)		HV Equivalent Reactance (Single-phase to neutral) (Ω)		No of φs	Transformer Description	Transformer Equivalent Resistance (Ω)	Transformer Equivalent Reactance (Ω)							Loss of Diversity Allowance (kW)			ADMD A		ADMD B		ADMD C			
2	X	200		0.000576		3	3φ 800kVA	0.00268	0.00986							8			3.4		0		0			
3			← Basic Data →																← Houses Type A →		← Houses Type B →		← Houses Type C →		← Point Loads →	
4	Line Section	Upstream Section	Length (m)	Line Description	Sect φs	No of φs	Normal Phase Resistance per km (Ω/km)	Normal Phase Reactance per km (Ω/km)	Normal Neutral Resistance per km (Ω/km)	Normal Neutral Reactance per km (Ω/km)	Fault Phase Resistance per km (Ω/km)	Fault Phase Reactance per km (Ω/km)	Fault ECC Resistance per km (Ω/km)	Fault ECC Reactance per km (Ω/km)	Section Normal Phase Impedance (Ω)	Section Normal Phase/ Neutral Impedance (Ω)	Section E/F Loop Resistance (Ω)	Section E/F Loop Reactance (Ω)	Distributed	Connected at End Node	Distributed	Connected at End Node	Distributed	Connected at End Node	Polyphase Point Load at End Node (kW)	1φ Point Load at End Node (kW)
5	X			Substation		3																				
6	A	X	110	3c 185 Waveform	0	3	0.166	0.074	0.166	0.013	0.186	0.074	0.166	0.013	0.0199922	0.0377531	0.03872	0.00957	21	0	0	0	0	0	0	0
7	B	a	30	3c 95 Waveform	0	3	0.322	0.074	0.322	0.017	0.361	0.074	0.322	0.017	0.0099118	0.0195119	0.02049	0.00273	0	0	0	0	0	0	0	0
8	C	b	130	3c 95 Waveform	0	3	0.322	0.074	0.322	0.017	0.361	0.074	0.322	0.017	0.0429512	0.0845517	0.08879	0.01183	27	0	0	0	0	0	0	0
9	D	a	150	3c 95 Waveform	0	3	0.322	0.074	0.322	0.017	0.361	0.074	0.322	0.017	0.0495591	0.0975596	0.10245	0.01365	24	0	0	0	0	0	0	0
10	E		0	0	0												0	0	0	0	0	0	0	0	0	0
11	F		0	0	0												0	0	0	0	0	0	0	0	0	0
12	G		0	0	0												0	0	0	0	0	0	0	0	0	0
13	H		0	0	0												0	0	0	0	0	0	0	0	0	0
14	J		0	0	0												0	0	0	0	0	0	0	0	0	0
15	K		0	0	0												0	0	0	0	0	0	0	0	0	0
16	L		0	0	0												0	0	0	0	0	0	0	0	0	0
17	M		0	0	0												0	0	0	0	0	0	0	0	0	0
18	N		0	0	0												0	0	0	0	0	0	0	0	0	0
19	P		0	0	0												0	0	0	0	0	0	0	0	0	0
20	Q		0	0	0												0	0	0	0	0	0	0	0	0	0
21	R		0	0	0												0	0	0	0	0	0	0	0	0	0
22	S		0	0	0												0	0	0	0	0	0	0	0	0	0
23	T		0	0	0												0	0	0	0	0	0	0	0	0	0
24	U		0	0	0												0	0	0	0	0	0	0	0	0	0
25	V		0	0	0												0	0	0	0	0	0	0	0	0	0
26	ZA		0	0	0												0	0	0	0	0	0	0	0	0	0
27	ZB		0	0	0												0	0	0	0	0	0	0	0	0	0
28	ZC		0	0	0												0	0	0	0	0	0	0	0	0	0
29	ZD		0	0	0												0	0	0	0	0	0	0	0	0	0
30	ZE		0	0	0												0	0	0	0	0	0	0	0	0	0
31	ZF		0	0	0												0	0	0	0	0	0	0	0	0	0
32	ZG		0	0	0												0	0	0	0	0	0	0	0	0	0
33	ZH		0	0	0												0	0	0	0	0	0	0	0	0	0
34	ZJ		0	0	0												0	0	0	0	0	0	0	0	0	0
35	ZK		0	0	0												0	0	0	0	0	0	0	0	0	0
36	ZL		0	0	0												0	0	0	0	0	0	0	0	0	0
37	ZM		0	0	0												0	0	0	0	0	0	0	0	0	0
38	ZN		0	0	0												0	0	0	0	0	0	0	0	0	0
39	ZP		0	0	0												0	0	0	0	0	0	0	0	0	0
40	ZQ		0	0	0												0	0	0	0	0	0	0	0	0	0
41	ZR		0	0	0												0	0	0	0	0	0	0	0	0	0
42	ZS		0	0	0												0	0	0	0	0	0	0	0	0	0
43	ZT		0	0	0												0	0	0	0	0	0	0	0	0	0
44	ZU		0	0	0												0	0	0	0	0	0	0	0	0	0
45	ZV		0	0	0												0	0	0	0	0	0	0	0	0	0
46	Services																									
47	Type A	c	10	35 SAC XC			0.868	0.077	0.91	0.077	0.9729412	0.077	0.91	0.077	0.0087141	0.0178466	0.0188294	0.00154								
48	Type B		0	0			0	0	0	0	0	0														
49	Type C		0	0			0	0	0	0	0	0														

Figure 2.2 – Detailed Calculations Sheet – Columns AA to AU

	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1														Substation Equivalent Resistance (1φ Fault) (Ω)	Substation Equivalent Reactance (1φ Fault) (Ω)						
2			1			81.6	351							0.00268	0.010436						
3	Volt Drop											E/F Loop Impedance						Fault and Fuse Protection			
4	Distributed Houses Load per Phase (kW)	Section Houses	Houses Yes/No	End Node Houses and Polyphase Load per Phase (kW)	Assumed Load per Phase, as imposed Upstream (kW)	Downstream Load per Phase (kW)	Section Current (A)	Section Volt drop (V)	Upstream Volt-drop (V)	Total Volt-drop to End Node of Section (V)	Total Volt-drop to End Node of Section (%)	Mains only Upstream E/F Loop Resistance (Ω)	Mains only Upstream E/F Loop Reactance (Ω)	Mains only Cumulative E/F Loop Resistance (Ω)	Mains only Cumulative E/F Loop Reactance (Ω)	Mains only Cumulative E/F Loop Impedance (Ω)	Total (S/S + Mains) Cumulative E/F Loop Impedance (Ω)	(S/S + Mains Imped'nce) E/F Loop Current (A)	(First Sheet) Least Downstrem E/F Loop Current (A)	(Extension Sheet) Least Downstrem E/F Loop Current (A)	Largest Fuse to Protect Section (A)
5			1																		
6	23.8	21	1	0	23.8	57.8	351	6.0281971	0	6.0281971	2.5117488	0	0	0.03872	0.00957	0.0398851	0.0459804	4436.67	1319.5864	99999	400
7	0	0	1	0	0	30.6	139	1.3738872	6.0281971	7.4020843	3.0842018	0.03872	0.00957	0.05921	0.0123	0.0604741	0.065934	3094.0012	1319.5864	99999	355
8	30.6	27	1	0	30.6	0	139	3.2153732	7.4020843	10.617457	4.4239406	0.05921	0.0123	0.148	0.02413	0.1499542	0.1545939	1319.5864	1319.5864	99999	355
9	27.2	24	1	0	27.2	0	124	3.3590027	6.0281971	9.3871998	3.9113333	0.03872	0.00957	0.14117	0.02322	0.1430669	0.1477347	1380.8534	1380.8534	99999	355
10		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
11		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
12		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
13		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
14		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
15		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
16		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
17		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
18		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
19		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
20		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
21		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
22		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
23		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
24		0	0		0	0			0			0	0	0	0	0	0.0107746		99999		
25		0	0		0	0			0			0	0	0	0	0	0.0107746		0		
26		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
27		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
28		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
29		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
30		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
31		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
32		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
33		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
34		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
35		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
36		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
37		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
38		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
39		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
40		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
41		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
42		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
43		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
44		0	0		0	0			0			0	0	0	0	0	0.0107746			99999	
45		0	0		0	0			0			0	0	0	0	0	0.0107746				
46															Serv.LoopZ	Total Loop Z					Max Fuse
47				14.8			62	1.1005384	10.617457	11.717996	4.8824983				0.0188929	0.1733127					355
48				8			33	0	0	0	0				0	#N/A	#N/A				
49				8			33	0	0	0	0				0	#N/A	#N/A				

Figure 2.3 – Detailed Calculations Sheet – Columns AV to BM

	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM
1		HV Equivalent Reactance (Flicker) (Ω)	Substation Equivalent Resistance (Flicker) (Ω)	Substation Equivalent Reactance (Flicker) (Ω)							Power Factor (cos ϕ)	Reactive Factor (sin ϕ)						
2		0.000864	0.00268	0.010724							0.30	0.9539392						
3	Motor Starting and Flicker																	
4	Upstream Phase Resistance (Ω)	Upstream Phase Reactance (Ω)	Cumulative Phase Resistance (Ω)	Cumulative Phase Reactance (Ω)	Upstream Neutral Resistance (Ω)	Upstream Neutral Reactance (Ω)	Cumulative Neutral Resistance (Ω)	Cumulative Neutral Reactance (Ω)	Dirty Load Phases	Customer Conn Path	Volt Dip per Ampere (at PCC) (0.3 pf) (V/A)	Greatest Starting Current - Frequent Start (1%) (A)	Greatest Starting Current - Infrequent Start (3%) (A)	Single-phase Service Total Resistance (Ω)	Single-phase Service Total Reactance (Ω)	Total Volt Dip per Ampere (Customer) (0.3 pf) (V/A)	Voltage Dip at Customer Frequent Start (%)	Voltage Dip at Customer Infrequent Start (%)
5									3	1	0.011034	218	653			0.01103404	0.3766804	1.1300412
6	0	0	0.01826	0.00814	0	0	0.01826	0.00143		1	0.0242771	99	297	0	0	0.02427711	0.8287724	2.4863172
7	0.01826	0.00814	0.02792	0.01036	0.01826	0.00143	0.02792	0.00194		1	0.0292929	82	246	0	0	0.02929285	1	3
8	0.02792	0.01036	0.06978	0.01998	0.02792	0.00194	0.06978	0.00415		1	0.0510277	47	141	0.01778	0.00154	0.05102775	1.7419863	5.2259588
9	0.01826	0.00814	0.06656	0.01924	0.01826	0.00143	0.06656	0.00398		0	0.0493558	49	146	0	0	0.04935583	1.6849104	5.0547312
10	0	0			0	0				0	0			0	0	0	0	0
11	0	0			0	0				0	0			0	0	0	0	0
12	0	0			0	0				0	0			0	0	0	0	0
13	0	0			0	0				0	0			0	0	0	0	0
14	0	0			0	0				0	0			0	0	0	0	0
15	0	0			0	0				0	0			0	0	0	0	0
16	0	0			0	0				0	0			0	0	0	0	0
17	0	0			0	0				0	0			0	0	0	0	0
18	0	0			0	0				0	0			0	0	0	0	0
19	0	0			0	0				0	0			0	0	0	0	0
20	0	0			0	0				0	0			0	0	0	0	0
21	0	0			0	0				0	0			0	0	0	0	0
22	0	0			0	0				0	0			0	0	0	0	0
23	0	0			0	0				0	0			0	0	0	0	0
24	0	0			0	0				0	0			0	0	0	0	0
25	0	0			0	0				0	0			0	0	0	0	0
26	0	0			0	0				0	0			0	0	0	0	0
27	0	0			0	0				0	0			0	0	0	0	0
28	0	0			0	0				0	0			0	0	0	0	0
29	0	0			0	0				0	0			0	0	0	0	0
30	0	0			0	0				0	0			0	0	0	0	0
31	0	0			0	0				0	0			0	0	0	0	0
32	0	0			0	0				0	0			0	0	0	0	0
33	0	0			0	0				0	0			0	0	0	0	0
34	0	0			0	0				0	0			0	0	0	0	0
35	0	0			0	0				0	0			0	0	0	0	0
36	0	0			0	0				0	0			0	0	0	0	0
37	0	0			0	0				0	0			0	0	0	0	0
38	0	0			0	0				0	0			0	0	0	0	0
39	0	0			0	0				0	0			0	0	0	0	0
40	0	0			0	0				0	0			0	0	0	0	0
41	0	0			0	0				0	0			0	0	0	0	0
42	0	0			0	0				0	0			0	0	0	0	0
43	0	0			0	0				0	0			0	0	0	0	0
44	0	0			0	0				0	0			0	0	0	0	0
45	0	0			0	0				0	0			0	0	0	0	0
46											Voltage dip (%)							
47											2.4410712							

Figure 2.4 Detailed Calculations Sheet – Columns BR to CI

	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI
1																		
2																		
3	Unprotected Lengths									Slow Clearance Lengths								
4	100A Fuse - Unprotected Length (m)	160A Fuse - Unprotected Length (m)	200A Fuse - Unprotected Length (m)	250A Fuse - Unprotected Length (m)	315A Fuse - Unprotected Length (m)	355A Fuse - Unprotected Length (m)	400A Fuse - Unprotected Length (m)	500A Fuse - Unprotected Length (m)	630A Fuse - Unprotected Length (m)	100A Fuse - Slow-clearance Length (m)	160A Fuse - Slow-clearance Length (m)	200A Fuse - Slow-clearance Length (m)	250A Fuse - Slow-clearance Length (m)	315A Fuse - Slow-clearance Length (m)	355A Fuse - Slow-clearance Length (m)	400A Fuse - Slow-clearance Length (m)	500A Fuse - Slow-clearance Length (m)	630A Fuse - Slow-clearance Length (m)
5																		
6	-1957	-1123	-811	-613	-481	-373	-306	-204	110	-1957	-1123	-811	-613	-481	-373	-306	-204	-120
7	-1001	-562	-398	-294	-224	-137	30	30	30	-1001	-562	-398	-294	-224	-137	-89	-28	22
8	-872	-434	-269	-165	-96	-8	130	130	130	-872	-434	-269	-165	-96	-8	39	101	150
9	-882	-444	-279	-175	-106	-18	150	150	150	-882	-444	-279	-175	-106	-18	29	91	140
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
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38																		
39																		
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42																		
43																		
44																		
45																		
46																		
47																		
48																		
49																		

Figure 2.5 – Detailed Calculations Sheet – Columns CL to CZ

	CL	CM	CN	CO	CP	CQ	CR	CS	CT	CU	CV	CW	CX	CY	CZ
1	Substation High Voltage (V)	Substation Low Voltage (V)	MAD A (kW)	MAD B (kW)	MAD C (kW)	Other A Customers	Other B Customers	Other C Customers	Distributor Load per Phase (kW)	Total Tx Current (A)	Tx Equivalent Resistance (Power Flow) (Ω)	Tx Equivalent Reactance (Power Flow) (Ω)	Tx Power Factor	Tx Volt Drop (Gen + MAD) (V)	Tx Volt Drop (No Gen+Full Load) (V)
2	0	0	0	0	0	0	0	0	0	#VALUE!	0	0	1.00	#VALUE!	0
3	← Microgeneration →														
4		Polyphase Point MAD at End Node (kW)	Polyphase Generation at End Node (kW)	1φ Point MAD at End Node (kW)	1φ Generation at End Node (kW)	Distributed Houses MAD per Phase (kW)	End Node Houses MAD per Phase (kW)	Assumed Section Load per Phase, as imposed Upstream (kW)	Downstream Load per Phase (kW)	Section Phase Current (A)	Unbalance Factor (pu)	Section Volt-drop (V)	Upstream Volt-drop (V)	Total Volt-drop to End Node of Section (V)	Voltage at End Node of Section (High) (V)
5															
6		0	0	0	0		0	0	0	0.00	0.00		0		0
7		0	0	0	0		0	0	0	0.00	0.00		0		0
8		0	0	0	0		0	0	0	0.00	0.00		0		0
9		0	0	0	0		0	0	0	0.00	0.00		0		0
10		0	0	0	0		0	0	0	0.00	0.00		0		0
11		0	0	0	0		0	0	0	0.00	0.00		0		0
12		0	0	0	0		0	0	0	0.00	0.00		0		0
13		0	0	0	0		0	0	0	0.00	0.00		0		0
14		0	0	0	0		0	0	0	0.00	0.00		0		0
15		0	0	0	0		0	0	0	0.00	0.00		0		0
16		0	0	0	0		0	0	0	0.00	0.00		0		0
17		0	0	0	0		0	0	0	0.00	0.00		0		0
18		0	0	0	0		0	0	0	0.00	0.00		0		0
19		0	0	0	0		0	0	0	0.00	0.00		0		0
20		0	0	0	0		0	0	0	0.00	0.00		0		0
21		0	0	0	0		0	0	0	0.00	0.00		0		0
22		0	0	0	0		0	0	0	0.00	0.00		0		0
23		0	0	0	0		0	0	0	0.00	0.00		0		0
24		0	0	0	0		0	0	0	0.00	0.00		0		0
25		0	0	0	0		0	0	0	0.00	0.00		0		0
26		0	0	0	0		0	0	0	0.00	0.00		0		0
27		0	0	0	0		0	0	0	0.00	0.00		0		0
28		0	0	0	0		0	0	0	0.00	0.00		0		0
29		0	0	0	0		0	0	0	0.00	0.00		0		0
30		0	0	0	0		0	0	0	0.00	0.00		0		0
31		0	0	0	0		0	0	0	0.00	0.00		0		0
32		0	0	0	0		0	0	0	0.00	0.00		0		0
33		0	0	0	0		0	0	0	0.00	0.00		0		0
34		0	0	0	0		0	0	0	0.00	0.00		0		0
35		0	0	0	0		0	0	0	0.00	0.00		0		0
36		0	0	0	0		0	0	0	0.00	0.00		0		0
37		0	0	0	0		0	0	0	0.00	0.00		0		0
38		0	0	0	0		0	0	0	0.00	0.00		0		0
39		0	0	0	0		0	0	0	0.00	0.00		0		0
40		0	0	0	0		0	0	0	0.00	0.00		0		0
41		0	0	0	0		0	0	0	0.00	0.00		0		0
42		0	0	0	0		0	0	0	0.00	0.00		0		0
43		0	0	0	0		0	0	0	0.00	0.00		0		0
44		0	0	0	0		0	0	0	0.00	0.00		0		0
45		0	0	0	0		0	0	0	0.00			0		0
46															
47					0		0	0		0		0			0
48					0		0	0		0		0			0
49					0		0	0		0		0			0

15.4 'Inputs and Results' Sheet

The 'Inputs and Results' Sheet provides the normal user interface, through which network design parameters are entered and within which results appear. Its general layout reflects that of the left hand portion of 'Detailed Calculation' Sheet (Columns A:Z), but it displays far fewer columns. The layout of the sheet is shown in Figure 3, where the cells and ranges described below are highlighted with bold outlines.

15.4.1 Sheet 'Inputs and Results': Cell E4; Project Reference

Input: "Project Name/Number" in free format.

15.4.2 Sheet 'Inputs and Results': Cell N4; Designer's Name

Fixed datum: Copies of the workbook are personalised. The registered designer's name appears in this locked cell.

15.4.3 Sheet 'Inputs and Results': Cell Q4; Date

Input: "Date"; any recognisable date will be converted to the format 'dd Month yyyy'.

15.4.4 Sheet 'Inputs and Results': Cell E6; Substation Name

Input: "Substation Details", "Name" in free format.

15.4.5 Sheet 'Inputs and Results': Cell L6; Substation HV Fault Level (MVA)

Input: "Substation Details", "HV Fault Level"; from drop-down menu (Sheet 'Data', Range A3:A9, named "HVFL") (200,150, 100, 50, 25, 10) or from keyboard. Any value outside the range 10 to 250MVA is highlighted by its appearing in red.

15.4.6 Sheet 'Inputs and Results': Cell Q6; Transformer Description

Input: "Substation Details", "Transformer Description"; from drop-down menu only (Sheet 'Data', Range C13:C35, named "Transformer").

15.4.7 Sheet 'Inputs and Results': Cell D8; Loss of Diversity Allowance (kW)

Input: "Loss of Diversity Allowance"; from drop-down menu or keyboard. The only accepted values are 4 (appears in red) and 8 (kW) (Sheet 'Data', Range L15:L16, named "LoD"). If no houses are connected to the distributor, no entry is required. However, if houses are subsequently entered, a warning message is displayed.

15.4.8 Sheet 'Inputs and Results': Cells J8, M8 and P8; ADMD (kW)

Input: "ADMD", "Type A", "Type B" and "Type C"; from drop-down menu (Sheet 'Data', Range J15:J22, named 'ADMD') or keyboard. No more than one decimal place is displayed. Values over 5 (kW) appear in red, indicating that they will be treated as off-peak loads; values over 20 (kW) appear in white on a red background.

15.4.9 Sheet 'Inputs and Results': Range B12:B31; Line Section

Fixed data: "Line Section". Each of up to 20 sections of the distributor is denoted by a letter in the range "A" to "V". ("I" and "O" are not used.) "X" denotes the substation. For distributors with more than 20 sections, see subsection 3.5.

15.4.10 Sheet 'Inputs and Results': Range C12:C31; Upstream Section

Input: "Upstream Section"; from keyboard, not case-sensitive. The letter, which denotes its upstream section, is entered in each cell referring to a present section. Letters referring to the present section itself or to those lower down the list are not accepted and are blocked with a "Stop" message. (Inputs which do not match any valid line section designations are similarly blocked.) This is to ensure that loops and parallel connections cannot be input. Section A is bound to be immediately downstream of X, the substation.

15.4.11 Sheet 'Inputs and Results': Range D12:D31; Length (m)

Input: "Length"; from keyboard. Each value entered must be a positive integer; otherwise, it is blocked with a "Stop" message. Values over 500 appear in red.

15.4.12 Sheet 'Inputs and Results': Range E12:F31; Description

Input: "Description"; from drop-down menu in Column E (Sheet 'Data', Range AB42:AB103, named "LinesShort"). Descriptions of cables, with a non-concentric neutral core, end in "(". The presence of this open parenthesis at the end of the short Description renders the contents of the corresponding cell in Column F visible (Conditional Formating). This is set to "SNE)", but may be changed to "Bond)", to take account of a downstream neutral-earth bond, by means of the drop-down menu in Column F (Sheet 'Data', Range L29:L30, named "Bond").

15.4.13 Sheet 'Inputs and Results': Range G12:G31 Section ϕs

Input: "1" or "2", according to the number of phase conductors in the present section: not necessary where this number matches the number of phases in the upstream section.

15.4.14 Sheet 'Inputs and Results': Range H12:H31; No of ϕs

Result: "No of ϕs" (Number of phases). The results are copied from Sheet 'Detailed Calculation' Range F6:F25. (The result will match the number of phases of the transformer, unless it is constrained by the number of conductors in the present or any upstream section.)

15.4.15 Sheet 'Inputs and Results': Range I12:N31; Houses

Input: Numbers of "Distributed Houses" and "End Node Houses" for each house type, "A", "B" and "C"; from keyboard. Each value entered must be a positive integer. Otherwise it is blocked with a "Stop" message. Attempts to change the total number of houses to a number in excess of 200, will invoke a warning message; all house numbers totalling more than 200 appear in red. The entry of any number of houses requires a value for the 'Loss of Diversity' allowance to be entered. Otherwise a warning message is displayed.

15.4.16 Sheet 'Inputs and Results': Range O12:P31; End Load (kW)

Input: "Polyϕ End Load" (Polyphase End Load) and "1ϕ End Load" (Single-phase End Load); from keyboard. Each value entered must be a positive integer; otherwise it is blocked with a "Stop" message. Also, if the present section is single-phase, entries under “Polyϕ End Load” will not enter the calculation and will result in the legend “Invalid End Load” appearing in Column P. (See 3.3.17.)

15.4.17 Sheet ‘Inputs and Results’: Range Q12:Q31; Volt Drop at End Node (V)

Result: “Volt Drop at End Node (%)”. The results are copied from Sheet ‘Detailed Calculation’ Range AK6:AK25. Values in excess of 6.99 appear in red. However, if the Line Description is incomplete (e.g., because, for a 4c cable the cell in Column F has been made blank), the cell is overwritten with the legend “Invalid Line Description” (in red); if a value has been entered in Column N, but the section is single-phase, the cell is overwritten with the legend “Invalid End Load” (in red); or if the actual load current (‘Detailed Calculation’ Range AG6:AG25) in the present section exceeds its rating (‘Data’ Range D42:D127), the cell is overwritten with the legend “Section Overloaded” (in red).

15.4.18 Sheet ‘Inputs and Results’: Range S12:S31; Mains only Impedance (Ω)

Result “Mains only Impedance (Ω)”. The results are copied from Sheet ‘Detailed Calculation’ Range AP6:AP25. Values in excess of 0.35 appear in red.

15.4.19 Sheet ‘Inputs and Results’: Cell S32; High Loop Impedance Warnings

Result “High Loop Impedance Warnings”. Where any of the loop impedance values, as described in subsection 5.3.18, exceeds 0.8 (Ω), the legend “Z excessive” appears in red. Otherwise, where any value exceeds 0.35 (Ω), the legend “Loop Z high” appears.

15.4.20 Sheet ‘Inputs and Results’: Cell C32, Loss of Diversity Warning

Result: “Loss of Diversity Warning”. Entry of a number of houses without any entry of ‘Loss of Diversity’ allowance invokes a warning, “Please enter a figure for Loss of Diversity” in red.

15.4.21 Sheet ‘Inputs and Results’: Cell I32, Number of Customers Warning

Result: “Number of Customers Warning”. Total number of customers exceeding 200 invokes a warning “More than 200 customers”, in red.

15.4.22 Sheet ‘Inputs and Results’: Cell Q32, Total Distributor Load (A)

Result: “Total Distributor Load (A)”. The result is copied from Sheet ‘Detailed Calculation’ Cell AG2. Values in excess of the rating of Section A appear in red. (There may be rare cases, where the total distributor load is not all carried by Section A, but is shared between two or more sections.)

15.4.23 Sheet ‘Inputs and Results’: Range R32:S32; High Impedance Warning

If any value in the Ranges ‘Inputs and Results’ and ‘Inputs and Results Extension’ Q12:Q31 exceeds 0.35, the legend “Loop Z high” appears, or if any such value exceeds 0.8, the legend “Z excessive” (in red).

15.4.24 Sheet ‘Inputs and Results’: Range C35:C37; Service Upstream Section

Input: “Section”; from keyboard. The input is the single letter which denotes a section to which each type of house is connected. The section selected should be the worst case, identifiable from the Volt Drop at End Node results and the layout of services on the network.

15.4.25 Sheet 'Inputs and Results': Range D35:D37; Service Length (m)

Input: "Length"; from keyboard. Up to three service types, according to the house types, may be input. Values must be positive integers. Values in excess of 30(m) invoke a warning message and appear in red.

15.4.26 Sheet 'Inputs and Results': Range E35:E37; Service Description

Input: "Description"; from drop-down menu (Sheet 'Data', Range C128:C141, named "Services").

15.4.27 Sheet 'Inputs and Results': Range G35:G37; Total Volt Drop (%)

Results: "Total Volt Drop (%)". The results are copied from 'Detailed Calculation' Range AK47:AK49. Values in excess of 7(%) appear in red.

15.4.28 Sheet 'Inputs and Results': Range J35:J37; Total Loop Impedance (Ω)

Results: "Loop Impedance (Ω)". The results are copied from 'Detailed Calculation' Range AP27:AP29. Values in excess of 0.8(Ω) appear in red.

15.4.29 Sheet 'Inputs and Results': Range K35:K37; Loop Impedance Warnings

Results: Loop impedance warnings. Values of loop impedance (J35:J37) in excess of 0.35(Ω) invoke the warning message "Loop Z high for CNE network", those in excess of 0.54(Ω) the warning message, in red, "Loop Z high; max c/o fuse 80A" and those in excess of 0.8(Ω), "Loop Z excessive".

15.4.30 Sheet 'Inputs and Results': Cell Q35; Max Fuse for Transformer

Result: "Max Fuse for Transformer". The value is derived from a look-up range (Sheet 'Data': Range C13:G35) according to the transformer selected. The rating appears in red, if it is less than that required to carry the load.

15.4.31 Sheet 'Inputs and Results': Cell Q36; Max Recommended Fuse for Section A

Result: "Fuse for Section A Rating". The value is derived from a look-up range Sheet 'Data': Range C42:M127) according to the Description of Line Section A. The rating appears in red, if it is less than that required to carry the load.

15.4.32 Sheet 'Inputs and Results': Cell Q37; Max Fuse for LV Main Protection

Result: "Max Fuse for LV Main Protection". The result is copied from Sheet 'Detailed Calculation' Cell AU47. The rating appears in red, if it is less than that required to carry the load. Where any Line Description is invalid , the cell is overwritten with the legend "Invalid Line Description" (in red); or where a 100A fuse is insufficiently small to protect the whole distributor, the cell is overwritten with the legend, "No fuse can protect all" (in red).

15.4.33 Sheet 'Inputs and Results': Cell Q38; Min Fuse for Load

Result: "Min Fuse for Load". The result is derived from Sheet 'Detailed Calculation' Cell AG2, when compared with the range of fuse ratings in Sheet 'Data' Range E41:N41. The rating appears in red, if it is greater than any of the other three fuse ratings described above. The fuse ratings are listed in Sheet 'Data' in reverse order, in order to allow the function 'MATCH' to select the next standard fuse rating more than the load. Sheet 'Data'

Cell E41 contains a dummy fuse rating of 99999. This is in order to provide a value in excess of 630, so invoking the legend "Fuseway Overloaded" (in red).

15.4.34 Sheet 'Input and Results': Cell R35; Small Transformer Overload Warning

Result: "Small Transformer Overload Warning". If the transformer is of small rating (3-phase: < 100kVA; 1-phase: < 15kVA; split-phase: < 25kVA), a warning message "Beware Tx overload" is displayed. This is to guard against the possibility that the load is within the rating of the smallest fuse (100A) and yet exceeds the rating of the transformer.

Figure 3 – Inputs and Results Sheet

LV AFFIRM - Network Design Calculator - For detailed instructions, see CP226.

Version 6.2

Project Name/Number	Sample Network 1 - all customers of the same type	Designer	P Twomey	Date	04 August 2011
Substation Details - Name	X	HV 3-φ Fault Level	200 MVA	Transformer Description	**3φ 800kVA**
Loss of Diversity	8 kW	ADMD - TypeA	3.4 kW	Type B	kW
				Type C	kW

Line Sect'n	Up-stream Section	Length (m)	Description	Sect φs	No of φs	Dist'd Houses Type A	End Houses Type A	Dist'd Houses Type B	End Houses Type B	Dist'd Houses Type C	End Houses Type C	Polyφ End Load (kVA)	1φ End Load (kVA)	Cumulative Results: Volt Drop at End Node (%)	Cumulative Results: Mains only Impedance (Ω)
A	X	110	**3c 185 Waveform**		3	21								2.51	0.040
B	a	30	**3c 95 Waveform**		3									3.08	0.060
C	b	130	**3c 95 Waveform**		3	27								4.42	0.150
D	a	150	**3c 95 Waveform**		3	24								3.91	0.143
E															
F															
G															
H															
J															
K															
L															
M															
N															
P															
Q															
R															
S															
T															
U															
V															

Total Distributor Load (A) 351

Services	Section	(m)	Description	Total Volt Drop (%)	Total Loop Impedance (incl S/S) (Ω)
Type A	c	10	**35 SAC XC**	4.88	0.173
Type B					
Type C					

Substation Fuses	(A)
Max Fuse for Transformer	630
Fuse for Section A Rating	500
Max Fuse for Mains Protection	355
Min Fuse for Load	355

15.5 'Motors and Flicker' Sheet

The 'Motors and Flicker' Sheet provides the means of entering the parameters associated with the connection of a motor (or other disturbing load). It displays the largest acceptable starting currents or step-changes in current and gives some guidance on the largest acceptable motors. The layout of the sheet is shown in Figure 4.

15.5.1 Sheet 'Motors and Flicker': Range E4:O6; Project and Substation Details

The basic details of the project and substation are copied from Sheet 'Inputs and Results' Range E4:Q6.

15.5.2 Sheet 'Motors and Flicker': Cell O12; Point of Common Coupling

Input: "Point of Common Coupling (PCC)"; from keyboard. The letter(s) (not case sensitive) denoting the upstream section must be entered. Invalid letters, outside the ranges A to V and ZA to ZV, invoke a "Stop" message.

15.5.3 Sheet 'Motors and Flicker': Cell P12; Error Message

Result: If Cell O12 remains blank while there is an entry in Cell O25, the message, "Enter the position of the PCC." appears.

15.5.4 Sheet 'Motors and Flicker': Cell O14; Number of Phases Available at PCC

Result: "Number of phases available at the PCC". The value is copied from Sheet 'Detailed Calculation' Range F5:F45 according to the section selected as immediately upstream of the PCC.

15.5.5 Sheet 'Motors and Flicker': Cell O18; Number of Phases Used

Input: "Number of phases used by the motor"; from keyboard. The value must be an integer, not more than the number of phases available.

15.5.6 Sheet 'Motors and Flicker': Cell I20; Power Factor of Disturbing Load

Input: "Power factor of the disturbing load". This is set, by default, to 0.3. Otherwise, input from keyboard. Values other than 0.3 appear in red. Values must be in the range 0 to 1.

15.5.7 Sheet 'Motors and Flicker': Cell N20; Flicker Voltage (V/A)

Result: "Flicker voltage". The value is copied from Sheet 'Detailed Calculations' Range BF5:BF45, according to the section selected as immediately upstream of the PCC. (This is the voltage dip per ampere at a power factor of 0.3.)

15.5.8 Sheet 'Motors and Flicker': Cell G22; Power Factor of Disturbing Load

Result: Copied from Cell I20.

15.5.9 Sheet 'Motors and Flicker': Cells N22, N23; Step-Change in Current

Result: "Largest acceptable step-changes in current (at 0.3 power factor)". The values are copied from Sheet 'Detailed Calculations' Range BG5:BH45, according to the section selected as immediately upstream of the PCC.

15.5.10 Sheet 'Motors and Flicker': Cell O25; Point of Customer's Connection

Input: "Point of Customer's Connection"; from keyboard. The letter(s) (not case sensitive) denoting the immediately upstream section, including any three-phase service, may be entered.

15.5.11 Sheet 'Motors and Flicker': Cell P24; Error Messages

Result: If the section represented by Cell O25 is not at or downstream of the PCC, the message, "This connection is not at the PCC or downstream of it. Please correct." appears. This is now a rigorous test of connectivity, based on the computation in Sheet 'Detailed Calculation', Column BE.

15.5.12 Sheet 'Motors and Flicker': Cells N27, N28; Voltage Dip at Customer's Terminals (%)

Result: "Voltage Dip at Customer's Terminals". The values are copied from Sheet 'Detailed Calculations' Range BL6:BM45, according to the section selected as the customer's connection.

15.5.13 Sheet 'Motors and Flicker': Cells N34, N35; Approximate Motor Sizes: Direct Start (kWe)

Result: "Approximate Electrical Ratings of Motors: Direct Start". The values are calculated from the maximum acceptable currents in Cells N22 and N23, assuming starting currents of 7 times the full-load running current.

15.5.14 Sheet 'Motors and Flicker': Cells N37, N38; Approximate Motor Sizes: Star-Delta Start (kWe)

Result: "Approximate Electrical Ratings of Motors: Star-Delta Start". The values are calculated from the maximum acceptable currents in Cells N22 and N23, assuming starting currents of 4 times the full-load running current.

15.5.15 Sheet 'Motors and Flicker': Cell K42; Power Factor of Disturbing Load

Result: Copied from Cell I20.

15.5.16 Sheet 'Motors and Flicker': Cell N42; Expected Step Change in Current (A)

Input: "Expected Step Change in Current". The step change in current (A) (maximum starting current), expected to result from the customer's proposed equipment (method of starting) may be entered.

15.5.17 Sheet 'Motors and Flicker': Cell N44; Least Acceptable Interval (s)

Result: "Least Acceptable Interval between Step Changes". The voltage dip at the PCC caused by the current as entered in Cell N42, is calculated in Cell BF47 of Sheet 'Detailed Calculation'. This value of voltage dip is used in the look-up table (Range Q15:R28 of Sheet 'Data') to give the least acceptable interval between step changes. These results conform to Figure 4 of ENA ER P28.

Figure 4 – Motors and Flicker Sheet

LV AFFIRM - Network Design Calculator - Motors and Flicker — Version 6.2

Project Name/Number	Sample Network 1 - all customers of the same type	Designer: P Twomey	Date: 04/08/11
Substantion Details - Name: X	HV Fault Level 200 MVA	Transformer:	3φ 800kVA

Basic Stage 2 Assessment

Point of Common Coupling (PCC)

Enter the letter(s) denoting the section of the network, which has the PCC at its downstream end		b
Number of phases availabe at the PCC		3

Disturbing Load

Enter the number of phases used by the motor (or other disturbing load)		3
The flicker voltage, caused by a step-change in current (at 0.30 power factor) at the PCC is:		0.029 V/A
The largest acceptable step-changes in current (at 0.30 power factor) are:	Frequent	82 A
("Frequent" here means at intervals of less than 2 hour.)	Infrequent	246 A
Enter the letter(s) denoting the section of the network, which has the customer's connection at its downstream end		c
The voltage dips at the customer's terminals, caused by these step-changes in current are:	Frequent	1.7 %
	Infrequent	5.2 %

Approximate Guide to Motor Sizes

The approximate electrical ratings of motors, which can be expected to cause the step-changes shown above are as follows:

Direct Starting:	Frequent	8 kWe
	Infrequent	25 kWe
Star-Delta Starting:	Frequent	15 kWe
	Infrequent	44 kWe

Further Stage 2 Assessment

Enter the expected step change in current (starting current of the motor at 0.30 power factor)	200 A
Least acceptable interval between step changes (motor starts)	6 minute

15.6 Sheet 'Inputs and Results Extension'

The 'Inputs and Results Extension' Sheet provides for a further 20 sections in addition to the 20 provided for by Sheet 'Inputs and Results'.

15.6.1 Sheet 'Inputs and Results Extension': Range E4:P8; Basic Details

Project, Substation and ADMD details are copied from Sheet 'Inputs and Results.

15.6.2 Sheet 'Inputs and Results Extension': Range B11:B30; Line Section

Fixed data: "Line Section". Each of the second 20 sections of the distributor is denoted by letters in the range "ZA" to "ZV". ("ZI" and "ZO" are not used.)

15.6.3 Sheet 'Inputs and Results Extension': Range C11:Q30; Line Section Inputs and Results

This range, for further sections "ZA" to "ZV" beyond the first 20 provided for on Sheet 'Inputs and Results' operates in identical manner to the corresponding range on Sheet 'Inputs and Results'. See subsections 3.3.10 to 3.3.19.

15.6.4 Sheet 'Inputs and Results Extension': Range B31:Q37; Substation Results and Services

Values in this range are copied from Sheet 'Inputs and Results'.

15.7 Sheet 'Unprotected Lengths'

The 'Unprotected Lengths' Sheet shows for each section, that part of its length (m), if any, which would not be protected by each of the standard ratings of fuses at the substation. The layout of the sheet is shown in Figure 5.

15.7.1 Sheet 'Unprotected Lengths': Cell E4; Project Name/Number

The Project Name is copied from Sheet 'Inputs and Results' Cell E4.

15.7.2 Sheet 'Unprotected Lengths': Range B10:B49; Line Section

Fixed data: "Line Section". Each of the 40 sections of the distributor is denoted by letters in the ranges "A" to "V" and "ZA" to "ZV". ("I" and "O" are not used.)

15.7.3 Sheet 'Unprotected Lengths': Range C10:C49; Section Length (m)

The length of each section is inserted. The values are taken from Sheet 'Inputs and Results' and 'Inputs and Results Extension' Ranges D12:D31.

15.7.4 Sheet 'Unprotected Lengths': Range D10:D49; Line Description

The line description, including type and cross-section, of each section is inserted. The values are taken from Sheet 'Detailed Calculation' Ranges D6:D45.

15.7.5 Sheet 'Unprotected Lengths': Range E10:E49; Fuse for Section Rating

The fuse rating corresponding to the rating of the section is entered. The values are taken from Sheet 'Data', Column M.

15.7.6 Sheet 'Unprotected Lengths': Range F10:N49; Unprotected Lengths

Results are taken from Sheet 'Detailed Calculation', Range BR6:BZ45. Negative figures, representing completely protected sections, are ignored, the cells being left blank. Figures which exceed the length of the section are replaced with the length of the section.

Figure 5 – Unprotected Lengths Sheet

LV AFFIRM - Network Design Calculator - Unprotected Lengths Version 6.2

Project Name/Number Sample Network 1 - all customers of the same type

The unprotected lengths (m) of any section are shown below, according to the fuse rating selected. "Unprotected" means either that the maximum fault clearance time could be exceeded, or that the section is at risk of thermal damage, caused by the passage of fault current, before a fuse would operate.

Section	Length (m)	Description	Fuse for Sect Rat'g (A)	Fuse Rating (A) 100	160	200	250	315	355	400	500	630
A	110	3c 185 Waveform	500									110
B	30	3c 95 Waveform	315							30	30	30
C	130	3c 95 Waveform	315							130	130	130
D	150	3c 95 Waveform	315							150	150	150
E												
F												
G												
H												
J												
K												
L												
M												
N												
P												
Q												
R												
S												
T												
U												
V												
ZA												
ZB												
ZC												
ZD												
ZE												
ZF												
ZG												
ZH												
ZJ												
ZK												
ZL												
ZM												
ZN												
ZP												
ZQ												
ZR												
ZS												
ZT												
ZU												
ZV												

15.8 Sheet 'Loadings and Ratings'

The 'Loadings and Ratings' Sheet shows, for each section, the load on the section and, for underground cable, the four most usual ratings. The layout of the sheet is shown in Figure 6.

15.8.1 Sheet 'Loadings and Ratings': Cell D4; Project Name/Number

The Project Name is copied from Sheet 'Inputs and Results' Cell E4.

15.8.2 Sheet 'Loadings and Ratings': Range B13:B52; Line Section

Fixed data: "Line Section". Each of the 40 sections of the distributor is denoted by letters in the ranges "A" to "V" and "ZA" to "ZV". ("I" and "O" are not used.)

15.8.3 Sheet 'Loadings and Ratings': Range C13:C52; Line Description

The line description, including type and cross-section, of each section is inserted. The values are taken from Sheet 'Detailed Calculation' Range D6:D45.

15.8.4 Sheet 'Loadings and Ratings': Range D13:D52; Section Loading

The loading of each section is entered. Values are taken from Sheet 'Detatiled Calculation' Range AG6:AG45.

15.8.5 Sheet 'Loadings and Ratings': Range E13:H52: Section Ratings

Up to four ratings for each section are entered, (for cables: cyclic and sustained for both laid-direct and in a single-way duct). The values are taken from Sheet 'Data', Range X42:AA127.

15.8.6 Sheet 'Loadings and Ratings': Range I13:N52; Grouped Ratings

Six additional cyclic ratings for cables laid in groups are entered, for groups of 2, 3 and 4 cables, laid direct at 150mm spacing and in touching ducts. The values are taken from Sheet 'Data', Range AC42:AH127.

Figure 6 – Loadings and Ratings Sheet

LV AFFIRM - Network Design Calculator- Loadings and Ratings

Version 6.2

Project Name/Number Sample Network 1 - all customers of the same type

The loading and ratings of each section are shown below.

Note: The rating of the substation fuse-board, feeder pillar or link-box might limit the effective ratings of cables to less than those shown below.

			Laid Direct (Cable)		In Single-Way Duct		Grouped Cables - Cyclic					
			Cyclic	Sustained	Cyclic	Sustained	Direct - Space 150mm			Ducts - Touching		
Section	Description	Loading (A)	Rating (A)	Rating (A)	Rating (A)	Rating (A)	2 (A)	3 (A)	4 (A)	2 (A)	3 (A)	4 (A)
A	3c 185 Waveform	351	440	390	325	305	425	415	405	320	310	310
B	3c 95 Waveform	139	300	270	220	205	290	280	280	215	210	210
C	3c 95 Waveform	139	300	270	220	205	290	280	280	215	210	210
D	3c 95 Waveform	124	300	270	220	205	290	280	280	215	210	210
E												
F												
G												
H												
J												
K												
L												
M												
N												
P												
Q												
R												
S												
T												
U												
V												
ZA												
ZB												
ZC												
ZD												
ZE												
ZF												
ZG												
ZH												
ZJ												
ZK												
ZL												
ZM												
ZN												
ZP												
ZQ												
ZR												
ZS												
ZT												
ZU												
ZV												

15.9 Sheet 'Slow Fault Clearance'

The 'Slow Fault Clearance' Sheet shows for each section, that part of its length (m), if any, in which a fault would not be cleared within the maximum clearance time by each of the standard ratings of fuses at the substation. The layout of the sheet is shown in Figure 7.

15.9.1 Sheet 'Slow Fault Clearance': Cell E4; Project Name/Number

The Project Name is copied from Sheet 'Inputs and Results' Cell E4.

15.9.2 Sheet 'Slow Fault Clearance': Range B14:B53; Line Section

Fixed data: "Line Section". Each of the 40 sections of the distributor is denoted by letters in the ranges "A" to "V" and "ZA" to "ZV". ("I" and "O" are not used.)

15.9.3 Sheet 'Slow Fault Clearance': Range C14:C53; Section Length (m)

The length of each section is inserted. The values are taken from Sheet 'Inputs and Results' and 'Inputs and Results Extension' Ranges D12:D31.

15.9.4 Sheet 'Slow Fault Clearance': Range D14:D53; Line Description

The line description, including type and cross-section, of each section is inserted. The values are taken from Sheet 'Detailed Calculation' Ranges D6:D45.

15.9.5 Sheet 'Slow Fault Clearance': Range E14:E53; Fuse for Section Rating

The fuse rating corresponding to the rating of the section is entered. The values are taken from Sheet 'Data', Column M.

15.9.6 Sheet 'Slow Fault Clearance': Range F14:N53; Slow Clearance Lengths

Results are taken from Sheet 'Detailed Calculation', Range CA6:CI45. Negative figures, representing satisfactory clearance within the maximum time, are ignored, the cells being left blank. Figures which exceed the length of the section are replaced with the length of the section.

Figure 7 – Slow Fault Clearance Sheet

LV AFFIRM - Network Design Calculator- Slow fault clearance

Version 6.2

Project Name/Number Sample Network 1 - all customers of the same type

NB: This is NOT the 'Unprotected Lengths' Sheet. The lengths shown may be used for Health and Safety considerations only.

The lengths (m) of any section are shown below, in which a fault would not be disconnected by the fuses, **within the maximum fault clearance times** according to the fuse rating selected.
No account is taken here of the risk of thermal damage.

Section	Length (m)	Description	Fuse for Sect Rat'g (A)	Fuse Rating (A) 100	160	200	250	315	355	400	500	630
A	110	3c 185 Waveform	500									
B	30	3c 95 Waveform	315									22
C	130	3c 95 Waveform	315							39	101	130
D	150	3c 95 Waveform	315							29	91	140
E												
F												
G												
H												
J												
K												
L												
M												
N												
P												
Q												
R												
S												
T												
U												
V												
ZA												
ZB												
ZC												
ZD												
ZE												
ZF												
ZG												
ZH												
ZJ												
ZK												
ZL												
ZM												
ZN												
ZP												
ZQ												
ZR												
ZS												
ZT												
ZU												
ZV												

15.10 Sheet 'Microgeneration'

The 'Microgeneration' Sheet provides a means of modelling the effects of small units of generation, connected to the LV Network. Inputs include the voltage conditions of the HV Network, the transformer tap setting, the values of MAD, the total amount of generation and the total number of customers connected to the substation, and the size of the unit under consideration. Outputs are the highest and lowest voltages, expected to arise on the modelled distributor. The layout of the sheet is shown in Figure 8.

15.10.1 Sheet 'Microgeneration': Range B4:T4; Project Basic Details

The basic details of the project are copied from Sheet 'Inputs and Results' Range E4:Q4.

15.10.2 Sheet 'Microgeneration': Cell E6; HV System Voltage

Result: "HV System (kV); The nominal voltage of the HV Network is inferred from the entries in Cells E7 and E8 below.

15.10.3 Sheet 'Microgeneration': Cell E7; Primary Busbar High Voltage

Input: "Actual High from FLA (kV)"; The normal high point of the voltage profile is entered from the keyboard.

15.10.4 Sheet 'Microgeneration': Cell E8; Primary Busbar Low Voltage

Input: "Actual Low from FLA (kV)"; The normal low point of the voltage profile is entered from the keyboard.

15.10.5 Sheet 'Microgeneration': Cell E9; HV Network Voltage Drop (Low Load)

Input: "Low Load HV Drop (%)"; The percentage voltage drop from the primary busbar to the distribution substation, under low load conditions, is entered from the keyboard.

15.10.6 Sheet 'Microgeneration': Cell E10; HV Network Voltage Drop (High Load)

Input: "High Load HV Drop (%)"; The percentage voltage drop from the primary busbar to the distribution substation, under high load conditions, is entered from the keyboard.

15.10.7 Sheet 'Microgeneration': Cell L7; Transformer Tap Number

Input: "Transformer Tap No"; The distribution transformer tap number is entered from a drop-down list (1, 2, 3, 4, 5).

15.10.8 Sheet 'Microgeneration': Cell L8; Power Factor of Transformer Power Flow

Input: "Power Factor of Transformer Power Flow"; The power factor of the power flow through the transformer is entered from the keyboard. The value is expected to be in the range 0.7 to 1.

15.10.9 Sheet 'Microgeneration': Cell L9; Total Generation on other Distributors (kW per phase)

Input: "Total Gen on other Distrib'rs (kW per ϕ)"; The total generation per phase, connected to other distributors from the same substation is entered from the keyboard.

15.10.10 Sheet 'Microgeneration': Cell L10; Unbalance Factor

Input: "Unbalance Factor"; The per unit neutral voltage drop, to be added to downstream export flow (net generation), is entered from a drop-down list (1, 0.8, 0.6, 0.4, 0.2, 0.0), or from the keyboard.

15.10.11 Sheet 'Microgeneration': Range O8:O10; Single-phase service MAD (kW)

Input: "MAD (kW)"; The MAD applicable to each Type of single-phase service is entered fro a drop-down list (0.16, 0.17, 0.23, 0.31, 0.45, as in Table A1 of CP221), or from the keyboard.

15.10.12 Sheet 'Microgeneration': Range P8:P10; Single-phase Service Generation (kW)

Input: "Gen (kW)"; The generation connected to each type of single-phase service is entered from the keyboard.

15.10.13 Sheet 'Microgeneration': Range Q8:Q10; Other Customers on Substation

Input: "Others on S/S"; The number of customers of each type, connected to other distributors from the same substation, is entered from the keyboard.

15.10.14 Sheet 'Microgeneration': Range R8:R10; High Voltage (V)

Result: The high value of voltage, ie that arising from the generation with the MAD, for each service type is copied from Sheet 'Detailed Calculation', Range CZ47:CZ49, where any service, including one of zero length, is connected. Values in excess of 253 (V) appear in red. If, however, three-phase MAD or generation has been entered on a section, which is not three-phase, this cell is made blank.

15.10.15 Sheet 'Microgeneration': Range S8:S10; Low Voltage (V)

Result: The low value of voltage, ie that arising with full after diversity demand, without any generation, is calculated by subtracting the transformer voltage drop (no generation, full load) (Cell CZ2) and the total voltage drop (Range AJ47:AJ49) from the substation high voltage (Cell CM2) , where any service, including one of zero length, is connected. Values below 220 (V) appear in orange and those below 216 in red. If, however, three-phase MAD or generation has been entered on a section, which is not three-phase, this cell is made blank.

15.10.16 Sheet 'Microgeneration': Range T8:T10; Pass/Fail

Result: Cells are red, if either of the high voltage (Range S8:S10) or low voltage (Range T8:T10) results appears in red, otherwise orange if the low voltage result appears in orange, or otherwise green. If three-phase MAD or generation has been entered on a section, which is not three-phase, the legend "ϕ mismatch" is shown.

15.10.17 Sheet 'Microgeneration': Ranges B15:B34, L15:L34; Line Section

Fixed data: Letters, A to V and ZA to ZV, representing the line sections are listed.

15.10.18 Sheet 'Microgeneration': Ranges C15:C34, N15:N34; 3-phase End Node MAD (kW)

Entry: The MAD of any three-phase point load at an end node is entered from the keyboard.

15.10.19 Sheet 'Microgeneration': Ranges D15:D34, O15:O34; 3-phase Generation at End Node (kW)

Entry: The rating of three-phase generation associated with any point load is entered from the keyboard (kW)

15.10.20 Sheet 'Microgeneration': Ranges E15:E34, P15:P34; Single-phase End Node MAD (kW)

Entry: The MAD of any single-phase point load at an end node is entered from the keyboard.

15.10.21 Sheet 'Microgeneration': Ranges F15:F34, Q15:Q34; Single-phase Generation at End Node (kW)

Entry: The rating of single-phase generation associated with any point load is entered from the keyboard (kW).

15.10.22 Sheet 'Microgeneration': Ranges H15:H34, R15:R34; Distributed MAD (kW)

Result: The distributed MAD per phase in each section is copied from Sheet 'Detailed Calculation', Range CQ6:CQ45.

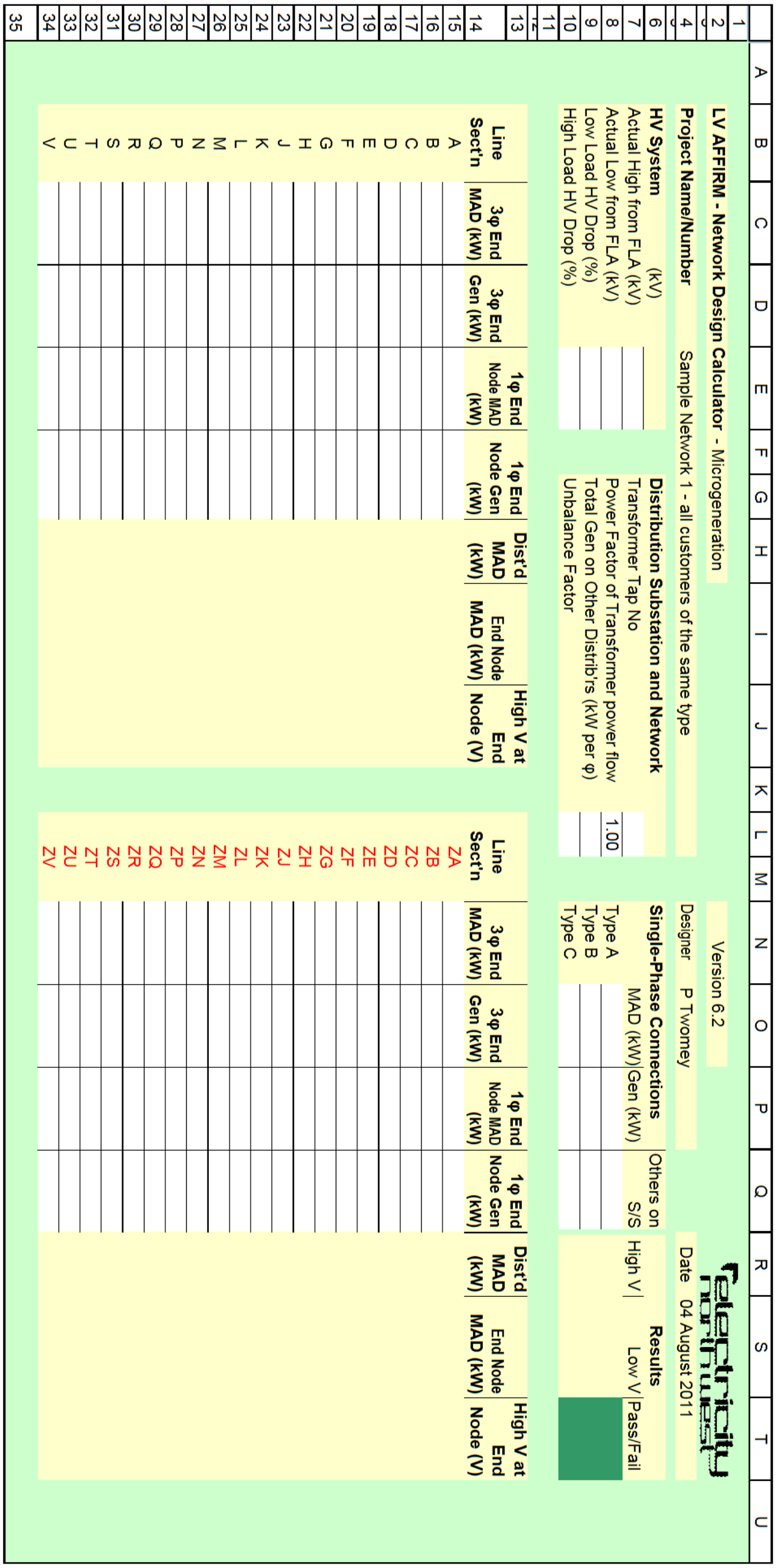
15.10.23 Sheet 'Microgeneration': Ranges I15:I34, S15:S34; End Node MAD (kW)

Result: Where the section is not three-phase, but entries have been made in Ranges C15:D34 or N15:O34, the legend "ϕ mismatch" is shown in red. Otherwise The end node MAD per phase in each section is summed from Sheet 'Detailed Calculation', Range CO6:CO45 (single-phase MAD at end node), CR6:CR45 (end-node houses MAD) and one third of the values in CM6:CM45 (polyphase MAD at end node).

15.10.24 Sheet 'Microgeneration': Ranges J15:J34, T15:T34; High Voltage at End Node (V)

Result: Values are copied from Sheet 'Detailed Calculation' Range CZ6:CZ45. Values in excess of 253 (V) appear in white on a red background.

Figure 8 – Microgeneration Sheet



LV AFFIRM - Network Design Calculator - Microgeneration			Version 6.2	electricity north west
Project Name/Number	Sample Network 1 - all customers of the same type		Designer P Twomey	Date 04 August 2011

HV System (kV)		**Distribution Substation and Network**		**Single-Phase Connections**	MAD (kW)	Gen (kW)	Others on S/S	**Results** High V	Low V	Pass/Fail
Actual High from FLA (kV)		Transformer Tap No								
Actual Low from FLA (kV)		Power Factor of Transformer power flow	1.00	Type A						
Low Load HV Drop (%)		Total Gen on Other Distrib'rs (kW per φ)		Type B						
High Load HV Drop (%)		Unbalance Factor		Type C						

Line Sect'n	3φ End MAD (kW)	3φ End Gen (kW)	1φ End Node MAD (kW)	1φ End Node Gen (kW)	Dist'd MAD (kW)	End Node MAD (kW)	High V at End Node (V)	Line Sect'n	3φ End MAD (kW)	3φ End Gen (kW)	1φ End Node MAD (kW)	1φ End Node Gen (kW)	Dist'd MAD (kW)	End Node MAD (kW)	High V at End Node (V)
A								ZA							
B								ZB							
C								ZC							
D								ZD							
E								ZE							
F								ZF							
G								ZG							
H								ZH							
J								ZJ							
K								ZK							
L								ZL							
M								ZM							
N								ZN							
P								ZP							
Q								ZQ							
R								ZR							
S								ZS							
T								ZT							
U								ZU							
V								ZV							

Appendix X – Details on the Use of "Columns ()" Function

X1 Notes on the use of "Columns()" Function

The Excel function "VLOOKUP", which enables data to be extracted from a table, requires four arguments, one of which is "col_index_num". This defines the column of the table in which the target datum is located and is the number of columns, by which the target column is displaced from the left hand edge of the table. If this argument is entered as a figure, it needs to be manually changed, if at any time the number of columns in the table is increased or decreased. An alternative is to define this number through the use of the "COLUMNS()" function, whose arguments are cell references, eg (A1,A10). This returns the number 10. However, if a column is added, such that column 10 becomes column 11, the argument of "COLUMNS()" automatically adjusts to become (A1,A11), returning 11, thus maintaining the correct reference for the target column.

This feature may also be of benefit when similar "VLOOKUP" formulas need to be copied to a range of cells, the correct variations to the formulas being achieved through the judicious use of the "$" symbol.

X2 Detailed Explanation of Formula in Sheet 'Detailed Calculation' AT6 (and Similarly in AT7:AT45), Giving Maximum Fuse Rating for the Section

```
=IF(OR($B6="",$D6=0,$AR6="",$AR6=99999),"",
OFFSET(Data!$M$41:$V$41,0,(MATCH($AR6,(OFFSET(Data!$N$41:$V$126,
(MATCH($D6,Data!$C$42:$C$126,0)),0,1,9)),1)),1,1))
```

See Table A2 Overleaf.

=IF(OR($B6="",$D6=0,$AR6="",$AR6=99999),"",				Returns null, if column B (upstream section) is null, if column D (line description) is zero, or, if column AR (least downstream E/F loop current) is either null or 99999.
OFFSET				Returns Rating of Fuse
(Data!$M$41:$V$41,				Defines search range - all Fuse Ratings
0,				Vertical offset - zero
(MATCH			Matches Fault Current to required Fuse Current	Returns relative column number specific to MATCHed Fuse Rating - used as horizontal offset
($AR6,			Specifies Least Fault Current	
(OFFSET		Returns search range for MATCH	Returns range of 9 minimum Fuse Currents specific to the Line Type, one for each Fuse Rating - used to search for a match	
(Data!$N$41:$V$126,		Defines overall search range for OFFSET		
(MATCH	Matches Row in Data for specific Line Type	Returns relative row number specific to MATCHed Line Type - used as vertical offset (number of rows)		
($D6,	Specifies Line Type			
Data!$C$42:$C$126,	Defines search range			
0))	Specifies exact match			
,0,		Horizontal OFFSET - zero		
1,		Height of OFFSET range - 1 row		
9))		Width of OFFSET range - 9 columns		
,1))			Specifies MATCH to largest Fuse Current less than Fault Current	
,1,				Height of OFFSET range - 1 row
1))				Width of OFFSET range - 1 column

X3 Detailed Explanation of Formula in Sheet 'Detailed Calculation' BR6 (and Similarly in BR7:BR45, BS6:BZ45), Giving Unprotected Length

```
=IF($F6="","",IF($AP6=0,"",IF(AND(VLOOKUP($D6,Data!$C$42:$V$126,COLUMNS($C$1:N$1),0)>
VLOOKUP(VLOOKUP($D6,Data!$C$42:$W$126,COLUMNS($C$1:$W$1),0),Data!$M$149:$V$151,COLUMNS(
$M$1:N$1),0),
VLOOKUP($D6,Data!$C$42:$V$126,COLUMNS($C$1:N$1),0)>$AS6),
$C6,(($AQ6)-
(204/VLOOKUP($D6,Data!$C$42:$V$126,COLUMNS($C$1:N$1),0)))*$C6/(($Q6^2+$R6^2)^0.5))))
```

=IF($F6="","",IF($AP6=0,"",			Returns null, if column F is null (no transformer or no upstream section), or if Column AP is zero (zero cumulative earth fault loop impedance), otherwise
IF(AND(			if both
VLOOKUP	Returns minimum fusing current.		(actual minimum fusing current for section
($D6,	Defines look-up value (section description) for VLOOKUP.		
Data!$C$42:$V$126,	Defines overall search range for VLOOKUP.		
COLUMNS($C$1:N$1),	Defines column (100A fuse) to search.		
0)	Requires an exact match.		
>			is greater than
VLOOKUP(		Returns minimum fusing current.	minimum fusing current to operate 100A fuse in the time required for the type of section) and
VLOOKUP	Returns look-up value for VLOOKUP.	Returns maximum fault clearance time, as a look-up value.	
($D6,	Defines look-up value (section description) for VLOOKUP.		
Data!$C$42:$V$126,	Defines overall search range for VLOOKUP.		
COLUMNS($C$1:$W$1),	Defines column to search.		
0),	Requires an exact match.		
Data!$M$138:$V$140,		Defines overall search range for VLOOKUP.	
COLUMNS($M$1:N$1),		Defines column (100A fuse) to search.	
0),		Requires an exact match.	

(VLOOKUP	Returns minimum fusing current.		(actual minimum fusing current for section
($D6,	Defines look-up value (section description) for VLOOKUP.		
Data!$C$42:$V$126,	Defines overall search range for VLOOKUP.		
COLUMNS($C$1:N$1),	Defines column (100A fuse) to search.		
0),	Requires an exact match.		
>			is greater than
$AS6),			actual fault current)
$C6,			then the full length of the section, otherwise
(($AQ6)			the total cumulative earth-fault loop impedance
-(204/		minus, 204 [V], divided by	minus the maximum earth-fault loop impedance for the section
VLOOKUP	Returns minimum fusing current	actual minimum fusing current for the section	
($D6,	Defines look-up value (section description) for VLOOKUP.		
Data!$C$42:$V$126,	Defines overall search range for VLOOKUP.		
COLUMNS($C$1:N$1),	Defines column (100A fuse) to search.		
0)))	Requires an exact match.		
*			multiplied by
$C6			the length of the section
/			divided by
(($Q6^2+$R6^2)^0.5)))			the impedance of the section.