Network Design Manual

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Revision Log

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Version	7.6	Prepared by	T Haggis	Date	Sept 2005
Notes:	Section 1.3.2.2 Circuit Ratings for Industrial /Commercial Loads – 19 MVA and 32 MVA limits set for standard 33/11kV transformers Section 1.4.7.2 High Load Routes added Section 1.2.5.3 kVA rating of residential cables adjusted to from 230v to 240v base – kVA rating provided alongside amps. 1.2.6.7 Emergency Fire Fighting Supplies – new BS5588-5:2004 replaces BS5588-5:1991 and relaxes the need for an independent HV fire fighting supply. 1.2.8.3 Outdoor meter boxes – minimum heigth of box changed from 750mm to 450mm to align with Engineering Recommendation G81. 1.2.10.2 Transformer size calculation – 50 kVA transformers not to be used for residential loads. Section 1.3.1.3 Meter tails 2 per phase – now restrcietd to one per phase. Section 1.3.1.3 kVA rating of industrial cables adjusted to from 230v to 240v base – all rating incresed slightly. Typing error corrected for rating of 300 Wavecon - 256 kVA changed to 265 kVA and again adjustedto 275kVA to reflect 240v base. Sections 1.3.1.7/8/9 - kVA bands adjusted to reflect changes to cable ratings above 200 becomes 210 kVA and 250 becomes 275 kVA. 1.3.1.11 Arrangement F. 11kV extension, 500 to 1000kVA substation & LV Air Circuit Breaker. – where transformer is sited inside the customer's boundary fence a Ring Mian Unit is now used instead of a Switch Disconnector. 1.3.1.11 Arrangement F. 11kV extension, 500 to 1000kVA substation & LV Air Circuit Breaker. – some of the detail removed and transferred to the "LV Air Circuit Breaker 500 to 1000 kVA Substation Application Guide" 1.3.2.3/4/5/6/7/8 Standard HV Supply Arrangements H to L – Switchgear types amended to include Lucy RMU & metering unit. 1.4.6.4 Overhead Line Rules – New ABSDs to be connected solid without live line taps. Table 3.2.1.5 LV Cable data – Consac cables added Tables 3.3.2.A to E - Autumn 11kV OHL ratings included plus additional sizes Tables 3.3.1.4 A&B also 3.3.1.5A XLPE ratings recalculated using Crater V3.0 and 3 core XLPE ratings added. Table 3.3.1.5B – new table added for group of 2 XLPE Sustained & Cyclic ratings 3.3.4.1 11kV Distribution Substation Switchgear – tables updated to include Lucy Switchgear and Central Networks contract references Version 7.5 Tables 3.3.1.5 B,C,D,E,F now become Tables 3.3.1.5 C,D,E,F,G in version 7.6 to reflect					

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INTRODUCTION

Central Networks is regulated by the Authority under primary legislation of the Electricity Act 1989 as amended by the Utilities Act 2000 (the Act), the Competition Act 1998 and through the granting of an Electricity Distribution Licence.

Central Networks has a duty under the Act to develop and maintain an efficient, co-ordinated and economical system of electricity distribution and to facilitate competition in the supply and generation of electricity.

All new additions and modifications to the distribution system must comply with the requirements of this Manual which provides for an adequate standard of network performance and reliability consistent with Central Networks' obligations under the Act.

The requirements of this manual also apply to any assets to be adopted by Central Networks under Competition in Electricity Connections.

This Manual relates to the areas of:

- Central Networks East – formally East Midlands Electricity
- Central Networks West –formally Aquila / GPU / Midlands Electricity.

Where technical differences exist between the two areas they are identified in the text. Otherwise this Manual applies equally to both areas.

If any instances occur whereby the requirements of this Manual cannot be complied with or where it is desired for a specific reason to depart from them, written permission must first be obtained from:

The Network Manager
Network Strategy & Regulation
Central Networks

1. Network Configuration

This section is provided for persons who may be unfamiliar with the technical aspects of the Central Networks' network. This may include: persons designing assets to be adopted by Central Networks, Central Networks' contractor's staff, Central Networks staff new to network design work.

It describes how the Central Networks distribution system is configured so that they can identify where it may differ from other Distribution Network Operator's systems. e.g. The Central Networks' distribution system generally uses resistance earthing at Primary Substations. Other DNOs may have solid earthing or arc suppression coil. Others may employ different transformer vector groups etc. The fundamental aspects need to be understood before commencing any design work on Central Networks' distribution system.

1.1 Overview

Central Networks takes electricity from National Grid Transco substations at 132kV and distributes it to end user customers via a network comprising 132kV, 66kV, 33kV 11kv 6.6kV and LV (400/230v) circuits.

Alternative circuits are provided where required to comply with the Energy Networks Association Engineering Recommendation P2/5 minimum standards of supply security. Alternative supplies and network switching points may be provided in excess of P2/5 requirements to meet the Regulator's customer service targets.

The following section describes salient details of the Central Networks distribution system to assist with overall design considerations. Whilst the descriptions are typical of the majority of the Central Networks distribution system some parts may differ in detail due to historical reasons or to address specific engineering issues. Before extending or modify the distribution system the designer must consider the specific part of the network involved and design accordingly. Particular attention must be paid to the Network Modification Procedure section of this manual.

1.1.1 400kV & 275kV Grid Substations

400kV & 275kV Grid Substations (also know as Grid Supply Points or GSPs) are owned by National Grid Transco and contain 400/132kV or 275/132kV step-down transformers feeding busbars from which Central Networks 132kV circuits originate.

1.1.2 132kV Grid circuits

132kV Grid circuits normally comprise of overhead lines with earth wire on steel lattice towers. Underground cables are used where overhead routes are inappropriate or unobtainable. Duplicate circuits are normally arranged as a parallel pair to provide full alternative supplies in the event of one circuit outage in compliance with P2/5. Some use is made of single circuit unearthed construction wood pole lines.

Main protection provides fault clearance times under 200ms using distance or unit protection schemes. Back-up protection is by IDMT relays.

1.1.3 132kV Substations

132kV Substations (also know as Bulk Supply Points or BSPs) are normally owned by Central Networks and contain 132 kV switchgear, 132/33kV and/or 132/11kV transformers and 33kV and/or 11kV switchgear from which 33kV and 11 kV circuits originate. Certain areas of Central Networks West (e.g. Hereford & Worcester) employ 66kV as a primary voltage instead of 33kV. Some Bulk Supply Points feed into 6.6kV city networks in which case the secondary voltages are 6.6kV instead of 11kV. Grid transformers are normally installed in pairs to provide full alternative supplies in the event of one circuit outage in compliance with Engineering Recommendation P2/5.

Transformers have unit protection, Buchholz relays and employ pilot wire inter-tripping to source. The LV circuit breakers (33, 11, 6.6kV) have directional protection to prevent back-feeding 132kV earth faults.

Transformers have on-load tap changers for voltage control. Typical vector groups are YNd11 or YNd1 for the 132/33kV transformers and YNyn0 for the 132/11Kv transformers. Earthing transformers of vector group Zy1 or Zy11 provide substation LVAC supplies and either have sufficient impedance to limit earth fault current or work in conjunction with a separate Neutral Earthing Resistor. Earth fault currents are limited to a maximum of the full load current of the transformer. Lower values may apply according to network earthing requirements.

1.1.4 66kV & 33kV Primary circuits

66kV & 33kV Primary circuits normally comprise of overhead lines on wood poles (unearthed construction) or steel lattice towers (with earth wire). Underground cables are used where overhead routes are inappropriate or unobtainable. Duplicate circuits are normally arranged as a parallel pair to provide full alternative supplies in the event of one circuit outage. Older duplicate circuits have both circuits located closely together on double circuit overhead line supports or in adjacent trenches leaving them at risk from simultaneous damage. Modern designs remove this 'linked risk' by installing single circuits as pairs but on separate routes wherever practicable.

Main protection provides fault clearance times under 200ms using high set over current relays. Some circuits may have the protection slugged to a maximum of 500ms to accommodate downstream protection stages such as Pole Mounted Auto Reclosers. There are some distance and unit protection schemes on certain circuits. Back-up protection is by IDMT relays.

1.1.5 Primary Substations

Primary Substations are normally owned by Central Networks and contain 33 kV switchgear, 33/11kV transformers and 11kV switchgear from which 11 kV circuits originate. Certain areas of Central Networks West (e.g. Hereford & Worcester) employ 66kV as a primary voltage instead of 33kV. Some Primary substations feed into 6.6kV city networks in which case the secondary voltages are 6.6kV instead of 11kV. Primary transformers are normally installed in pairs to provide full alternative supplies in the event of one circuit outage. However, some Primary Substations have single transformers and rely on alternative supplies from the 11kV network but arranged to comply with Engineering Recommendation P2/5.

Transformers have unit protection, Buchholz relays and employ pilot wire inter-tripping to source on underground circuits and fault throwers on overhead circuits. Neutral Voltage Displacement detection is provided on incoming overhead circuits. The LV circuit breakers (11, 6.6kV) have directional protection to prevent back-feeding 33kV phase faults.

Transformers have on-load tap changers for voltage control. Vector group is Dyn11. Earth fault currents are limited to a maximum of 1000 amps per transformer by neutral earthing resistors although lower values may apply according to network earthing requirements.

1.1.6 11kV Secondary circuits

11kV Secondary circuits normally comprise of overhead lines on wood poles (unearthed construction) in rural areas and underground cables in urban areas or where overhead routes are inappropriate or unobtainable. Most circuits contain a mix of underground cable and overhead line. Circuits are generally arranged as radial feeders terminating at normally open switches to form an open ring main. Alternative supplies are applied either by manual switching or by remote operation of automated switches by System Control. Switches are situated at distribution substations and on overhead line poles to enable routine and emergency work to be carried out within the requirements of Engineering Recommendation P2/5 and the Regulator's customer service targets.

1.1.7 Secondary Substations

Secondary Substations deliver energy to Central Networks' low voltage networks and to industrial/commercial customer owned networks.

The vector group of 11kV/LV transformers is Dyn11 and off-load tap changers are provided for voltage adjustment. Where customers take a supply at 11kV they own their 11kV/LV transformers and sometime operate their own internal 11kV circuits. The majority of customers take supply from the Low Voltage network supplied by 11kV/LV transformers owned by Central Networks.

Pole mounted transformers are either connected directly to ring main overhead lines or spur lines by solid jumpers, live line taps, expulsion fuses, links or automatic sectionalising links as appropriate to the local network configuration. Pole transformer locations have to be selected with consideration to the risk of accidental contact with 11kV terminals taking into account the present and future use of the land. Free-standing pole mounted transformers (cable connected rather than overhead supplied) are no longer permitted in Central Networks East. Padmount transformers or Compact Unit Substations are used where overhead line connections do not meet the requirements of the risk assessment process. This policy will be applied in Central Networks West once Padmount transformers have been introduced.

Ground mounted transformers have local switchgear incorporating transformer protection fuses or circuit breakers. This switchgear is normally a Ring Main Unit that provides switching and earthing facilities for the connected 11kV ring circuit cables. Some transformers are radial connected on tee-off cables. These may be equipped with Ring Main Units or cable elbow connectors in the case of padmount transformers.

Any radial connection of pole and ground mounted transformers is carefully regulated by Central Networks to ensure compliance with the requirements of Engineering Recommendation P2/5 and the Regulator's customer service targets. The provision of LV back-feeds and/or facilities for the connection of mobile generators is an integral part of network design.

1.1.8 Low Voltage (LV) Network

Low Voltage (LV) Network comprises of three phase underground cables or overhead lines on wood poles normally arranged as multi branched radial feeders. Some LV circuits interconnect with adjacent transformers via underground link boxes or overhead fuse-gear to provide back-feeds during routine and emergency work to ensure compliance with the requirements of Engineering Recommendation P2/5 and Regulator's customer service targets.

The majority of existing underground cables are paper insulated, lead covered, steel tape armoured construction. Most cables are 4 core (3 phase + neutral) but areas of 5 core (3 phase + street light + neutral), 2 core (1 phase + neutral) and 3 core (2 phase + neutral) also exist.

In some locations plain lead or steel wire armoured cables exist and some of the older cables may be of concentric construction.

TN-S earthing is provided to many customers. TN-C-S earthing is also provided to customers where the cable has been converted to Protective Multiple Earthing (PME).

A large proportion of existing overhead line is of bare wire construction. TT earthing is provided to many customers. TN-C-S earthing is also provided to customers where the line has been converted to Protective Multiple Earthing (PME).

New LV networks are constructed of underground cable. Three core XLPE insulated cable with waveform combined neutral/earth (CNE) screen is employed to enable live jointing to take place without interruption of the neutral/earth. TN-C-S earthing is available from waveform cables which are all PME.

Replacement of, or extensions from, existing open wire overhead lines are by Aerial Bundled Conductor (ABC). TN-C-S earthing is available from ABC lines which are all PME.

LV Circuits are protected by HRC fuses to BS88 part5. Central Networks' policy is to fuse new LV mains such that phase to neutral faults on mains and services are cleared within 100 seconds. Voltage drop and loop impedance criteria are used to ensure the appropriate quality of supply and circuit protection times are achieved. Refer to the Loop Impedance Policy section of this manual for more detail.

Services are breech jointed directly onto mains. Three phase and single phase services are used as appropriate to the load.

All new domestic properties have outdoor meter boxes unless prohibited by local planning regulations. Where the use of internal services is unavoidable they are terminated in a cut-out immediately inside the building. New installations in blocks of flats have a three phase supply installed at a central service / metering position and lateral connections to flats are provided and owned by the owner/occupiers.

1.2 LV Network

1.2.1 General Considerations at LV

Supplies to groups of new customers shall normally be provided by underground cables. Exceptionally, overhead lines may be used where the use of underground cable is not reasonably practicable.

Mains cables shall normally laid along one side of the road. Road crossings shall be provided to service properties on the opposite side. Double-sided mains may be used to accommodate large concentrations of load or as a means of reinforcing existing developments. Cables shall be installed in footpaths or service strips and positioned relative to other utility apparatus in accordance with National Joint Utilities Group recommendations.

LV mains cables shall be laid in black rigid twinwall corrugated ducts to ENATS 12-24 with warning tape. Short sections of LV mains cable may be laid direct only where ducts cannot be used such as sharp bends or at jointing positions. Warning tape shall be used in these situations. Warning tape may be omitted where trenchless excavation is employed.

All road crossings shall be ducted.

The Central Networks Cables, Cable Laying and Accessories Manual provides further detail.

LV circuits shall normally be arranged as multi-branched radial feeders. There shall be a maximum of 100 customer connected to each LV circuit. Un-used ways in the substation LV feeder pillar shall be cabled and bottle ended outside the substation to enable future circuits to be added without making the feeder pillar dead. The bottle ends shall not have PME earth electrodes installed as this may compromise the separation of the HV and LV earth electrode systems.

Selected LV circuits shall interconnect with adjacent transformers via underground link boxes or overhead fuse-gear to provide back-feeds during routine and emergency work on the 11kV system to ensure compliance with the requirements of Engineering Recommendation P2/5 and the Regulator's customer service targets. Refer to sub-section 1.4.5.6 of this Manual for LV interconnection requirements.

Services are breech jointed directly onto mains. Commercial and Industrial properties normally have three phase services. Domestic properties have single phase services and these are distributed across the phases of the mains cable as evenly as possible to balance the load. Electrically heated properties may have three phase services according to local network requirements. Block of flats have a three phase supply installed at a central service / metering position and lateral connections to flats are provided and owned by the owner/occupiers.

The Standard Equipment Ratings and Data section of this manual defines the types and sizes of cable and overhead lines that shall be used the designer.

Voltage drops are calculated as per section 6 of this Manual

1.2.2 LV Earthing

All new construction shall be to PME specification in accordance with the Central Networks Earthing Manual - Section E6 Protective Multiple Earthing.

Existing networks should only be converted to PME where PME terminals are requested by customers and if it is technically and economically practical to do so.

Regulation 8(2)b of the Electricity Safety Quality & Continuity (ESQC) Regulations 2002 states *"the earth electrodes are (to be) 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."*

- Substation HV & LV earths shall be:
  - segregated at sites where the Earth Potential Rise (EPR) is over 430 volts – Hot Sites
  - combined at sites where the Earth Potential Rise (EPR) is below 430 volts – Cold Sites

  according to the requirements of the Central Networks Earthing Manual.

- Where an LV circuit is to pass near HV equipment such as 11/33kV earthed poles or 132/275/400 kV towers the appropriate 430v or 650v EPR contour must be identified and precautions taken against earthing the LV neutral within the zone either directly or via street furniture.

A PME terminal is the preferred method of earthing for the majority of premises. However, it is not suitable for every connection.

This table shows where a PME terminal may or may not be provided		
Type of premises	**PME ?**	**Comments**
Domestic houses and commercial / industrial premises in non-steel framed buildings	YES	Equipotential bonding must comply with the current edition of BS7671
Existing domestic houses with downstairs bathrooms on concrete or non-insulated floor	NO but	PME can be provided if an equipotential mat has been installed in the concrete base and bonded in accordance with the current edition of BS7671. PME may also be provided if all water and waste pipes within the bathroom are plastic.
Commercial / industrial premises in steel framed buildings	YES but	YES if there is only one service into the building and equipotential bonding complies with the current edition of BS7671 Multiple services – NO - may result in high EMF due to neutral currents returning via the steel frame. See section 3.2.21 of section E6 of the Earthing Manual
Caravan, mobile home	NO	Prohibited by ESQC Regs
Permanently fixed 'mobile' home	YES but	Provided it is not mounted on wheels and does not have a conductive surface – i.e. it is a prefabricated dwelling. See section 3.2.21 of section E6 of the Earthing Manual
Railway electric traction systems	NO	See section 3.2.1 of section E6 of the Earthing Manual
Construction Sites	NO	See section 3.2.2 of section E6 of the Earthing Manual
Temporary building not a construction site	YES but	See section 3.2.3 of section E6 of the Earthing Manual
Farms and horticultural premises	NO but	OK for the house but the remainder of the buildings need special consideration, especially dairies. See section 3.2.4 of section E6 of the Earthing Manual
Sports Pavilions and Swimming Pools	NO but	Can be used provided the bonding arrangements are specially designed. See section 3.2.5 of section E6 of the Earthing Manual
Mines and Quarries	NO but	OK for the offices but must be segregated from the production facilities. See section 3.2.7 of section E6 of the Earthing Manual
Petrol Filling Stations	NO but	OK for associated buildings like shops but must be segregated from the petrol filling areas. See section 3.2.8 of section E6 of the Earthing Manual. Also Association for Petroleum & Explosives Administration / Institute of Petroleum Guide.

Continued	**PME ?**	**Comments**

Type of premises		
Pubs and bars (tanker delivery supply)	YES	See section 3.2.9 of section E6 of the Earthing Manual
High Rise Buildings	YES	See section 3.2.10 of section E6 of the Earthing Manual
Supplies provided from a separate position to the building	YES but	See section 3.2.11 of section E6 of the Earthing Manual
Outside water taps	YES	Not precluded by the current edition of BS7671. See section 3.2.12 of section E6 of the Earthing Manual
LV Embedded Generators	YES	Refer to section 5.2 of EA Engineering Recommendation G59/1
Street lighting and street furniture	YES	See section 3.2.14 of section E6 of the Earthing Manual
Lightning protection systems	YES	See section 3.2.15 of section E6 of the Earthing Manual and BS6651
Roadside public telephones, bollards, ticket machines etc.	NO but	There are some limited exceptions. See section 3.2.16 of section E6 of the Earthing Manual
Cathodic protection installations	NO but	There are some limited exceptions. See section 3.2.17 of section E6 of the Earthing Manual
Small radio stations and cell phone stations	NO but	OK for domestic or business radio stations. See section 3.2.18 of section E6 of the Earthing Manual
Cell phone base stations on 132/275/400 kV towers	NO	EA Engineering Recommendation G78 applies.
Outside broadcast caravans	NO	Previous approval has been withdrawn by the Dept of Trade & Industry.

1.2.3 LV Protection

LV Circuits are protected by High Rupturing Capacity (HRC) fuses to BS88 part 5. Central Networks' policy is to fuse new LV circuits such that phase to neutral faults on mains and services are cleared within 100 seconds after allowing a 15% voltage reduction for arc resistance. This limits the length of mains and services according to the combined loop impedance of the transformer, main and service cable and substation fuse size. Long street lighting circuits shall be protected by an additional cut-out fuse normally installed in the first lamp on the run or a street lighting authority owned distribution pillar.

The 100 second fault clearance times do not comply with the current edition of BS7671 "Requirements for Electrical Installations". Therefore service cables must be either terminated in outdoor meter boxes or in cut-outs installed at the first reasonably practicable location within the building such that the minimal length of service cable is within the building. Any Central Networks equipment inside the building after the cut-out must comply with the current edition of BS7671. i.e. 5 second earth fault clearance time.

Section 1.2.8 of this Manual specifies acceptable service locations for each building type.

Cut-outs are fitted with fuses to BS 1361 (services to 100 amps) or BS88 Part5 (services to 630 amps). The current edition of BS7671 "Requirements for Electrical Installations" allows the installation designer to rely upon the cut-out fuse to protect his main switchboard / consumer unit. There is therefore a maximum permissible loop impedance related to each size of cut-out fuse to ensure fault clearance within 5 seconds.

Refer to Tables 1 to 4 in the LV Earth Loop Impedance Policy Section 5.3.4 of this Manual for fuse size / loop impedance data.

Substation LV fuses must also grade with the HV protection of the local distribution transformer. Central Networks standard transformer HV protection schemes comply with ENATS 12-6 and allow the following maximum fuse sizes to be installed:

Refer to Table 1.2.3 LV Fuse sizes for further information.

Table 1.2.3 LV Fuse sizes					
Transformer size	Type	Nominal impedance	Max fuse size amps	**Normal fuse size**	
				Residential non electric heating	Residential electric heating & Industrial / Commercial
1	2	3	4	5	6
1000 kVA	Ground mounted	4.75%	**630**	315	400 Notes 1& 2
750 / 800 kVA	Ground mounted	4.75%	**630**	315	400 Notes 1 & 2
500 kVA	Ground mounted	4.75%	**400**	315	400
300 / 315 kVA	Ground mounted	4.75%	**315**	315	315
200 kVA	Ground mounted	4.75%	**200**	200	200
50 kVA 1Ø	ANSI Padmount	2.5%	**315**	315	315
100 kVA 3Ø	ANSI Padmount	2.5%	**200**	200	200
200 kVA 3Ø	ANSI Padmount	2.5%	**400**	315	400
315 kVA 3Ø	Pole mounted	4.75%	**400**	315	400 Notes 3 & 4
200 kVA 3Ø	Pole mounted	4.75%	**400**	315	400 Note 5
100 kVA 3Ø	Pole mounted	4.75%	**200**	200	200
50 kVA 3Ø	Pole mounted	4.5%	**200**	200	200
100 kVA 1Ø	Pole mounted 2 wire	4.5%	**400**	315	400
50 kVA 1Ø	Pole mounted 2 wire	4.5%	**200**	200	200
25 kVA 1Ø	Pole mounted 2 wire	4.5%	**200**	200	200
100 kVA 1Ø	Pole mounted 3 wire	4.5%	**200**	200	200
All	100 amp Cut-out	-	**-**	80	100

Column 2 lists standard transformers to Electricity Association Technical Standard ENATS 35-1 except for Padmounts which are to American National Standards Institute (ANSI) C57-12-25/26 standard.

Column 4 lists the maximum sizes allowable for HV/LV protection discrimination.

Column 5 lists the sizes to be installed on LV feeders supplying non-electric heated residential properties. The maximum fuse size of 315 amps is chosen to enable the maximum LV feeder length to be utilised within voltage drop limits and without unduly restricting the length for loop impedance criteria. Mains may be 95, 185 & 300 mm^2

Column 6 lists the sizes to be installed on LV feeders supplying electric heated residential properties and industrial / commercial properties. Mains may be 95, 185 & 300 mm^2.

Note 1 – Some existing feeders with copper cables supply loads over 400 amps. On these circuits the fuse size may be increased to 630 amps. However, L.V. distribution fuse-boards to ESI Standard 37-2, as supplied with standard EME unit substations, have a standard 500A outgoing way with a 6-hour overload rating of 555A. Therefore, the loading of a 630A fuse-link fitted in such a switchboard must be limited to these values

Note 2 – Industrial supply Arrangements C and D in Section 1.3.1.7 and 1.3.1.8 use a 630 amp fuse at the substation in order to grade with the 400 amp cut-out fuses.

Note 3 - Where feeding onto an LV network two cables shall be used to split the load using 2 sets of 315 amp fuses.

Note 4 - Where a single customer requires a supply up to 260 kVA then an LV cabinet shall be used with one set of 400 amp fuses supplying a 300 mm^2 cable. (Transformer output is limited to the 360 amp / 260 kVA rating of a 300 mm^2 cable in ducts.)

Note 5 - 400 amp fuses should only be used to supply a single cable from a 200 kVA P/T to utilise the full overload rating of the transformer for a single customer. Where two cables are supplied then 2 sets of 315 amp fuse shall be used.

1.2.4 After Diversity Maximum Demands

The following values shall be used as the basis for design. Note that the method of using these values depends of the part of the network being designed i.e. mains, services or transformer. Further sections of this manual define the method of application

1.2.4.1 Residential Loads

'Non-electric' and 'No Central Heating' values of After Diversity Maximum Demand (ADMD) assume small or average houses and flats up to 4 bedrooms. For larger properties increase the ADMD by 0.5kW per additional bedroom.

Heating Type	**ADMD kW (LV Mains)**
No central heating – gas available in the dwelling	2.0
No central heating – gas not available in the dwelling	3.0
Gas / Oil or Solid fuel central heating	2.0
Direct electric heating – ceiling / panel /convector	2.0 plus 50% of installed space heating load (ignore water heating)
Electric storage heating	100% of installed storage and 100% of water heating load
Electric storage heating plus direct heating	100% of installed storage and 50% of direct heating +100% of water heating load
Note that the above values are "after diversity" demands and apply directly to the design of mains cables. When designing individual services or sizing transformers, further formulae are applied to adjust the diversity element as defined in the appropriate sections of this manual.	

1.2.4.2 Commercial and Industrial Loads

The following table provides examples of typical commercial & industrial loads based on Central Networks' experience.

Customers tend to request a supply that is the arithmetical sum of the installed equipment and this can give rise to an unrealistic maximum demand. Customer's load estimates should be benchmarked against this table.

Property Type	Typical ADMD
Small shop	Single ph 8 kW
Café/Restaurant	Three ph 15 kW
Take away	Three ph 20 kW
Church	Three Ph supply lots with infra-red direct heating up to 50 kW
Farm	Three Ph up to 100 kW
Farm with grain dryer	Three Ph 200 kW depending on fan motor/heater
Beauty salon/ Tanning shop	Three ph 10 kW
Hair dressers	single ph 5 kW
Pubs	Three ph 20 kW exceptionally up to 120 kW
Garages/workshops	Three Ph 30 kW Compressor Motors and Welders
Village stores/ small supermarkets	Three Ph 20 kW
Milking parlours	Three Ph 50 kW (normally Single Ph motors)
Sewage pumps	Three Ph 20 kW - 150Kw Compressor Motors?
Small hotels/guest houses	Three Ph 20 kW
Small businesses	Three ph 20 kW
Residential care/nursing homes	Three Ph most have lifts and all-day heating can be 100 kW.
Note that the above values are "after diversity" demands and apply directly to the design of mains cables. When designing individual services or sizing transformers, further formulae are applied to adjust the diversity element as defined in the appropriate sections of this manual.	

Other industrial and commercials loads need to be established in conjunction with the customer's electrical consultant or contractor.

1.2.5 Residential Housing Developments

1.2.5.1 Connection Strategy for Residential Loads

All proposed industrial / commercial connections shall comply with Section 1.4.2 Connections Strategy.

1.2.5.2 Voltage Regulation - Residential Housing

- Section 6 of this Manual, Low Voltage Network Design Calculations, detailes the method to be used to calculate voltage regulation on LV mains and services. The ADMDs shown in section 1.2.4.1 for residentail loads shall be used.

- Voltage regulation from LV busbars of the HV/LV transformer to any service cut-out shall not exceed:

  - 6% of 230 volts when supplied from "Standard 11kV Feeders".

  - 4% of 230 volts when supplied from "Long 11kV Feeders".

A 'Long 11kV Feeder' is defined as extending beyond the 15km radius of a Bulk Supply Point or Primary Substation. See Section 4 Network Voltage Policy.

This voltage regulation may be apportioned between the main and service cable provided that:

- The maximum service cable voltage drop is limited to 2.5%. *This is to prevent excessive voltage appearing on the neutral/earth of PME supplies.*

- On new non-electrically and direct acting electrically heated properties the overall loop resistance is no greater than 0.24 ohms (comprising the sum of transformer, main and service cable go/return resistances). *The 0.24 ohm limit applies to 'Greenfield' housing developments only. Where extensions are made from existing LV networks this limit may be relaxed in accordance with the LV Earth Loop Impedance Policy section of this Manual. Also note that the resistance and not the impedance value is referred to here – this is in recognition that large single phase switched loads on residential developments are normally resistive e.g. electric showers up to 7.2 kW.*

- On new electrical storage heated properties the total space and water heating load must not cause a step voltage change greater than 3% when switched by the metering time/tele switch.

	Maximum Loop Resistance for simultaneously switched heating devices								
Nameplate kW rating @230v	6	7	8	9	10	11	12	13	14
Max Loop Resistance for 3% step voltage change	0.24	0.21	0.18	0.16	0.14	0.13	0.12	0.11	0.10

1.2.5.3 Mains Cables – Residential Housing

Mains cable loading shall be based on the arithmetic sum of the After Diversity Maximum Demands (ADMDs) of the properties connected to the cable.

The maximum continuous summer rating of the cable in ducts shall be used.

The following Combined Neutral Earth (CNE) cables shall be used;

Size	**Application**	**Continuous summer rating in ducts**	
95mm^2 Wavecon	Branches, cul de sacs etc. Note 1	201 amps	145 kVA Note 3
185mm^2 Wavecon	Main feeders and interconnectors	292 amps	210 kVA Note 3
300mm^2 Wavecon	Electric heating sites. Other sites where current rating, loop impedance and/or voltage drop criteria cannot be achieved with 185mm^2 Note 2	382 amps	275 kVA Note 3

Note 1 - Small developments may only require 95mm^2 main feeders and branches.

Note 2 - the neutral of 300mm^2 Wavecon is only 185mm^2 and will have a reduced effect on loop impedance reduction.

Note 3 – kVA rating based on 240v nominal running voltage – 4.167 amps per kVA

1.2.5.4 Service Cable Loading - Residential Housing

The service cable design load shall be calculated according to the type of heating to be used. The formulae for "Non-electric heating" and "No central heating installed" make allowance for the future installation up to 6kW of storage heating and electric water heating.

For houses over four bedrooms increase the ADMD by 0.5kW per additional bedroom.

The minimum design load for any service shall be 12kW

Service cable loading shall be based on the formulae:

Non-electric heating (i.e. gas, oil solid fuel)

Service design load = (2x ADMD x N) +8 kW

= 12kW single house

= 16kW if looped to second house

ADMD is normally 2kW

N = 1 for single house. 2 if loop service is installed.

No central heating installed and gas not available

Service design load = (2x ADMD x N) +8 kW

= 14kW

ADMD is normally 3kW

N = 1 loop service is not permitted

Direct acting electric heating (i.e. panel, ceiling heaters)

Service design load = (2x ADMD x N) +8 kW + 50% of electric space heating load (ignore water heating)

ADMD is normally 2kW

N = 1 loop service is not permitted

Electric storage heating

Service design load = 4kW + 100% of installed electric storage and 100% of water heating load

Mixed electric storage heating and direct heating

Service design load = 4kW + 100% of installed electric space and 100% of water heating load + 50% of direct acting heating.

1.2.5.5 Service Cable Voltage drop calculations - Residential Housing

For voltage drop calculations the current per kW shall be based on a typical network running voltage of 240v which equates to 4.167 amps per kW.

1.2.5.6 Service cable / cut-out maximum thermal loading

The nameplate kW ratings of electrical appliances are based on a nominal voltage of 230v. At higher voltages the kW output of heating appliances rises above the nameplate rating as they draw more current.
i.e.

The current taken by 1kW @ 230v is 1000 ÷230 = 4.35 amps	(I=W ÷ V)
This equates to a resistance of 230 ÷ 4.35 = 52.9 ohms	(R=V ÷ I)
At 253 volts the current rises to 253 ÷ 52.9 = 4.8 amps	(I=V ÷ R)
This equates to 253 x 4.8 = 1.2 kW at 253v	(W=V x I)

Therefore an appliance with a nameplate rating of 1kW will become a load of 1.2kW when supplied at the upper statutory limit of 253v. Whilst this is not critical when sizing mains cables and transformers it must be taken into account when establishing the maximum load capability of a service cable and cut-out combination. Furthermore, a 100 amp cut-out installed in an outdoor meter box has a reduced rating of 90amps. This must not be exceeded either on a single installation or through the connection of a looped service.

The following table over the page shows the maximum loads allowed on services.

Maximum thermal loading on services				
Service Size	**Application**	**Cable continuous rating in ducts**	**Cut-out rating in meter box**	**Maximum connected load ADMD or Heating Name Plate Rating**
$25mm^2$ Hybrid	Street lighting / furniture service	94 amps	N/A	N/A
$35mm^2$ Hybrid	Single phase house service 80A cut-out fuse **Non- electric heating**	115 amps 24kW	80amps = 16 kW	4.0 kW ADMD Load = 2AN+8 = 2x4x1+8 = 16kW
$35mm^2$ Hybrid Looped Service	Single phase house services 80A cut-out fuse **Non- electric heating**	115 amps 24kW	80amps = 16 kW (90amps = 18 kW main and loop)	2.5 kW ADMD Load = 2AN+8 = 2x2.5x2+8 = 18 kW
$35mm^2$ Hybrid	Single phase house service 100A cut-out fuse **Direct Acting Electric heating**	115 amps 24kW	90 amps = 18 kW	12kW of Space Heating Load = 2AN+8 +50% heating = 2x2x1+8 + 12/2= 18kW
$35mm^2$ Hybrid	Single phase house service 100A cut-out fuse **Electric storage heating or** **Mixed storage / direct**	115 amps 24kW	90 amps =18 kW	14kW of Space & Water Heating Load = 4kW + 100% of storage +50% of direct = 18kW
$35mm^2$ Wavecon	3 phase house service 100A cut-out fuses **Electric storage heating or** **Mixed storage / direct**	100 amps 62kW	90 amps = 54 kW	50kW of Space & Water Heating Load = 4kW + 100% of storage +50% of direct = 54kW =18+18+14 of heating +4 of domestic load.
		Load to be split: R Ø / Y Ø / B Ø House 1: 14+4 / 18 / 18 House 2: 18 / 14+4 / 18 House 3: 8 / 18 / 14+4 House 4: 14+4 / 18 / 18 Etc.		
NOTE the load ratings assume 4.8 amps per kW i.e. appliance rated at nominal 230v running at 253v.				

Looped services may be used on non electric heated houses subject to step voltage change and loop impedance considerations being satisfied.

Looped services shall not used for houses with electric heating.

Looped services from 3 phase cut-outs are not permitted.

NOTE. Single phase cut-outs are designed, tested and approved for the additional heat generated by the looped cable within the cut-out cable box cover. Three phase cut-outs have not been designed for this duty and the heat generated by the additional 3 phase conductors with the confined space of the cable box may cause thermal failure.

1.2.5.7 Servicing method

Two methods of servicing houses are acceptable:

i) Sites with footpaths or service strips and cables laid to NJUG 7 - Service joints – up to four services per joint.

ii) PPG33 sites - Underground Service Distribution Boxes of an approved design may be used where appropriate. All mains and services to be ducted where run in roadways.

Planning Guidance Note PPG3 sites normally have few/no footpaths or service strips requiring mains ands services to be laid in the roadway.

1.2.5.8 Fusing - Residential Housing

Non-electric heating

House service cut-outs shall be fused at 80 amps

Feeders supplying non-electric heating residential developments shall be fused at a maximum of 315 amps to enable cables lengths to be maximised whilst providing protection within the LV Earth Loop Impedance Policy.

Note – on non-electric heating developments loop impedance will normally be the limiting factor on feeder length rather than volt drop or load current.

Electric heating

House service cut-outs shall be fused at 100 amps

185mm^2 Wavecon feeders supplying electric heating sites shall be fused at 315 amps

300mm^2 Wavecon feeders supplying electric heating sites shall be fused at 400 amps.

Note – on electric heating developments, voltage drop and/or load current will normally limit feeding distances rather than loop impedance criteria.

1.2.6 Supplies to Flats

1.2.6.1 Voltage Regulation - Flats

Section 6 of this Manual, Low Voltage Network Design Calculations, detailes the method to be used to calculate voltage regulation on LV mains and services.

Voltage regulation from LV bus-bars of the HV/LV transformer to any cut-out at the central metering position shall not exceed:

- 6% of 230 volts when supplied from "Standard 11kV Feeders".
- 4% of 230 volts when supplied from "Long 11kV Feeders".

A 'Long 11kV Feeder' is defined as extending beyond the 15km radius of a Bulk Supply Point or Primary Substation. See Section 4 Network Voltage Policy 6% of 230 volts

provided that:

- The overall loop resistance is no greater than 0.24 ohms at the service position at the head of the most remote rising main (comprising the sum of transformer, main and service cable go/return impedances).
- On electrical storage heated properties the total space and water heating load must not cause a step voltage change greater than 3% when switched by the metering time/tele switch.

	Maximum Loop Resistance for simultaneously switched heating devices								
Nameplate kW rating @230v	6	7	8	9	10	11	12	13	14
Max Loop Resistance for 3% step voltage change	0.24	0.21	0.18	0.16	0.14	0.13	0.12	0.11	0.10

1.2.6.2 Service Cable Loading for Flats

The service cable design load shall be calculated according to the type of heating to be used. The formulae for "Non-electric heating" and "No central heating installed" make allowance for the future installation up to 6kW of storage heating and electric water heating.

The minimum design load for any service shall be 12kW

Non electric heating (i.e. gas, oil, solid fuel)

ADMD shall be 2 kW

Service cable design load = (ADMD x number of flats) +8 kW

e.g.

2 flats = 2kW x 2+ 8kW =12kW

26 flats = 2kW x 26 + 8kW =60kW

No central heating installed and gas not available

ADMD shall be 3 kW

Service cable design load = (ADMD x number of flats) +8 kW

e.g.

2 flats = (3kW x 2)+ 8kW =14kW

26 flats = (3kW x 26) + 8kW =86kW

Direct acting electric heating (i.e. panel, ceiling heaters)

ADMD shall be 2 kW + 50% of installed electric space heating load (ignore water heating)

Service cable design load = (ADMD x number of flats) +8 kW.

e.g.

2 flats with 8kW of panel heaters each = (2kW + 8kW/2) x 2) +8kW =20kW

26 flats with 10kW of panel heaters each = (2kW +10kW/2) x 26) + 8kW =190kW

Electric storage heating

ADMD shall be 100% of installed electric storage and water heating load

Service cable design load = (ADMD x number of flats) + 4kW

e.g.

2 flats with 8kW of storage & water heating = (8kW x 2) +4kW =20kW

26 flats with 10kW of storage & water heating
= (10kW x 26) +4kW =264kW

Mixed electric storage heating and direct heating

ADMD shall be 100% of installed electric space and water heating load plus 50% of direct acting heating.

Service cable design load = (ADMD x number of flats) + 4kW

e.g.

2 flats with 6kW of storage & water heating plus 4kW of panel heaters
= (6kW + 4kW/2) x 2 +4kW =20kW

26 flats with 6kW of storage & water heating plus 4kW of panel heaters
= (6kW + 4kW/2) x 26 +4kW =212kW

1.2.6.3 Service cable / cut-out maximum thermal loading - Flats

Continuous summer cable ratings in ducts shall be used for services to flats;

The nameplate kW ratings of electrical appliances are based on a nominal voltage of 230v but may operate at up to 253v. As explained in section 1.2.5.3, a 1kW appliance nameplate rating equates to 1.2kW of load at 253v. The following service loadings are based on a current of 4.8 amps per kW:

35mm2 Hybrid – 90* Amps ≈ 18 kW
35mm2 Wavecon - 90* Amps ≈ 54 kW
95mm2 Wavecon - 201 Amps ≈ 125 kW
185mm2 Wavecon - 292 Amps ≈ 183 kW
300mm2 Wavecon - 382 Amps ≈ 239 kW

Note *
100 amp cut-out is limited to 90 amps in meter box or indoor cabinet
Maximum of 2 customers per phase on $35mm^2$ cable

These are the **minimum** size service cables to be used according to the service cable design load. Sizes may have to be increased for voltage drop and loop impedance criteria depending on the location of the substation and size of mains cable.

1.2.6.4 Properties Converted into Flats

Converting existing properties into flats presents a number of service design challenges. This section of the Manual provides approved solutions for some commonly encountered circumstances. Other situations (e.g. space over shops converted to flats) should be approached using good engineering practice employing the spirit and intent of the approved solutions to provide a safe installation.

Two storey buildings

Two outdoor service boxes installed at ground level each to supply one floor only. The consumer's switchgear must be within 3 metres of each service position. This requires that the first floor consumer's switchgear be directly above the meter box.

This method is only suitable where

- Space is available for meter boxes (surfaced or cavity)
- The building is not listed or in a conservation area where the Local Planning Authority does not allow outdoor boxes.

Three or more floors

When the building has more than two floors or is covered by conditions listed above an internal location can be used subject to:

- The internal location is a maximum 3 metres into the building from the outside front or side wall of the property.

- It is situated on a ground floor within common area adjacent to front door.

- The service cable is protected in black PVC duct clearly marked "Electric Cable Duct" and laid under a solid floor. Cables must not be routed under suspended floors

The meter position accommodation must:

- be for electrical equipment only
- be of adequate size for installation of Central Networks cut-out equipment.
- be of adequate size for installation of metering equipment
- be formed in brick or block work only [NOTE 1]. Plasterboard partitions are not acceptable
- have full width opening doors for access to equipment
- be fire resistant to comply with fire regulations.
- not contain other utility service equipment (e.g. water or gas)
- not be used as a storage room
- not be under stairs where headroom is less than 2 metres

NOTE 1 – The provision of brick or block may not be possible in timber framed buildings. The wall behind the service/metering equipment must be fitted with a steel sheet (min 1mm thick) bonded to the cut-out PME terminal. *This is to protect persons drilling through the wall from electric shock.*

Cut-out arrangements shall be:

- 1 flat - all types of heating– single phase 100 amp cut-out. An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. One 35mm^2 hybrid cable.
- 2 flats - non-electric heating – single phase 100 amp cut-out plus loop to second cut-out. An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. One 35mm^2 hybrid cable.
- 2 flats - electric heating – single phase 100 amp cut-out per flat. An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. Two 35mm^2 hybrid cables.

- 3 flats - all types of heating– three phase 100 amp cut-out - An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. One 35mm^2 Wavecon service cable.
- 4 to 10 flats (or 3 to 9 flats plus landlords supply) 10 way 100 amp cut-out - 95mm^2 Wavecon service cable.

  Note – it is forbidden to loop from 3 phase cut-outs as they have no certification for the additional thermal duty.

1.2.6.5 Purpose Built Flats

Services shall be installed at group metering positions and the developer shall provide and install lateral wiring to each flat complying with the current edition of BS7671 "Requirements for Electrical Installations". These laterals shall remain the property of the building landlord or individual flat owners as appropriate.

The position and number of service positions shall depend on the distance from each flat such that the lateral wiring can be installed within the design requirements of the current edition of BS7671 "Requirements for Electrical Installations".

In order of preference the number / position of services shall be:

1. A single position on the ground floor.
2. A single position on the ground floor plus a rising main to some or all floors.
3. Several positions on the ground floor plus a rising mains to some or all floors.

PME bonding to the building metalwork shall be made at the central metering position / rising main only. *This is to limit the circulation of neutral current around the building metalwork. See Central Networks' Earthing Manual Section E6 for more information*

Where a landlord's supply in excess of 70 kVA is required, e.g. for lifts, then a CT metered Industrial / Commercial supply should be provided for this purpose.

Group meter positions must:

- be for electrical equipment only
- be of adequate size for installation of Central Networks' cut-out equipment.
- be of adequate size for installation of metering equipment
- be formed in brick or block work only [NOTE 1]. Plasterboard partitions are not acceptable
- have full width opening doors for access to equipment
- be fire resistant to comply with fire regulations.
- not contain other utility service equipment (e.g. water or gas)
- not be used as a storage room
- not be under stairs where headroom is less than 2 metres
- not be in below ground level i.e. basements

NOTE 1 – The provision of brick or block may not be possible in timber framed buildings. The wall behind the service/metering equipment must be fitted with a steel sheet (min 1mm thick) bonded to the cut-out PME terminal. *This is to protect persons drilling through the wall from electric shock.*

Cut-out arrangements shall be:

- 1 flat - all types of heating– single phase 100 amp cut-out. An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. One 35mm^2 hybrid cable.
- 2 flats - non-electric heating – single phase 100 amp cut-out plus loop to second cut-out. An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. One 35mm^2 hybrid incoming cable plus one 35mm^2 hybrid cable loop.
- 2 flats - electric heating – single phase 100 amp cut-out per flat. An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. Two 35mm^2 hybrid cables.
- 3 flats - all types of heating– three phase 100 amp cut-out - An additional bus bar connected 100 amp cut-out may be used for the landlord's supply if required. One 35mm^2 Wavecon service cable.
- 4 to 10 flats (or 3 to 9 flats plus landlords supply) 10 way 100 amp cut-out - 95mm^2 Wavecon service cable.
- 10 to 24 flats (or 9 to 23 flats plus landlord's supply) – 400 amp or 600 amp cut-out. 24 way 100amp multi-way cut-out mounted immediately above the cut-out or on the appropriate floor of the rising main. 185mm^2 or 300mm^2 Wavecon cable dependant on service cable design load.
- 25 to 30 flats (or 24 to 29 flats plus landlord's supply) – 400 amp or 600 amp cut-out. 30 way 100amp multi-way cut-out mounted immediately above the cut-out or on the appropriate floor of the rising main. 185mm^2 or 300mm^2 Wavecon cable dependant on service cable design load.
- Above 30 flats – multiples of the above arrangements.

Notes

- *It is forbidden to loop from 3 phase cut-outs as they have no certification for the additional thermal duty.*
- *10 way 100 amp cut-outs fit cables up to 95 mm^2*
- *400 amp cut-outs fit cables up to 185mm^2*
- *600 amp cut-outs are required for 300mm^2 cable*

Rising Mains

- The incoming cable supplying a rising main shall be terminated in a cut-out immediately inside the building. The rising main shall be taken from the top side of this cut-out to the metering position floor. The rising mains shall not be taken directly from the substation to the metering position floor. *Note that this is to enable the rising main to be fused in accordance with section 1.2.6.5 in order to comply with the current edition of BS7671 "Requirements for Electrical Installations". Also it provides the facility for personnel not authorised to enter substations to isolate the rinsing mains.*

- The incoming cable shall be terminated in an insulated cut-out in-line with any metal clad distribution board. It is forbidden to terminate a main cable emanating directly from the substation into a metal clad multi-way distribution board. *The provision of the insulated cut-out provides the facility to make the metal clad distribution board dead prior to work. It also provides a suitable termination for the Wavecon cable and a neutral connection for PME bonding.*

- The developer is responsible for providing and installing suitable cable trays of 450mm or 600mm width for the full height of the risers. Cable tray sections must be connected using the manufacturer's specified couplings and properly bonded and earthed. (Cables trays shall be galvanised Admiralty Pattern or equivalent)

		Number of cables per tray	
Cable size	**Cable dia**	**450mm tray**	**600mm tray**
35 mm^2 Hybrid	20 mm	12	15
35 mm^2 Wavecon	31 mm	8	10
95 mm^2 Wavecon	35 mm	7	9
185 mm^2 Wavecon	47 mm	5	7
300 mm^2 Wavecon	56 mm	3	6

Cables shall be spaced one diameter apart to avoid de-rating.

- Nylon cable zip ties are to be used for fixing cables to trays. A cable cleat is to be installed below each cut out for added support.

- Rising voids and cable trays must be positioned on each floor to open out into common areas which provide 24-hour safe and unrestricted access to Central Networks personnel. Each location should be provided with fully opening doors.

- Central Networks standard Wavecon and Hybrid cables shall be used for rising mains unless local Fire and/or Building Regulations require additional measures such as low smoke emission cables. It is responsibility of the developer to seek the advice of the Local Fire Officer. However, the incoming service shall be standard Wavecon and Hybrid cable.

- The PME terminals of all cut-outs in a rising main shall be bonded together in accordance with the Central Networks Earthing Manual Section E6 Protective Multiple Earthing part 3.2.10.

Size of smallest cable in the Rising Main.	**Neutral size** **Cu**	**Size of Combined Neutral/Earth Bonding Conductor** (Colour green/yellow + blue marker tape at each end)
35mm^2 Wavecon	22 mm^2 cu	25mm^2 cu
95mm^2 Wavecon	60 mm^2 cu	70mm^2 cu
185mm^2 Wavecon	116 mm^2 cu	120mm^2 cu
300mm^2 Wavecon	116 mm^2 cu	120mm^2 cu

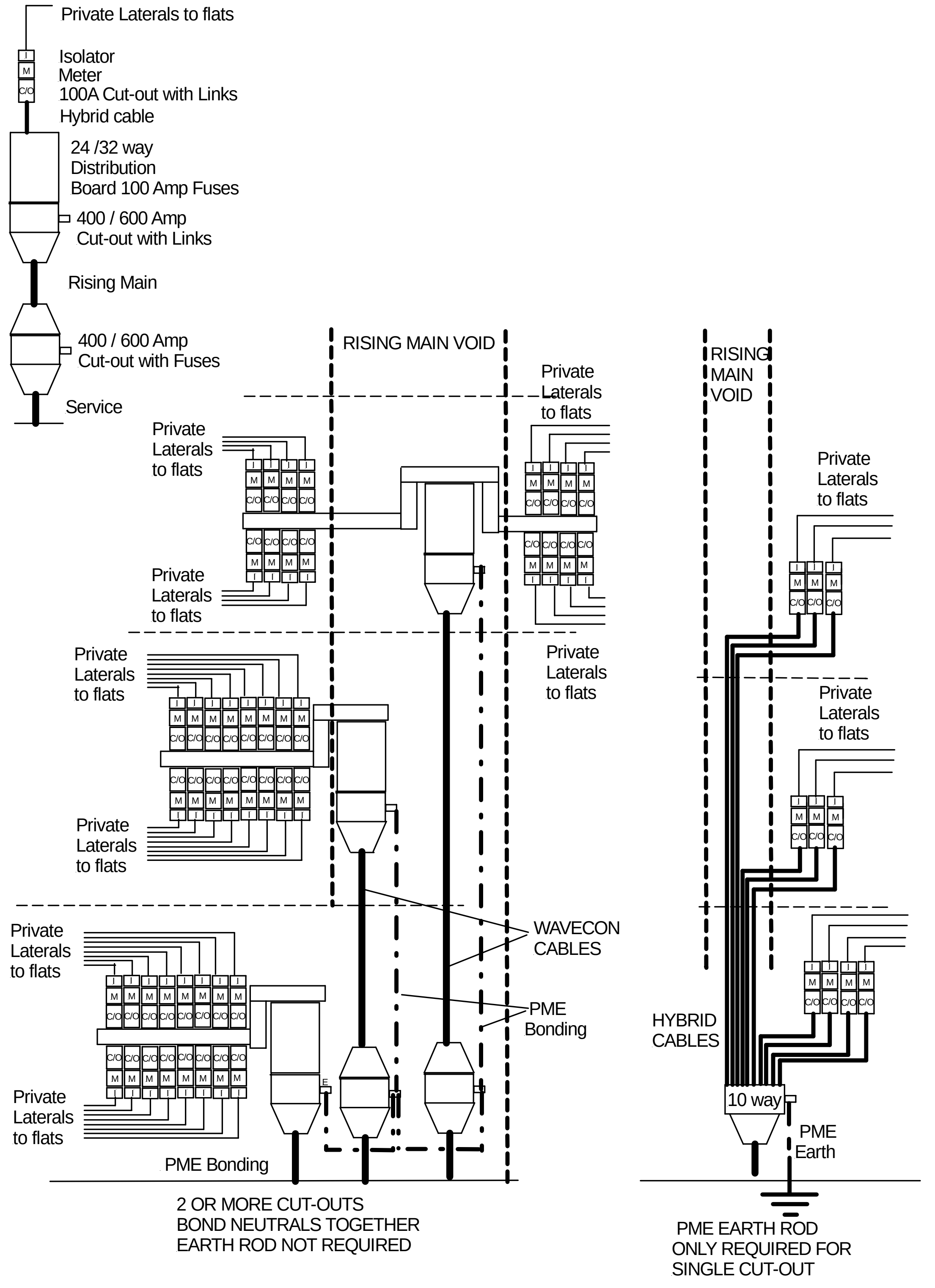
- Where there are two or more rising mains in the same rising void their neutrals shall be bonded together via their PME terminals with the appropriate sized cable which shall be identified as a combine neutral earth conductor. i.e. green/yellow cable with blue marker tape at each end. (see BS7671 clause 514-04-03)

- The PME terminal of a single cut-out at a group metering point shall be connected to an earth rod outside the building via 16mm^2 conductor (coloured green/yellow only).

- The developer's electrical contractor is responsible for the installation of private switchgear and sub mains from the common electrical riser to each dwelling.

- The landlord is responsible for providing access for occupiers to the equipment installed within the common risers for maintenance or to check meter readings.

- The developer is responsible for ensuring that the design and installation of the rising main void meets local fire regulations including any smoke or fire segregation provisions between floors.



Typical rising main arrangements using a multi-way distribution board on each floor or 10 way Cur-out on ground floor with Hybrid cables to upper floor(s).

1.2.6.6 Fusing Feeders, Services & Cut-outs in Flats

Substation feeders supplying flats shall be fused at:

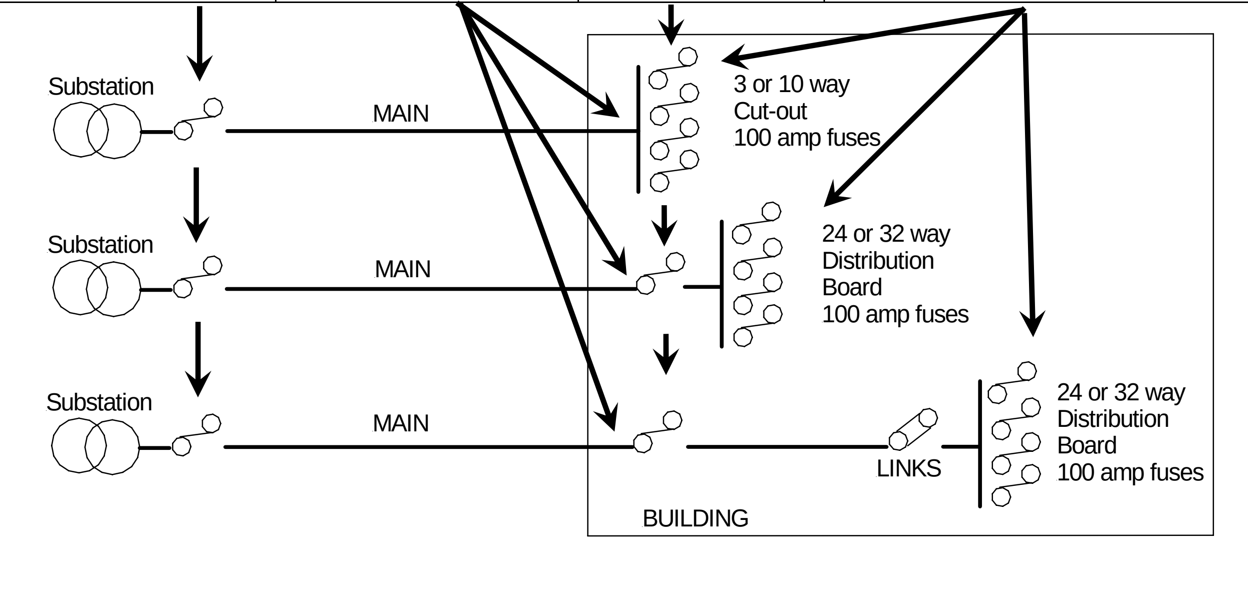
- 315 amps – feeders up to 185mm^2
- 400 amps – feeders of 300mm^2 *NB transformer must be 500kVA or greater*
- 630 amps – feeders of 300mm^2 and to grade with 400 amp fuse in cut-outs at high load sites. *NB transformer must be 800kVA or greater*

Feeder length will be limited by the loop impedance required to clear the substation fuse in 100 seconds, step voltage change criteria and voltage drop.

The first cut-out within the building shall be fused to clear earth faults on any Central Networks owned equipment inside the building within 5 seconds in accordance with the Earth Loop Impedance Policy section of this Manual and the current edition of BS7671 "Requirements for Electrical Installations".

This Table is a guide to fuse sizes and loop impedance criteria

Substation Fuse	Max loop impedance at first cut-out (100 sec)	Cut-out fuse	Max loop impedance at multi-way cut-out at remote end of any rising main (5 sec)
	Dominant loop impedance shown bold		
315 Amps	**0.24 ohms**	100 Amps	0.38 ohms
315 Amps	0.24 ohms	200 Amps	**0.20 ohms**
400 Amps	**0.19 ohms**	200 Amps	0.20 ohms
400 Amps	0.19 ohms	315 Amps	**0.13 ohms**
630 Amps	0.12 ohms	400 Amps	**0.096 ohms**



1.2.6.7 Emergency Fire Fighting Supplies – BS5588-5:2004

British Standard 5588-5:2004 "Fire Precautions in the design, construction and use of buildings – Part 5 Access and facilities for fire-fighting"

This standard requires that certain high rise buildings have dedicated lifts and stairs for use by fire fighters to quickly reach floors affected by fire. These lift shafts and stair wells may also be force ventilated to the clear smoke in a controlled manner. During the course of a fire the normal electricity supply may fail either as a deliberate act to make internal services safe or by the effect of the fire itself or water used in fire fighting.

Section 14 "Electrical Services" in BS5588-5 requires that the internal circuits supplying the lifts and ventilation fans are specially protected against fire and water. Also a secondary supply must be available which is independent of the normal supply. The customer's switchgear is normally arranged to run these circuits from the normal supply with auto changeover equipment to select the secondary supply when required.

The secondary supply may be a standby generator or secondary supply from the local distribution network. The previous version of this standard (BS 5588-5:1991) recommended the additional supply be taken from a different 11kV (or 6.6kV) circuit to the normal supply. This has now been rescinded in BS5588-5:2004.

The standard now provides for the secondary supply to be:

1. Standby generator capable of operating in fire conditions.

    This option is totally independent of faults that could be caused to the Central Networks system by the fire itself.

2. Where regular maintenance of a standby generator would not be expected the main and secondary supplies may come from the same external substation via two separate intakes and then by separate routes to the fire-fighting shaft.

    Central Networks' interpretation is that an external substation should be located such that it would not be affected by the fire. A substation incorporated into the building cannot be relied upon to maintain the secondary supply. Taking an LV supply from an adjacent substation may not be sufficient if both substations are on the same HV feeder as they would be shut down if the fire caused the HV feeder to trip. Central Networks will not normally be able to provide and guarantee a secondary supply from an independent HV feeder.

3. If protection against the occurrence of a fault on the high voltage system (unconnected with the fire) is required by the occupier then a standby generator or an independent power supply is required.

    BS5588-5:2004 does not define what form an independent power supply should take. Central Networks' interpretation is that it would not be provided by Central Networks.

Central Networks cannot guarantee the availability of a secondary supply under all circumstances. It is the customer's responsibility to ensure compliance with BS5588-5:2004 and should seek the advice of the local fire service and /or building control officer about the suitability of any proposed secondary supply.

1.2.7 In-fill Developments

In-fill developments shall be designed using the same principles as Residential Housing developments.

When calculating voltage drop, the ADMD of existing properties connected to the mains shall normally be assumed to be 2kVA unless the existence of electric heating is suspected. Where necessary the actual ADMD should be ascertained. e.g. by algorithms based on meter readings or by taking the most recent winter maximum demand reading of the local transformer and dividing it by the number of customers connected. This value must be multiplied by 1.33 to be applicable the reduced diversity on individual LV mains. Where the result is greater than 2kW this revised ADMD shall be used. If the local transformer does not have maximum demand indictors the ADMD of a similar locality where the maximum demand is known may be used.

Some older networks with a low housing density (e.g. suburbs and villages) will have mains that can accept additional load and remain within voltage limits but will exceed the loop impedance criteria set for new housing.

Refer to the LV Earth Loop Impedance Policy section of this Manual for further guidance and explanation.

The salient points of the LV Earth Loop Impedance Policy are summarised below together with guidance on their application.

Where the substation fuse clearance time at the cut-out cannot be achieved then in the following order of preference:

1. Consider if the substation feeder fuse can be reduced in size whilst ensuring that the maximum feeder demand is within the proposed fuse rating.

2. Consider installing a 2 way link box or pole mounted fuses to sub-fuse the network extension if the substation feeder fuse size cannot be reduced.

3. If 1 and 2 above are not reasonably practicable then ensure all service terminations are installed in out-door meter boxes.

The step voltage change loop resistance criteria of 0.24 ohms for new developments is relaxed for in-fill developments is relaxed from the cut-out position back to the point of common coupling with other customers. Any further relaxation should be agreed with the customer and the balance between cost and quality of supply made clear particularly where large electric showers or storage heating loads could be installed.

Note that loop resistance is referred to here because the 3% step voltage criteria is based on a 7.2 kW shower load which is mainly resistive. Fault clearance criteria are calculated using impedance values due to the power factor of the fault current. The resistance of an LV network is lower than it's impedance.

Where the loop impedance at the cut-out exceeds 0.35 ohms the designer of the premise's internal wiring shall be advised that this value exceeds the typical maximum values published in Engineering Recommendation G23/1

However, the absolute maximum Loop impedance provided at new properties shall be 0.52 ohms and where necessary networks shall be reinforced to attain this value.

Central Networks may be prepared to fund some or all of the cost of any reinforcement to meet loop impedance criteria.

1.2.8 Physical Position of Services

1.2.8.1 Residential Housing Underground Cable Service positions

The service cable shall be run from the main to the meter box in at straight line perpendicular to the main wherever reasonably practicable. Service cables shall be installed in ducts and provided with warning tape. (Refer to Cable, Cable Laying & Accessories Manual for details)

This requirement is to ensure that the service cable follows a predicable route where occupiers would anticipate their presence during normal gardening and DIY activities.

1.2.8.2 Residential Housing Overhead Line Cable Service positions

Overhead services shall not normally be provided to new houses except where expressly requested by the owner.

When renewing existing overhead services:

Central Networks West – copper concentric CNE service cable run as an aerial span and continued clipped to the wall to the service box

Central Networks East - Aerial Bundled Conductor (ABC) shall be used for the overhead span and anchored at high level on the building. The following methods of cabling from the aerial span to the service position are acceptable:

1. Continue the ABC on the wall to the meter box or existing internal meter position. Overhead Line Manuals Volume 1 Section 6 Drawings LV215 to LV219 details the installation methods and defines the zone that needs additional protection.
2. Convert the ABC to Hybrid cable and run on the wall to the service position as above. Because the Hybrid cable has an earthed metallic screen there is no requirement to provide the additional protection shown in drawing LV215. However, a cable guard is required where the cable is within 2.4m of the ground.

3. Entry to the meter box may be directly from the wall generally to drawing LV219 but using cut and mitred cable guards instead of tubing.
4. Alternatively the cable may be taken down to ground level, ducted underground and terminated into the meter box in the same manner as a totally underground service. This method may be less visually intrusive than the above methods.

1.2.8.3 Outdoor meter boxes

New and re-serviced domestic housing service terminations shall be in outdoor meter boxes mounted into an external wall on the front or side elevation of the property in front of any fence or gates to allow unrestricted access to Central Networks staff from the public environment.

Single phase service cables shall fixed to the surface of the wall and enter the meter box from the underside and be capped with a cable guard or contained within in a pipe. Single phase service cables shall not be run inside the wall cavity.

Three phase service cables shall enter the meter box via a pipe installed inside the cavity. *NOTE – The present design of large meter box does not allow surface entry. Installation via the wall cavity will be discontinued once the design of three phase meter box has been modified to enable external entry.*

The meter tails to the consumer unit shall not exceed 3 metres in length.

The meter operator may install a 100 amp isolator in these meter tails within the meter box to provide isolation facilities for the customer's consumer unit.

The following positions are not permitted:

- at the rear of the property
- at the side of the property behind fences or gates
- within a coal, dustbin or refuse store, garage, porch.
- Under windows unless minimum installation height can be achieved.

The box shall be installed at a:

- maximum height of 1800mm from ground level to the top of the box – *to enable access without ladders or steps.*
- minimum height of 450mm from ground level to the bottom of the box – *to reduce the risk of water entering the box as a result of flooding or fire fighting activities.*

These requirements are necessary for the following reasons:

- *To reduce risks to occupiers to the minium level*
    - o *Cables, fuses and meters generate heat during normal operation which must be properly dissipated to ensure the equipment does not overheat and catch fire. Outdoor meter boxes designed and manufactured to ENATS 12-03 have thermal characteristics that enable the service termination equipment to be operated*

  - *safely. The thermal performance of indoor service positions may be compromised by occupiers storing items close to the equipment resulting in overheating.*
  - *Service cables are directly connected to high energy ditribution mains protected by substation fuses up to 630 amp rating and designed to have a maximum fault clearance time of 100 seconds. The protection of fixed wiring complying with BS7671 inside buildings ensures fault clearance times of less than 5 seconds. By placing the service cut-out fuse in a meter box outside the building Central Networks is able to provide the same level of protection inside the building up to the consumer unit as afforded by BS7671.*
  - *An outdoor service position ensures that at the time of installation and during subsequent building work and occupation the risk of tradesmen or occupiers being injured by live high energy equipment is as low as is reasonably practicable.*
- *To provide access to service equipment*
  - *To enable regular meter reading by the meter operator to reduce the incidence of estimated billing*
  - *To reduce the hazards to meter operatives. Of all personnel involved in electricity distribution, meter operatives have the highest injury rate. The injuries that occur whilst inside private dwellings include slips trip & falls, dog attacks, assault by occupiers. Removing the need to enter dwellings reduces these hazards.*
  - *For testing of supplies to assist with effective network fault location*
  - *For main fuse removal to prevent embedded generation (e.g. photo voltaic, sterling engine combined heat & power gas boilers etc.) back-feeding the network during dead working. This emerging technology is now available for new build and retro fitting. The long term reliability of the loss of supply protection of these units is not yet proven.*
- *Service cable fixed to surface of wall*
  - *To prevent overheating of the cable due to cavity wall insulation*
  - *To ensure that cable/satellite TV and telecoms installers do not drill through a hidden service cable – risk of electrocution. Technology and product changes now make this a frequent activity undertaken by tradesmen and DIY enthusiasts .*
- Service not installed in coal, dustbin or refuse store, garage, porch.
  - *To prevent damage to service equipment and resulting danger from accidental contact during normal domestic activities.*
  - *To prevent damage and resulting danger from accidental contact by vehicles and/or materials stored in garages*
  - *To prevent danger to Fire Fighters from damaged service equipment where dustbin / refuse stores are set alight accidentally or maliciously.*

The following meter boxes to ENATS 12-03 are approved for use in Central Networks:	
	From left to right: 1. Small flush fitting box 2. Slim-line flush fitting box 3. Small surface mount box 4. Large flush fitting box (not shown)
	1. Small flush fitting box. ▪ Used for single phase services ▪ This is designed to fit into the outer leaf of a cavity wall in a space 7 bricks high by 1½ bricks wide. The overall outside dimensions are approximately 600mm high by 410mm wide. This box will accommodate a single phase cut-out, time-switch, two rate meter and isolator. ▪ Knock-outs are provided for service cable entry via the cavity or the wall surface. Cavity entry is not permitted by Central Networks.
	2. Slim-line flush fitting box. ▪ Used for single phase services ▪ This is designed to fit into the outer leaf of a cavity wall in a space 9 bricks high by 1 brick wide. The overall outside dimensions are approximately 830 mm high by 275 mm wide. This box will only accommodate a single phase cut-out and a single meter with built in tele-switch and isolator. ▪ When opting for slim-line boxes the developer must ensure that the intended meter operator can provide this type of meter. Knock-outs are provided for service cable entry by the cavity or the wall surface. Cavity entry is not permitted by Central Networks.

	3. Small surface mounted box. ▪ Used for single phase services ▪ Similar to item 1 but designed to fit on the surface of walls without a cavity. The overall outside dimensions are approximately 600 mm high by 400mm wide. The box projects about 235mm from the surface of the wall. This box will accommodate a single phase cut-out, time-switch, two rate meter and isolator. Knock-outs are provided for service cable entry via the wall surface only.
No photo available Similar to small flush fitting box	4. Large flush fitting box. ▪ Used for three phase services ▪ This is designed to fit into the outer leaf of a cavity wall in a space 9 bricks high by 2 bricks wide. The overall outside dimensions are 790 mm high by 565 mm wide. This box will accommodate a three phase cut-out, time-switch, two rate meter and isolator. Knock-outs are provided for service cable entry via the cavity only. For the time being cavity entry is permitted by Central Networks until such time as the standard design is altered to allow wall surface entry.

Indoor meter positions

Where the developer can demonstrate that the Local Planning Authority will not permit an outdoor meter box by virtue of the building being listed or in a conservation area a service position inside the house may be proposed. Central Networks' acceptance of any proposal will be subject to the following conditions:

1. The design of the indoor service position shall ensure that at the time of installation and during subsequent building work and occupation the risk of tradesmen or occupiers being injured by live high energy equipment is as low as is reasonably practicable.
2. The service cable shall be routed inside the building by the shortest and most direct route possible and shall be ducted. The internal end of the duct shall be sealed immediately after cable installation to prevent the ingress of natural gas.
3. The service equipment shall be installed on a brick or block-work wall. Where reasonably practicable this will be an external wall.
4. In timber framed buildings a suitable brick or block-work wall may not be available. In these cases a steel sheet (min 1mm thick) shall be fixed behind the service cable, cut-out and meter which shall be earthed. *This it to protect persons drilling through the wall from electric shock.*
5. The developer shall provide accommodation for the cable, cut-out and meter in a meter cabinet extending from floor level. The free air space inside the cabinet

should equal or exceed that of an out-door meter box and ventilation shall be provided to enable the heat generated by the service cable, cut-out fuse and meter to be safely dispated. Local fire regulations may require heat run tests to be carried out on the proposed design.

6. The service cable above the floor must not be obscured by panelling of any type or routed behind the backs of any cupboards or fitments. The cable may be covered with a cable guard or capping which is easily identified as cable protection. *There have been fatal accidents where persons have drilled through panelling into live service cables.*

7. The standard fibre glass outdoor meter box **shall not be used indoors** as it does not comply with the appropriate British Standards for fire resistance and fume emissions. The developers shall provide a meter box that complies with fire regulations and any local by-laws.

The following service positions are not permitted

- Inside a coal store, dust bin or refuse store, cellar, lavatory, kitchen or bathroom.
- Over doorways.
- On partition wall made of plasterboard, drywall or similar material.
- Under stairs where headroom is less than 2m
- Any location where it is not possible to comply with the current edition of BS7671 "Requirements for Electrical Installations".

Existing properties

Where existing underground and overhead service positions are altered at the request of the customer the new service shall be subject to the same provisions as for new developments.

Where existing underground and overhead services are replaced at Central Networks instigation, e.g. due to poor condition, it will not normally be reasonably practicable to alter the service position to fully comply with the provisions for new developments. Existing meter positions may be retained unless a more favourable position can be established at no additional cost or disturbance

1.2.8.4 Industrial and Commercial Service Positions

Service up to 100 Amps

Industrial and commercial service terminations up to 100 Amps per phase shall normally be in an outdoor meter box mounted into an external wall on the front or side elevation of the property in front of any fence or gates where practicable. Where the installation of a meter box is not feasible, e.g. shop frontage, then the service may be installed internally as per the provisions in section 1.2.8.1

The present design of large meter box does not facilitate cable entry from the outside surface of the wall. Until such time as the large box is re-designed to facilitate surface entry it is permissible to install 3 phase service cables via the wall cavity.

The meter tails to the consumer unit shall not exceed 3 metres in length.

The meter box shall not be accommodated within a coal, dustbin or refuse store, garage or porch.

Services over 100 Amps

The developer shall provide accommodation for the cable, cut-out and meter in a dedicated meter room / cupboard. The service cable above floor must not be obscured by panelling of any type or routed behind the backs of any cupboards or fitments.

The design of the indoor service position shall ensure that at the time of installation and during subsequent building work and occupation the risk of tradesmen or occupiers coming into accidental contact with live equipment is as low as reasonably practical.

The service cable shall be routed inside the building by the shortest route and most direct route possible and shall be ducted. The duct shall be terminated the service position either in a slow elbow bend or a pulling pit. The arrangement shall enable a cable of 56mm diameter with a 620mm minimum bending radius to be installed (i.e. up to 300mm^2 Wavecon). The internal end of the duct shall be sealed immediately after cable installation.

The standard fibre glass outdoor meter box **shall not be used indoors** as it does not comply with the appropriate British Standards for fire resistance and fume emissions. The developers shall provide a meter box that complies with fire regulations and any local by-laws.

The following service positions are not permitted

- Inside a coal store, dust bin or refuse store, cellar, lavatory, kitchen, bathroom.
- Over doorways.
- On partition wall made of plasterboard, drywall or similar material.
- Under stairs where headroom is less than 2m
- Any location where it is not possible to comply with the current edition of BS7671 "Requirements for Electrical Installations".

1.2.8.5 Service Positions in Flats

Guidance on service positions and rising mains is provided in the Supplies to Flats section.

1.2.9 Street Lighting / Furniture Supplies

Street lighting columns and other street furniture shall be serviced using :

Central Networks West - 16mm^2 or 25mm^2 copper concentric cable

Central Networks East - 25mm^2 Hybrid cable.

The earth loop impedance criteria specified in Section 5 LV Earth Loop Impedance Policy, of this Manual shall be observed to ensure that phase to neutral/earth faults are cleared effectively. This is to prevent PME earthed lamp columns and cabinets remaining alive for prolonged periods. Section 5.3.4 Street Lighting Services provides information on fuse sizes and loop impedance criteria.

1.2.9.1 New developments

- Street lighting cables up to 20m long may be directly jointed onto the main without the need for a loop impedance calculation. The normal LV design procedures will automatically ensure that loop impedance criteria are met.

- Street lighting cables over 20m long and those looped to other lamps / furniture must be subject to a loop impedance study and sub fusing shall be provided where necessary.

1.2.9.2 Existing networks

- New street lighting cables up to 5m long may be directly jointed onto existing mains without the need for loop impedance calculation.

- Street lighting cables over 5m long and those looped to other lamps / furniture must be subject to a loop impedance study and sub fusing shall be provided where necessary.

1.2.9.3 Complex / multiple connections

- Road junctions with traffic lights, carriageway lighting etc. A single service shall be provided to a lighting authority owned distribution pillar to enable them to carry out their own distribution to the street furniture. *Multiple service connections from the LV network to separate items of equipment, which themselves may be interconnected by light authority cables, become complex to design and control. There is scope for accidental parallels to be made between DNO mains and substations which could result in danger.*

- Runs of more than 2 looped street lighting columns (e.g. carriageway lighting) shall not be jointed directly to LV mains. A single service shall be provided to a lighting authority owned distribution pillar to enable them to carry out their own distribution to the street furniture

1.2.10 Transformers Supplying LV Networks

1.2.10.1 Type & Location

Substations and Padmounts shall be positioned in accordance with Section 1.4.6 Physical Siting of 11kV Substations and Equipment.

Note that Padmounts cannot be used in Central Networks West at present

LV networks on residential development shall be supplied from:

- A Ground Mounted Substation(s) provided specifically for the development and sited near the load centre to facilitate practical and economic LV network layout. The developer shall provide a substation site measuring 4m x 4m. (see section 1.4.6.4 Substation Legal Requirements).
    - The substation shall normally be housed in a Glass Reinforced Plastic (GRP) housing with approved explosion venting provisions.
    - The developer may elect to accommodate the substation in a brick built substation to match the surrounding properties. A tiled roof is not permitted on these buildings because they cannot be readily removed for equipment change-outs and they have no controlled explosion venting characteristics. The Central Networks Plant Specification Manual specifies the approved types of roofs and doors that may be used. Roof options include GRP hipped roofs designed to match various types of tiles.
    - Substations shall not be built into or onto residential properties or garages. Substations shall be free standing to prevent the transmission of noise/vibration into adjacent properties and to avoid collateral damage in the event of explosion.

  All substation housings/buildings must have suitable explosion venting built into the design – normally in the form of a lightweight tethered roof.

- An LV network extension from an existing Ground Mounted Substation, Padmount or Pole Transformer of sufficient capacity and where voltage drop and earth loop impedance criteria can be met. *This option applies mainly to small infill developments.*

- An LV network extension from a new Ground Mounted Substation, or where no other option exists, a Padmount or Pole Transformer located off the site and used to reinforce the local LV network. Where a 4m x 4m site cannot be obtained locally for a Ground Mounted Substation a smaller site may be used to accommodate a Padmount Transformer. *This option applies mainly to small infill developments.*

- A Pole Mounted Transformer installed on an 11kV overhead line. Where the 11kV overhead line is extended towards the development the pole transformer site shall be selected in accordance with a risk assessment procedure taking into account potential danger to the public and the present and projected use of the land. If a safe location cannot be established then an 11kV underground cable and a Ground Mounted Substation or Padmount shall be used.

Free-standing Pole Transformers shall not be used either within or at the periphery of residential developments. *Central Networks consider that the presence of exposed high voltage terminals close to houses presents an unacceptable risk to members of the public going about normal DIY, hobby and play activities at or near home through inadvertent contact or deliberate interference. The hazard is eliminated by the use of ground mounted non-exposed conductor equipment.*

The Ring Main Units of Ground Mounted Substations shall be loop connected into the 11kV network and LV back-feeds provided in accordance with Section 1.4.5 11kV Connectivity Rules.

Padmount and pole transformers shall be tee connected into the 11kV network and LV back-feeds provided in accordance with Section 1.4.5 11kV Connectivity Rules. Where the LV back-feeding provision of the 11kV Connectivity Rules cannot be met then a Ring Main Unit equipped Ground Mounted Substation shall be used.

1.2.10.2 Transformer size calculation

The initial calculated load shall not exceed the transformer name-plate rating. Any overload capability shall be used to accommodate future load growth.

Standard transformer sizes for use on residential developments		
Ground Mounted	**Padmount**	**Pole Mounted**
200 kVA	100 kVA	100 kVA
315 kVA	200 kVA	200 kVA
500 kVA		
800 kVA NOTE 1		
1000 kVA NOTE 1		
NOTE 1 – 800 kVA and 1000 kVA for electric heating developments only or where motor starting current (e.g. for lifts or pumps) dictates a larger size. NOTE 2 - 50 kVA transformers shall not be used to supply residential loads. The combination of unbalanced load and the high impedance of these units results in levels of negative phase sequence voltage which adversely effects electric motors.		

The maximum size of transformer supplying a non-electric heated residential development shall not exceed 500kVA. This is to enable LV back-feeding to be feasible in accordance with the criteria in Section 1.4.5 11kV Connectivity Rules.

Electrically heated developments will have relatively short LV feeders due to the high loading making back feeding feasible at light load periods.

On residential developments the total load on the transformer shall be calculated according to the following formula:

Load = N x A x Ft x F2

Where F2=1+12/AN A = ADMD in KW N = No of houses Ft = 70%

This formula recognises that large groups of customers and higher ADMDs will have greater load diversity than small groups at low ADMDs.

Calculated values of Ft x F2 are shown below

	Values of Ft x F2 for ADMDs of:						
No of houses N	**2 kW**	**3 kW**	**4 kW**	**6 kW**	**10 kW**	**15 kW**	**20 kW**
1	4.90	3.50	2.80	2.10	1.54	1.26	1.12
2	2.80	2.10	1.75	1.40	1.12	0.98	0.91
3	2.10	1.63	1.40	1.17	0.98	0.89	0.84
4	1.75	1.40	1.23	1.05	0.91	0.84	0.81
5	1.54	1.26	1.12	0.98	0.87	0.81	0.78
6	1.40	1.17	1.05	0.93	0.84	0.79	0.77
7	1.30	1.10	1.00	0.90	0.82	0.78	0.76
8	1.23	1.05	0.96	0.88	0.81	0.77	0.75
9	1.17	1.01	0.93	0.86	0.79	0.76	0.75
10	1.12	0.98	0.91	0.84	0.78	0.76	0.74
15	0.98	0.89	0.84	0.79	0.76	0.74	0.73
20	0.91	0.84	0.81	0.77	0.74	0.73	0.72
25	0.87	0.81	0.78	0.76	0.73	0.72	0.72
30	0.84	0.79	0.77	0.75	0.73	0.72	0.71
40	0.81	0.77	0.75	0.74	0.72	0.71	0.71
50	0.78	0.76	0.74	0.73	0.72	0.71	0.71
60	0.77	0.75	0.74	0.72	0.71	0.71	0.71
70	0.76	0.74	0.73	0.72	0.71	0.71	0.71
100	0.74	0.73	0.72	0.71	0.71	0.71	0.70
150	0.73	0.72	0.71	0.71	0.71	0.70	0.70
200	0.72	0.71	0.71	0.71	0.70	0.70	0.70
250	0.72	0.71	0.71	0.71	0.70	0.70	0.70
300	0.71	0.71	0.71	0.70	0.70	0.70	0.70

Examples

1. 4 houses at 2 kW ADMD   Trans load = 4 x 2kW x 1.75 = 14 kW
2. 70 houses at 6 kW ADMD   Trans load = 70 x 6kW x 0.72 = 302 kW
3. 200 houses at 3 kW ADMD   Trans load = 200 x 3kW x 0.71 = 426 kW

For residential properties assume that the power factor is nearly unity, therefore kW ≈ kVA. The transformer size should be selected at the next standard nameplate rating up from the calculated load using the Ft x F2 correction factor.

Note that in example 2 the simple use of the number of houses and ADMDs would result in 70 x 6KW = 420 KW and this would result in over-planting the substation with a 500kVA transformer when a 315 kVA would suffice.
Likewise example 3 would have resulted in the use of a 800kVA transformer instead of 500 kVA.

1.3 Industrial and Commercial Supplies

1.3.1 LV Metered Supplies

LV metered supplies are to be used for:

- Loads up to 1000kVA where
  - the customer has not specifically requested an HV metered supply
  - It is electrically feasible for the customer to distribute the load at LV within the site.

Only one point of LV supply will be provided to each customer within a building or site.

Where two or more customers occupy the same building refer to Section 1.3.1.3 Multi occupancy buildings.

Note that if two or more services were to be provided there is a danger that neutral current from the electrically remote one service(s) may return to the substation via the service cable electrically nearest the substation. This is due to the interconnection of the service neutrals by the PME equipotential bonding and other conductive routes such as metallic pipe-work. The passage of neutral current may cause high electro magnetic fields (emf) which may cause electronic equipment to malfunction. More importantly, the PME bonding and metallic pipes etc. are not designed to be load carrying and may represent a fire risk.

This does not prelude the use of two incoming cables supplied from the same substation to a single metering room as per Section 1.3.1.8 Arrangement D. "Second service direct from substation". In this case both services have the same size neutral and are of a similar length. The cut-outs are positioned within the same room and the neutrals bonded together with a large conductor capable of carrying full load current. *(185mm^2 and 300mm^2 Wavecon both have 116mm^2 copper neutrals and the bonding conductor is 120mm^2)*

Loads unsuitable for LV metered supplies

- All loads above 1000kVA.
- Loads where the customer specifically requests an HV metered supply.
- Loads where the customer's site is extensive and voltage considerations make distribution at LV impractical.
- Disturbing loads where the Point of Common Coupling with other customers needs to be at HV.

1.3.1.1 Connection Strategy for LV Industrial & Commercial Loads

All proposed industrial / commercial connections shall comply with Section 1.4.2 Connections Strategy.

1.3.1.2 Voltage Regulation for LV Industrial & Commercial Loads

Voltage regulation from LV busbars of the HV/LV transformer to any service cut-out shall not exceed:

- 5% of 230 volts when supplied from "Standard 11kV Feeders".
- 3% of 230 volts when supplied from "Long 11kV Feeders".

A 'Long 11kV Feeder' is defined as extending beyond the 15km radius of a Bulk Supply Point or Primary Substation. See Section 4 Network Voltage Policy.

Provided that

The overall power factor of the loads is better than 0.95 which will cause no more than 4% voltage drop on the LV bus-bars local secondary substation transformer at full load.

If the power is known to be worse than 0.95 or the transformer is to be run into overload the additional transformer voltage drop shall be deducted from the maximum allowable LV network voltage regulation. See Section 4.2.3 of this Manual.

and

The voltage drop on the mains and service cables are calculated according to the methodology described in the Low Voltage Network Design Calculations Section 6 of this Manual.

1.3.1.3 Cables for LV metered supplies

The service cable and meter tail size shall be selected according to the Authorised Supply Capacity.

Cable / cut-out maximum thermal loading

The nameplate kVA ratings of electrical machines such as motors, air conditioning units etc are based on a nominal voltage of 400v. Unlike heating appliances the current does not necessarily increase as the supply voltage increases. Generally at higher voltages the machine draws less current to maintain the same output. The kVA ratings of cables shall be based on a nominal running voltage of 415/240v.

For industrial and commercial loads the cable / cut-out loading is based on:
1000 VA ÷ √3 x 415 v = 1.39 amps per kVA

Continuous cable ratings in ducts shall be used for industrial services;

35mm^2 Wavecon - 100* Amps ≈ 70 kVA

95mm^2 Wavecon - 201 Amps ≈ 140 kVA

185mm^2 Wavecon – 292 Amps ≈ 210 kVA

300mm^2 Wavecon - 382 Amps ≈ 275 kVA

Note *
100 amp cut-out is limited to 90 amps (62 kVA) if the service terminates in an outdoor meter box or indoor cabinet without a free flow of air.

These are the **minimum** size cables to be used according to the Authorised Supply Capacity. Sizes may have to be increased for voltage drop and loop impedance criteria depending on the location of the substation and size of mains cable.

Examples of Meter Tail Sizes

Service Cable Size Wavecon cable	**Service Cable Current Rating**	**Cut-out Fuse Size**	**Suggested Number and Size of Meter Tails per phase**				**Suggested Minimum Size of Main Earthing Conductor**	**Min Size of Equipotential Bonding Conductor**
			PVC BS7671 Table 4D1A		**XLPE** BS7671 Table 4E1A			
Aluminium phase (Copper neutral)	Amps	Amps	Method 1 Clipped direct mm^2 cu	Method 3 in trunking mm^2 cu	Method 1 Clipped direct mm^2 cu	Method 3 in trunking mm^2 cu	From cut-out to customer's main earth bar	i.e. water, gas, oil, frame
35 mm^2 (22 mm^2)	100/90	100	1 x 35	1 x 35	1 x 35	1 x 35	16 mm^2	10 mm^2
95 mm^2 (60 mm^2)	201	200	1 x 70	1 x 95	1 x 50	1 x 70	35 mm^2	16 mm^2
185 mm^2 (116 mm^2)	292	315	1 x 150	1 x 240	1 x 95	1 x 150	70 mm^2	35 mm^2
300 mm^2 (116 mm^2)	382	400	1 x 185	1 x 400	1 x 150	1 x 240	95 mm^2	50 mm^2

NOTES
Two tails per phase are not permitted as they will not pass through metering CTs

The Customer's electrical contractor should refer to the current edition of BS7671 'Requirements for Electrical Installations' to confirm that these sizes are adequate for the proposed method installation.

1.3.1.4 Multi occupancy buildings

Where two or more customers occupy separate units within the same building there are two options available:

1. Group metering position. **Preferred option**. A single metering position is installed using a single or duplicate service cable (see arrangements A to D below). The developer should provide customer owned cabling from the group metering position to each to each unit. This option has two advantages:
   a. Lower cost of mains and services
   b. All earthing and bonding is made at a common point
   c. **A PME terminal is available for each unit** for TNCS earthing.

   If two or more service cables are required they must be positioned in the same room and have the same sized neutral conductors. The neutrals of the cut-outs shall be bonded together with 120mm^2 copper conductor coloured green/yellow with blue tape marker at each end to denote that it is a current carrying neutral/earth bond.

2. Individual services to each unit. A distribution main is provided outside the building and individual services are connected to each unit. This option may be considered in large buildings where it may be impractical to provide long customer owned cabling from a central metering point.

This option has the following disadvantages:

a. Higher cost of mains and services
b. Earthing and bonding is made at numerous points. Where TNCS earthing (PME) is used much of the neutral current will return via the building's metalwork and the service cable electrically closest to the substation. This will result in high electrical fields which may affect electrical equipment. More importantly, it may also overheat the PME bonding conductors and the neutral conductors of the service cable electrically closed to the substation. This effect is especially pronounced in metal framed buildings.
c. To avoid this phenomenon **PME shall not** be provided to any unit. All units should employ TT earthing. The current edition of BS7671 permits a building's metal frame to be used as the main earth electrode. *See Central Networks' Earthing Manual Section E6 for more information.*
d. Where current transformer (CT) metering is used the metal meter cabinet shall be bonded to the neutral of the cut-out. Any trunking between the metering cabinet and the customer's equipment shall be plastic or other insulating material.

Where multiple LV cables are used they shall originate from the same substation. Providing LV supplies from two or more substations to the same building is not permitted on safety grounds.

1.3.1.5 Standard Service Arrangements

The next pages contain drawings of the following standard LV supply arrangements:

Arrangement A. Direct connection from existing LV Network.
Arrangement B. Direct connection from modified LV network.
Arrangement C. Service direct from substation
Arrangement D. Second service direct from substation
Arrangement E. 11kV extension to new substation.
Arrangement F. 11kV extension, 500 to 1000kVA substation & LV Air Circuit Breaker.

These are designed to accommodate the majority of supply requirements. Standard items of plant are used as 'building blocks' to ensure a straight forward approach to construction, operation and maintenance on the Central Networks system.

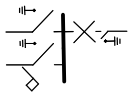
Any departure from these standards will be resisted unless exceptional local circumstances or supply requirements make a bespoke solution necessary. The Networks Manager must approve any proposed bespoke solution before it is installed.

With all these arrangements, reference should also be made to:

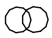
- Section 6 of this Manual – Low Voltage Network Design Calculations
- Section 5 of this manual – LV Earth Loop Impedance Policy

- Earthing Manual – PME requirements

KEY TO LV CIRCUIT SYMBOLS

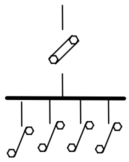


11kV Ring Main Unit - 2 x 630A ring switches 1 x circuit breaker 200 amp or 630 amp all with integral earth switches. Earth fault indicator on one ring switch

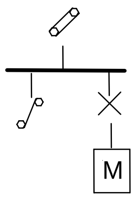


11kV/LV Transformer

Metering unit - Voltage reference and current transformers



Low Voltage distribution cabinet - incoming isolating links, outgoing 500 amp fuse ways



LV Air Circuit Breaker

Low Voltage distribution cabinet - incoming isolating links, one outgoing 500 amp fuse way Air Circuit Breaker up to 2500 amp and meter unit

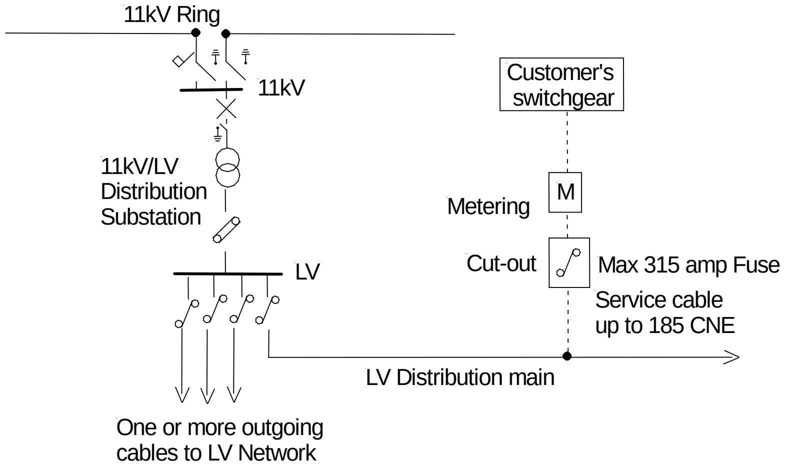
New LV cable

Existing LV cable

Boundary of customer's property

1.3.1.6 Arrangement A. Direct Connection from Existing LV Network.

<table>
<tr><td>



</td><td>

May be used for loads up to and including 210 kVA, provided that:

Cable ratings are not exceeded.
LV fuse ratings are not exceeded
Voltage drop and earth loop impedance limits are not exceeded

If these conditions cannot be met, then arrangement B, C or E may be used as appropriate.

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1.3.1.7 Arrangement B. Direct Connection from modified LV network.

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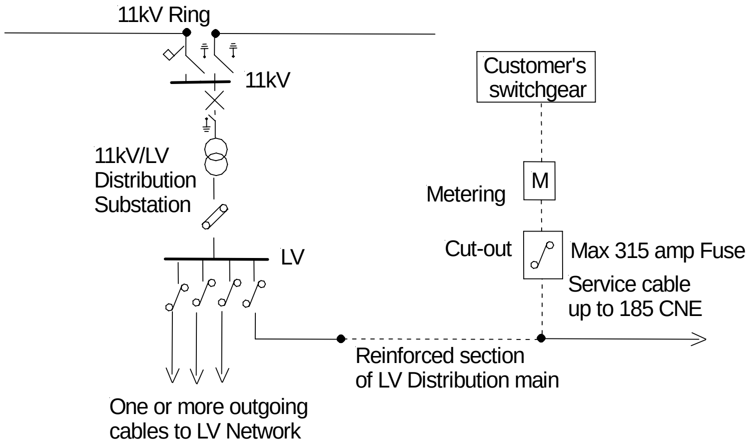


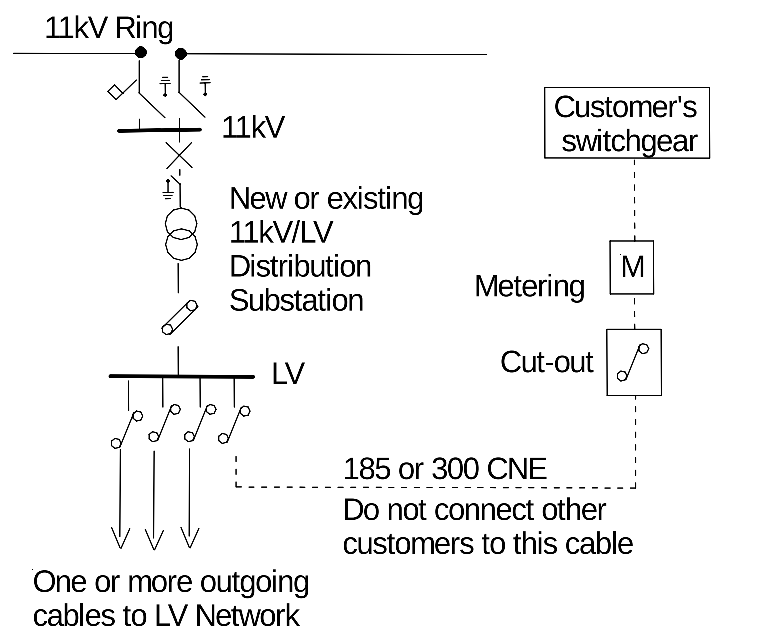
</td><td>

To be used for loads up to and including 210 kVA, where LV network modifications are required in order to meet the limits specified in Arrangement A.

If these conditions cannot be met with this arrangement, then arrangement C or E may be used as appropriate.

</td></tr>
</table>

1.3.1.8 Arrangement C. Service direct from substation.



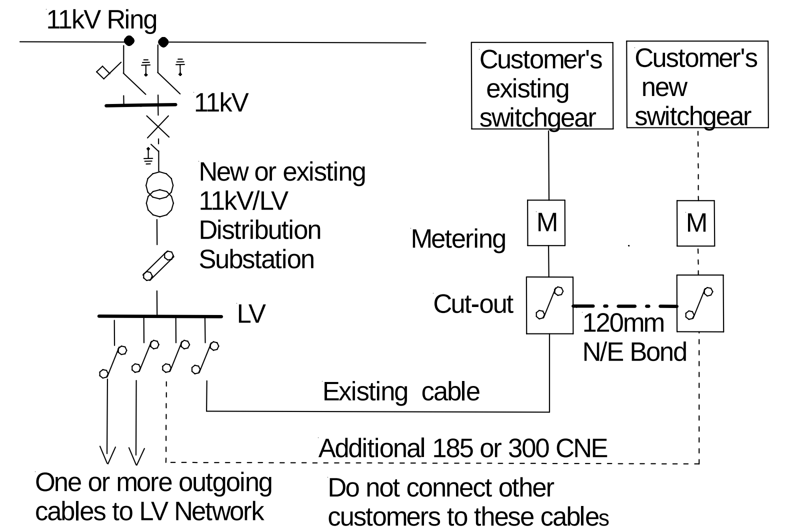
To be used for:

- Loads up to 210 kVA where arrangements A or B cannot be used, or
- Loads between 210 kVA and 275 kVA.

If voltage drop and / or earth loop impedance limits prevent this arrangement being used, then Arrangement E should be used.

1000 or 800 kVA transformer – 630 amp S/S fuse – 300 CNE cable – 400 amp cut-out fuse – 275 kVA load
500 kVA transformer – 400 amp S/S fuse – 300 CNE cable – 400 amp cut-out fuse – 275 kVA load
500 kVA transformer – 400 amp S/S fuse – 185 CNE cable – 315 amp cut-out fuse – 210 kVA load
315 kVA transformer – 315 amp S/S fuse – 185 CNE cable – 315 amp cut-out fuse – 210 kVA load
200 kVA transformer – 200 amp S/S fuse – 185 CNE cable – 200 amp cut-out fuse – 140 kVA load

1.3.1.9 Arrangement D. Second service direct from substation.



Only for up-rating existing supplies.
Use Arrangement F for new supply applications over 275 kVA.

To be used to **up-rate** an existing 275 kVA supply (Arrangement C) to 550 kVA. The customer must install a second LV switchboard to divide the loads into two separate blocks. Each block must not exceed 275 kVA.

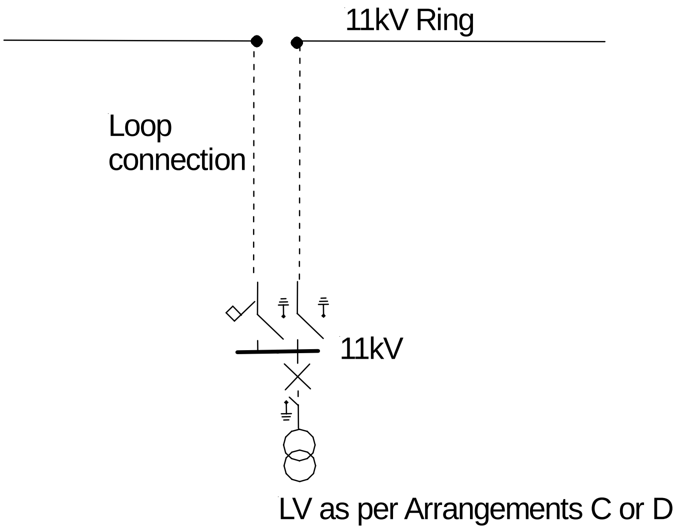
Maximum cable length is 200m at full load.

Both cables must come from the same substation and terminate in the same switch-room. The neutral must be bonded with 120mm^2 conductor.

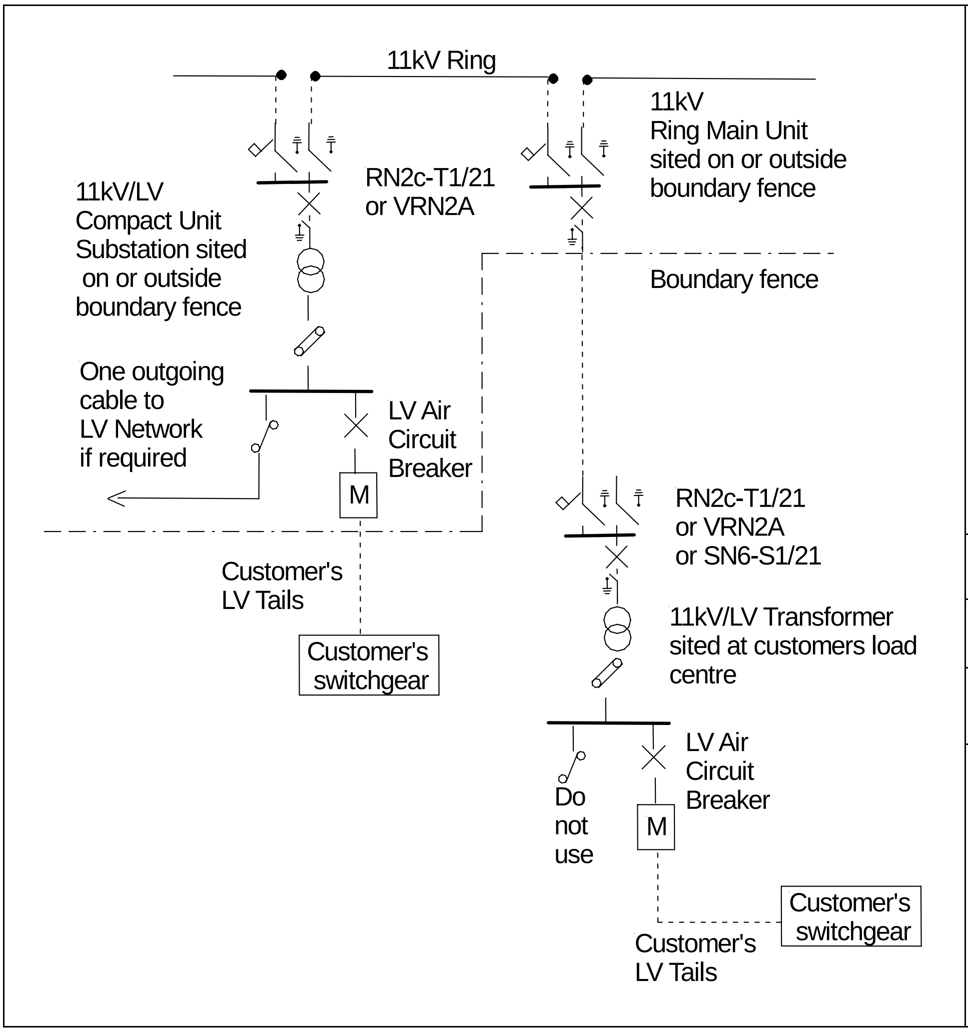
Refer to Arrangement F if new substation is required

1000 or 800 kVA transformer – 630 amp S/S fuse – 300 CNE cable – 400 amp cut-out fuse – 2 x 275 kVA load
500 kVA transformer – 400 amp S/S fuse – 300 CNE cable – 400 amp cut-out fuse – 2 x 250 kVA load*
315 kVA transformer – 315 amp S/S fuse – 185 CNE cable – 200 amp cut-out fuse – 2 x 140 kVA load*
* provided capacity is available on the substation

1.3.1.10 Arrangement E. 11kV extension to new substation.

	A new substation may be required for arrangements A to D. The substation shall be installed in a GRP housing or brick substation on or outside the customer's property boundary with direct access from the public environment. The new substation shall always be looped into the existing HV system in accordance with Section 1.4.5 11kV Connectivity Rules.

1.3.1.11 Arrangement F. 11kV extension, 500 to 1000kVA substation & LV Air Circuit Breaker.



To be used for:

Loads from 275 to 1000 kVA unless the customer specifically requires an HV supply.

Choice of Compact Unit Substation or separate Ring Main Unit and Transformer depending on load centre.

TRANSFORMER RATING	A.C.B. RATING
500kVA	800A
800kVA	1250A
1000kVA	1600A

Central Networks' "LV Air Circuit Breaker 500 to 1000 kVA Substation Application Guide"

This guidance document provides further technical detail ands information and should be made availble to the customer's electrical contractor.

Compact Unit Substation Option

The Compact Unit Substation must be located in a GRP housing or brick substation on the customer's property boundary with direct access from the public environment.

The Central Networks/Customer boundary will be the outlet terminals of the LV cabinet. The customer will provide and own the cable tails between Central Networks' LV cabinet and the customer's switch board. It is unlikely that the customer will be in possession of a licence to lay cables in the public highway so the substation will need to be sited on, or immediately adjacent to, land in the ownership of the customer.

One additional LV fuse-way is provided which can be used to supply the local network if required.

Separate Ring Main Unit & Transformer Option

Where the distance from the property boundary to the customer's load centre makes LV cabling impractical or uneconomic the transformer and LV Air Circuit Breaker cabinet may be located at the customer's load centre. In this case an 11kV Ring Main Unit must be placed at the customer's property boundary to enable Central Networks to perform network operations and fault restoration on the ring main without the need to enter the customer's property.

The transformer must be equipped with switchgear to isolate and earth the incoming cable and the transformer in order to enable operation under Central Networks' Safety Rules. This may be achieved using either:

- RN2c-T1/21 or VRN2A Ring Main Unit – in this case the size of the protection CTs and TLFs of the boundary RMU and the Transformer RMU must be the same.
- SN6-S1/21 Switch Disconnector

Note that due to purchase volumes the Ring Main Unit is a lower cost than the Switch Disconnector. All Central Networks' projects shall use the Ring Main Unit.

Refer to Table 3.3.4.1 of the Network Design Manual for a complete list of Central Networks approved 11 kV switchgear.

The Central Networks/Customer boundary will be the outlet terminals of the LV cabinet. The customer will provide and own the cable tails between Central Networks' LV cabinet and the customer's switch board.

As there will not be direct access from the public environment to the transformer and LV cabinet the additional LV fuse-way shall not be used to supply other customers.

Metering

The customer shall provide suitable accommodation for the meters.
The maximum length of cable from the metering CTs and VTs to the meter must be limited to 15m of 12 core 2.5mm^2 cable so that the maximum burden on the CTs is not exceeded. The metering cubicle should have dimensions a minimum of 1m wide x 1.5m high by 400mm deep to accommodate the meters and provide sufficient space for safe working.

(NOTE in practice the metering panel will need to no more than 12 m from the LV metering unit to allow the cable to be run down into the cable trench and up the wall to the metering panel.)

Length and rating of customer's LV cables

The customer's electrical contractor must design the LV cables to comply with the current edition of BS7671 "Requirements for Electrical Installations", including the following criteria:

1. An LV earth fault at any point up to the customer's first circuit breaker or fuse will trip the Central Networks owned Air Circuit Breaker within 5 seconds as required by the current edition of BS7671. The worst case scenario is for an earth fault at the substation end of an LV cable.
2. The customer's electrical designer should be provided with the protection settings applied to the Central Networks owned Air Circuit Breaker. An extract from the Central Networks Protection Manual is included below.
3. Where the Central Networks ACB is to provide both overload and short circuit protection the LV tails should be sized to carry overloads up to the setting of the Central Networks Air Circuit Breaker and not just the transformer name plate rated load or Authorised Supply Capacity (ASC). Overload settings are shown in column 2 of tables 1.3.1.10 A & 1.3.1.10 B below.
4. Alternatively the Central Networks ACB can be employed as short circuit protection only and the customer's main incoming circuit breaker or fuses may be employed as overload protection. In this case smaller LV tails may be permissible. (refer to BS 7671 clause 473-01-02). The customer's electrical contractor should ascertain that the characteristics of the Central Networks ACB provide effective short circuit protection for the size of LV tails selected.
5. Voltage drop on the customer's cable must comply with the current edition of BS7671 "Requirements for Electrical Installations" at transformer name plate rating.
6. Central Networks is not an enforcing or advisory body for BS 7671. Where questions of the adequacy of the customer's installation need to be resolved the electrical contractor should seek advice from the trade body providing his accreditation. e.g. Electrical Contractors Association (ECA), National Inspection Council for Electrical Installation Contracting (NICEIC) etc.

Examples of cable sizes for customer owned LV tails

The Central Networks "LV Air Circuit Breaker 500 to 1000 kVA Substation Application Guide" contains tables cable ratings for typical installation scenarios. Central Networks project managers and Service Providers should refer to this document to assess the fitness of the customers LV tails prior to energisation.

1.3.2 HV Metered Supplies

HV metered supplies are to be used for:

- All loads above 1000kVA
- Loads below 1000kVA, where the customer specifically requires an HV metered supply.
- Loads where the customer's site is extensive and voltage distribution at LV impractical.
- Disturbing loads where the Point of Common Coupling with other customers needs to be at HV.

Otherwise, use an LV metered arrangement.

1.3.2.1 Connection Strategy for HV Industrial & Commercial Loads

All proposed industrial / commercial connections shall comply with Section 1.4.2 Connections Strategy.

1.3.2.2 Circuit Ratings for Industrial /Commercial Loads

Ring Mains

All new 11 kV cables shall be laid in black rigid twinwall corrugated ducts to ENATS 12-24 with warning tape. Short sections of 11kV cable may be laid direct only where ducts cannot be used such as sharp bends or at jointing positions. Warning tape shall be used in these situations.
Where trenchless or narrow trenching cable laying techniques are used the cable shall be ducted but the warning tape shall be omitted.

Cable ratings on ring mains shall be based on the Winter 5 Day Distribution Rating – 50% or 75% Utilisation as appropriate to the type of circuit. See section 3.3.1.4.

New ring main cables shall be XLPE Triplex. The ratings shown below are obtained from Table 3.3.1.4B and assume two cables leading to a ring main substation, laid in the same trench with the ducts touching. i.e. a group of 2 cables not thermally independent.

185 mm^2 XLPE Al Triplex in ducts – 366 amps – normal ring mains
300 mm^2 XLPE Al Triplex in ducts – 485 amps – large capacity ring mains
300 mm^2 XLPE Cu Triplex in ducts – 625 amps – exceptional applications only

Tables 3.3.1.4D and 3.3.1.4E contain 5 Day Distribution Ratings – 50% Utilisation for existing 11kV belted Paper Insulated Cables - metric & imperial sizes.

The above ducted ratings of XLPE Triplex cable match the ratings of belted PICAS cable laid direct. However, care must be taken when connecting a ducted XLPE cable to a paper insulated cables. The XLPE cable ratings are obtained at a conductor temperature to $90^{O}C$. Paper cables are rated at $65^{O}C$. There is a danger of transferring excessive heat from the XLPE cable to the paper cable via the transition joint. To overcome this, ducted XLPE cable must be laid direct for a length of at least 1 metre after leaving a duct to allow the conductor temperature to drop to $65^{O}C$. (Thermodynamic calculations have demonstrated that a 1 metre length is sufficient reduce the core temperature by $25^{O}C$.)

The 5 Day Distribution ratings assume a mix of domestic, industrial and commercial loads. If the ring consists of exclusively industrial / commercial load then sustained ratings may have to be used.

Groups of mixed residential, industrial and commercial loads up to 3.8 MW at 11kV may be connected into 11kV ring mains provided there is sufficient circuit capacity to provide a full switched alternative supply on each half of the ring. The total of the loads connected to both sides of the normal open point must not exceed the circuit's 5 Day Distribution Rating. Refer to Section 1.4.4 1kV Circuit Configuration & Loading for further guidance.

Note – Whilst the normal open point should be located to split the load approximately 50/50 over the two halves of the ring it may sometimes be necessary to apply a 60/40 or even 30/70 split depending on circumstances. In this case 75% utilisation ratings must be applied to the cables.

Duplicate circuits

Industrial and commercial loads that cannot be accommodated on ring mains shall have a pair of dedicated 11kV cables direct from a Primary or BSP Substation.

All new 11 kV cables shall be laid in black rigid twinwall corrugated ducts to ENATS 12-24 with warning tape. Short sections of 11kV cable may be laid direct only where ducts cannot be used such as sharp bends or at jointing positions. Warning tape shall be used in these situations.

Cable ratings on duplicate circuits shall be based on the Summer Sustained Rating unless the proposed load cycle is known with confidence. See section 3.3.1.5. and Table 3.3.1.5A

Directional or unit protection may be installed to provide a firm supply for a single circuit outage if the customer requires this level of security.

Loads with an authorised supply capacity over 12MW must have a firm supply to comply with Engineering Recommendation P2/5.

Loads over 12 MW may require three or more firm circuits at 11kV or a 33kV supply as decided by Networks Manager.

Authorised Supply Capacity Based on sustained summer ducted ratings		Circuit sizes
11kV	**6.6 kV**	
5.9 MW	3.5 MW	185mm^2 al XPLE triplex two circuits O/H line two circuits 150mm^2 ACSR Central Networks East 100mm^2 AAAC Central Networks West
7.7 MW	4.6 MW	300mm^2 al XLPE triplex two circuits O/H line two circuits 150mm^2 ACSR Central Networks East 200mm^2 AAAC Central Networks West
9.8 MW	5.9 MW	300mm^2 copper XLPE triplex two circuits O/H line two circuits 300mm^2 HDA Central Networks East 200mm^2 AAAC Central Networks West
12MW	7.3 MW	400mm^2 cu XLPE triplex two circuits O/H line two circuits 300mm^2 HDA Central Networks East 300mm^2 AAAC Central Networks West
33kV		
19 MW	2 x 12/24 MVA 33/11kV Transformers (20^{O}C AFAF rating of 19 MVA) 150mm^2 cu XLPE double circuit 150mm^2 ACSR O/H line two circuits	
32 MW	2 x 24/40 MVA 33/11kV Transformers (20^{O}C AFAF rating of 32 MVA) 400mm^2 cu XLPE double circuit 300mm^2 HDA O/H line two circuits	
Over 32MVA	Special Design	

1.3.2.3 Standard HV Supply Arrangements

- The following standards shall be used for all new connections. Modifications to existing supplies shall wherever reasonably practicable comply with these standards.
- Only one point of HV supply will be provided to each customer within a building or site. *Note this does not prelude the use of two or more incoming cables supplied into the same or adjacent switchboards in the substation.*
- All substations shall be loop connected to provide switched alternative 11kV supplies in accordance with Section 1.4.5 "11kV Connectivity Rules"

- All substations shall be placed on or outside the boundary of the customer's property boundary so that Central Networks operational staff have direct access from the public environment at all times. Where necessary the customer's transformers and switchgear may be sited within the property at the load centre and connected to the Central Networks switchgear by cable. The standard arrangements cater for this option. *This requirement has become necessary due to the general increase in security arrangements at customer's sites. Significant supply restoration delays are being caused when Central Networks operational staff are unable to gain access or are refused access to substations inside customer's sites.*

The next pages contain drawings of the following standard HV supply arrangements:

Arrangement H. Single Transformer up to 3.8 MVA@11kV / 2.3 MVA@6.6kV
Arrangement I. Two or more Transformers totalling up to 7.6 MVA@11kV / 4.6 MVA@6.6kV
Arrangement J. Duplicate Ring Main Units totalling up to 7.6 MVA@11kV / 4.6 MVA@6.6kV
Arrangement K Customer switchboard up to 7.6 MVA@11kV / 4.6 MVA@6.6kV
Arrangement L. Duplicate firm HV Supply up to 12 MVA@11kV / 7.2 MVA@6.6kV

These are designed to accommodate most of supply requirements. Standard items of plant are used as 'building blocks' to ensure a straight forward approach to construction, operation and maintenance of the Central Networks system.

Any departure from these standards will be resisted by Central Networks unless exceptional local circumstances or supply requirements make a bespoke solution necessary. The approval of the Network Manger shall be obtained before any proposed bespoke solution is implemented.

With all these arrangements, reference should also be made to:

- Central Networks' Protection Manual Section 4.0 "Recommendations for the Protection of Customer-owned HV networks".
- Central Networks' Earthing Manual
- Network Design Manual Table 3.3.4.1 Central Networks approved 11kV switchgear.

KEY TO HV CIRCUIT SYMBOLS

11kV Ring Switch or Isolator with circuit earthing switch

11kV Circuit breaker with circuit earthing switch

→ Directional Protection

Bus bar

11kV Ring Main Unit - 2 x 630A ring switches 1 x circuit breaker 200 amp or 630 amp all with integral earth switches. Earth fault indicator on one ring switch

11kV/LV Transformer

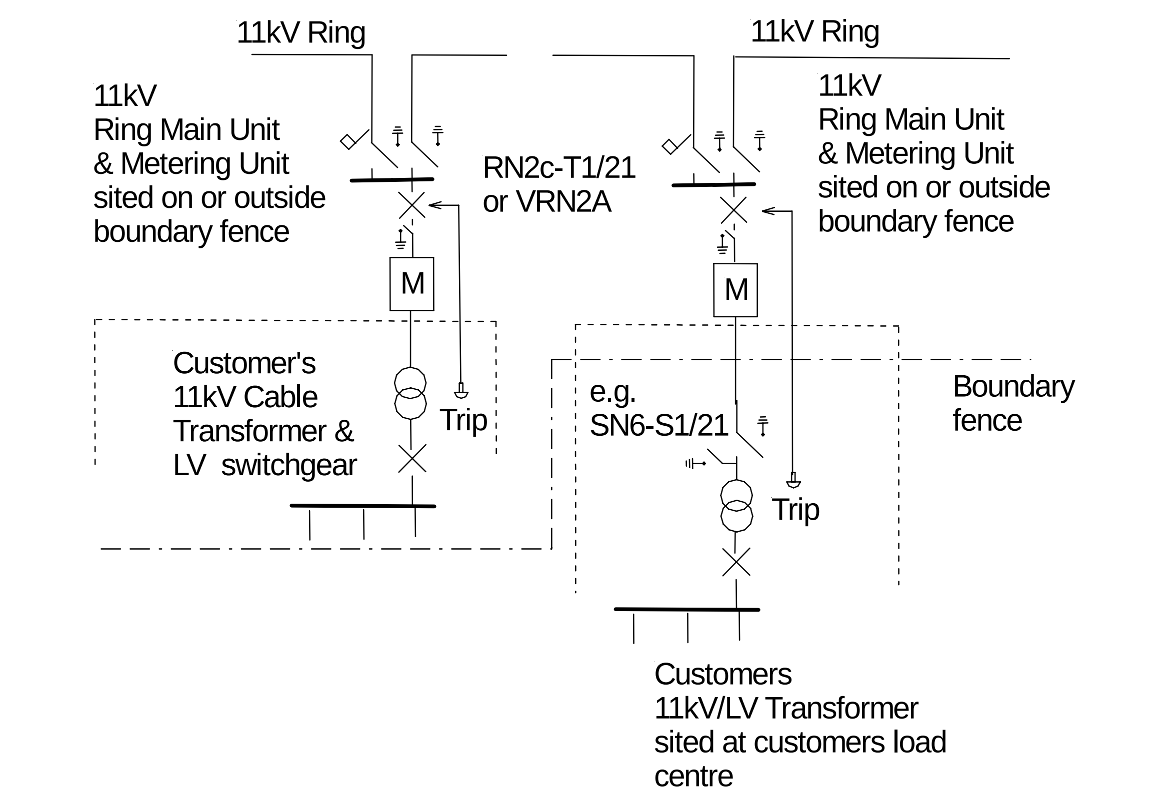
M Metering unit - Voltage transformer and current transformers

Trip Emergency trip switch for customer's use

Boundary of customer's property

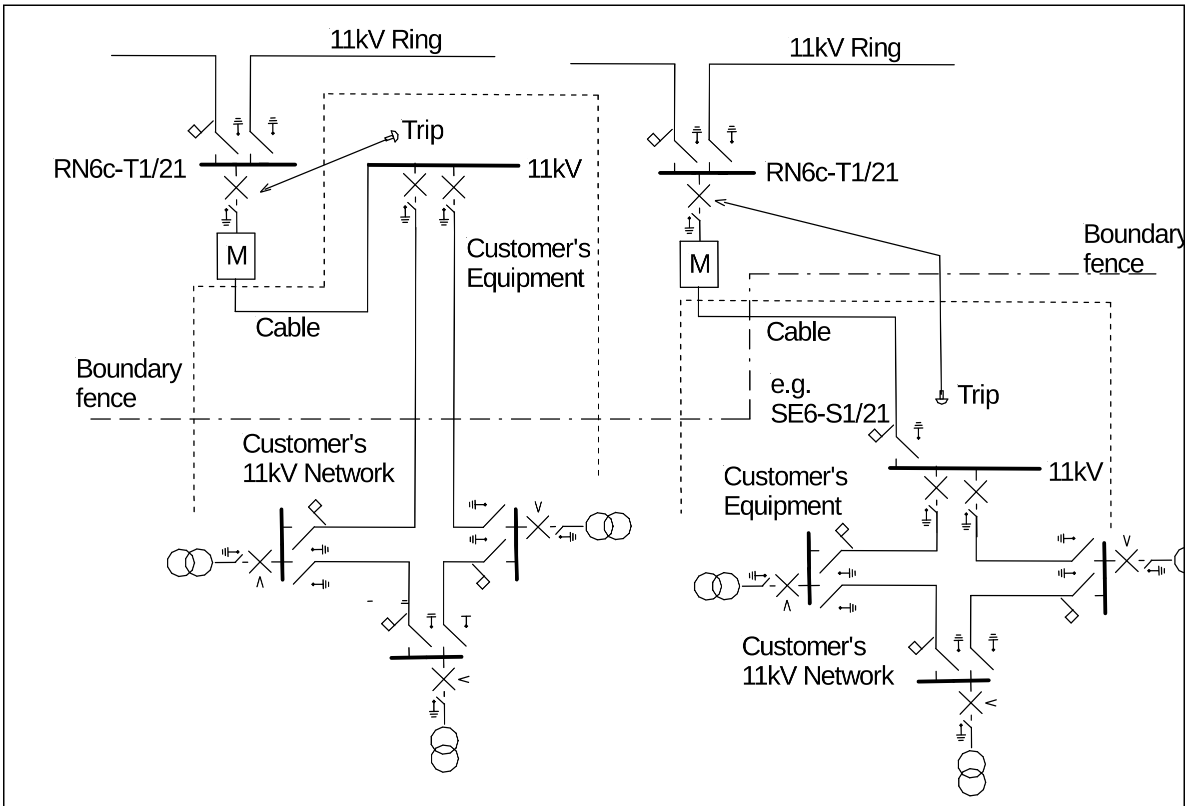
Limit of equipment ownership

1.3.2.4 Arrangement H Single Transformer up to 3.8 MVA@11kV / 2.3 MVA@6.6kV



- Non-extensible Ring Main Unit with HV metering unit.
  - RMU
    - Merlin Gerin RN2c-T1/21 with TLFuse protection - up to 1.0 MVA@11kv / 0.5 MVA@6.6kV
    - Merlin Gerin - RN2c-T2/21 with VIP 300 protection – up to 3.8 MVA@11kv / 2.3 MVA@6.6kV
    - Lucy Sabre VRN2A with TLF protection - up to 1.0 MVA@11kv / 0.5 MVA@6.6kV
    - Lucy Sabre VRN2A with Micom protection - up to 3.8 MVA@11kv / 2.3 MVA@6.6kV
  - Metering unit
    - Merlin Gerin MU2-M2/16 – 100/50/5 up to 1.9MVA@11kv / 1.1 MVA@6.6kV
    - Merlin Gerin MU2-M3/16 – 200/100/5 up to 3.8MVA @11kv / 2.3 MVA@6.6kV
    - Lucy AIMU – 100/50/5 up to 1.9MVA@11kv / 1.1 MVA@6.6kV
    - Lucy AIMU – 200/100/5 up to 3.8MVA@11kv / 2.3 MVA@6.6kV
- Central Networks RMU to be located in GRP housing or brick substation on or outside the customer's property boundary with direct access from the public environment.
- Customer's transformer may be sited adjacent to the substation or located remotely at the load centre.
- Central Networks recommend that the customer's transformer be equipped with a Switch Disconnector or Ring Main Unit (equivalent to SN2-S2/21, RN2c-T1/21 or VRN2A) where the HV cable cannot be traced visibly back to the Central Networks RMU to comply with Distribution Safetey Rules.
- RMU circuit breaker rated at 200 amps load current with 3.15kA earth switch. (minimum rating)
- TLF protection on circuit breaker for transformers up to and including 1000kVA rating, relay protection for transformers above 1000kVA rating.
- Provision must be made for remote emergency tripping of circuit breaker for use by the customer.

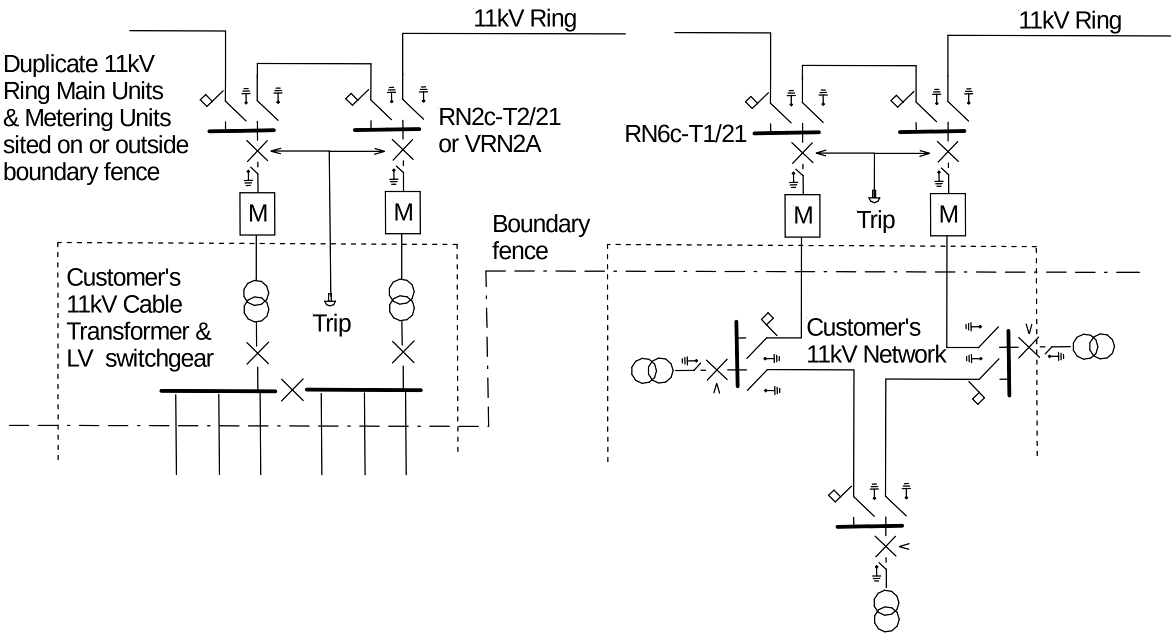
1.3.2.5 Arrangement I Two or more Transformers totalling up to 7.6 MVA@11kV / 4.6 MVA@6.6kV



- Non-extensible Ring Main Unit with HV metering unit.
  - RMU
    - Merlin Gerin RN6c-T1/21 with VIP 300 protection
  - Metering unit
    - Merlin Gerin MU2-M2/16 – 100/50/5 up to 1.9MVA@11kv / 1.1 MVA@6.6kV
    - Merlin Gerin MU2-M3/16 – 200/100/5 up to 3.8MVA@11kv / 2.3 MVA@6.6kV
    - Merlin Gerin MU2-N1/16 – 400/200/5 up to 7.6MVA@11kv / 4.6 MVA@6.6kV
- Relay protection on Central Networks circuit breaker to grade with customer's 11kV protection.

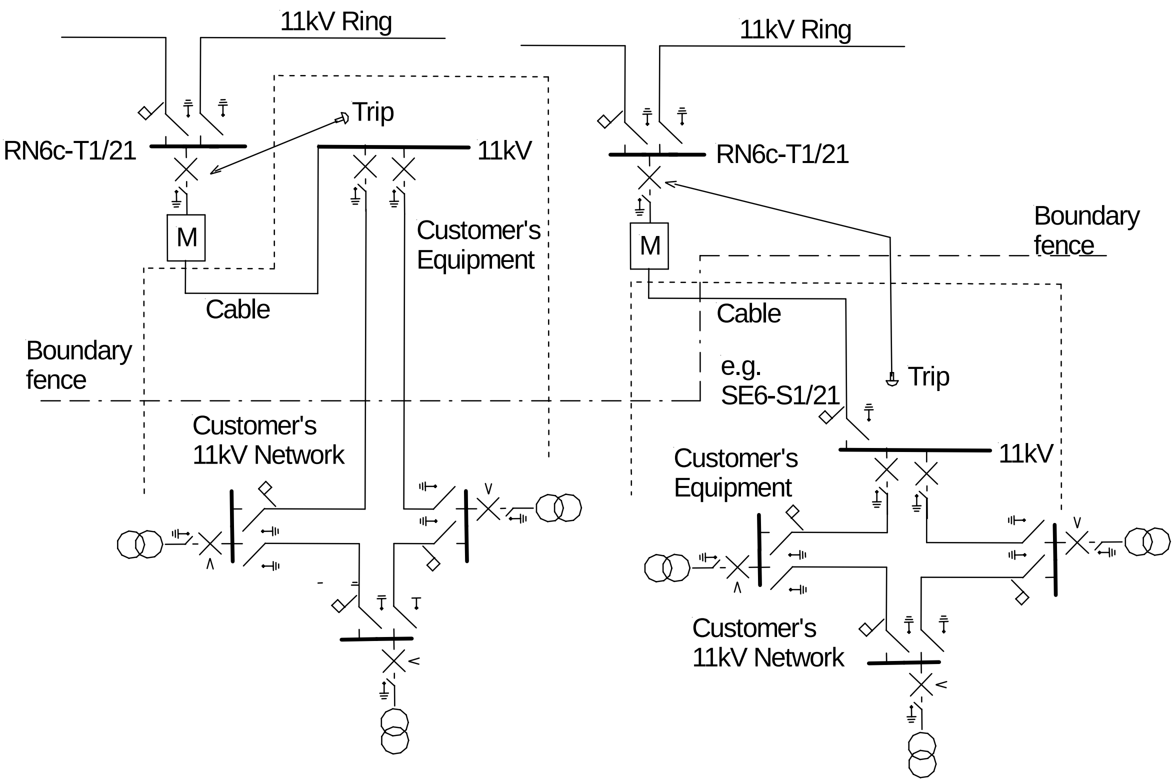
  NOTE that the RN6c is necessary even where the load is below 1.9MVA. This is because the 200/1 CTs of the RN2c restrict the setting range of the VIP 300 relay such that it cannot be set to grade with the customer's downstream protection. The 800/400/1 CTs of the RN6c provide sufficient setting range.
- Central Networks RMU to be located in GRP housing or brick substation on or outside the customer's property boundary with direct access from the public environment.
- Customer's 11kV switchgear and transformer may be sited adjacent to the substation or located remotely at the load centre.
- Central Networks recommend that the customer's switchboard be equipped with an incoming isolator (equivalent to Merlin Gerin SN6-S1/21) where the HV cable cannot be traced visibly back to the Central Networks RMU to comply with Distribution Safetey Rules.
- RMU circuit breaker rated at 630 amps load current and the earth switch must be fully rated.
- Provision must be made for remote emergency tripping of circuit breaker for use by the customer.

1.3.2.6 Arrangement J. Duplicate Ring Main Units totalling up to 7.6 MVA@11kV / 4.6 MVA@6.6kV



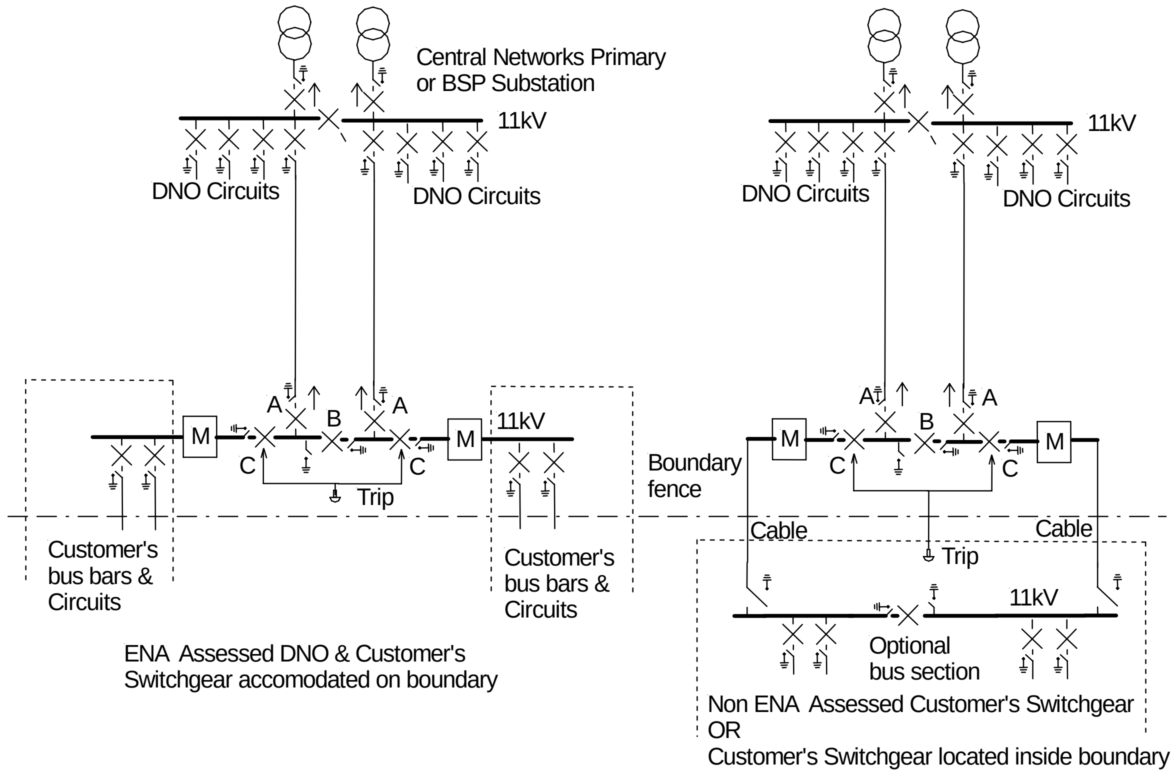
- This arrangement is applicable only where the customer requires a full switched alternative supply and total load will not exceed 7.6 MVA
- The Central Networks normal open point will NOT be placed on either of the interconnecting switches between the Ring Main Units to prevent the customer accidentally paralleling the Central Networks system via his own network.
- The consumer must maintain an open point on his ring main except by specific agreement with Central Networks. (e.g. the consumer's network may be designed to run as a closed ring employing unit protection.)
- Exceptionally, where the customer requires an enhanced level of security via auto changeover on his switchgear the open point may be placed between the two RMUs. However, this must have specific approval from the Network Manager. Before accepting this arrangement consideration must be given to system losses, regulation, security of other customer's supplies and the desirability of limiting the choices of future network developments. In this case interlocking will be required to prevent a system parallel being made via the customer's network.
- Non-extensible Ring Main Unit with HV metering unit.
    - RMU
        - Merlin Gerin - RN2c-T2/21 with VIP 300 protection – up to 3.8 MVA - two transformers – Back-feed only possible via LV
        - Lucy Sabre VRN2A with Micom protection - up to 3.8 MVA - two transformers – Back-feed only possible via LV
        - RN6c-T1/21– with VIP 300 protection up to 7.6 MVA - Back-feed possible via customer's 11kV network – NB RMU earth switch must be fully rated.
    - Metering unit
        - Merlin Gerin MU2-M2/16 – 100/50/5 up to 1.9 MVA@11kv / 1.1 MVA@6.6kV
        - Merlin Gerin MU2-M3/16 – 200/100/5 up to 3.8 MVA@11kv / 2.3 MVA@6.6kV
        - Merlin Gerin MU2–N1/16 – 400/200/5 up to 7.6 MVA@11kv / 4.6 MVA@6.6kV
        - Lucy AIMU – 100/50/5 up to 1.9 MVA@11kv / 1.1 MVA@6.6kV
        - Lucy AIMU – 200/100/5 up to 3.8 MVA@11kv / 2.3 MVA@6.6kV
        - Lucy AIMU – 400/200/5 up to 7.6 MVA@11kv / 4.6 MVA@6.6kV
- Central Networks RMUs to be located in GRP housing or brick substation on or outside the customer's property boundary with direct access from the public environment.
- Customer's 11kV transformers and/or substations may be sited adjacent to the substation or located remotely at the load centre.
- Customer's 11kV transformers should be equipped with an isolator where the HV cable cannot be traced visibly back to the controlling circuit breaker.
- Relay protection on Central Networks circuit breakers to grade with customer's 11kV protection.
- Provision must be made for remote emergency tripping of circuit breaker for use by the customer.

1.3.2.7 Arrangement K. Customer switchboard up to 7.6 MVA@11kV / 4.6 MVA@6.6kV



- Depending on the load this arrangement may be connected into a ring main or have dedicated circuits from a Primary Substation.
- This arrangement does not provide the same level of supply security as can be obtained from Arrangements J & L. However, motor actuators and radio control may be fitted to provide restoration by remote control or auto change-over where the network can accommodate it.
- Central Networks extensible equipment:
  - RMU - RN6c-T2/21– with VIP 300 protection
  - Metering unit MU2-M2 – 100/50/5A up to 1.9 MVA@11kv / 1.1 MVA@6.6kV
  - Metering unit MU2-M3 – 200/100/5A up to 3.8 MVA@11kV / 2.3 MVA@6.6kV
  - Metering unit MU2-M4– 400/200/5A up to 7.6 MVA@ 11kV / 4.6 MVA@6.6kV
- Central Networks equipment to be located in a brick substation on or outside the customer's property boundary with direct access from the public environment.
- Customer's 11kV switchgear may be sited adjacent to the Central Networks substation or located remotely at the load centre.
- Central Networks recommend that the customer's switchboard be equipped with an incoming isolator (equivalent to Merlin Gerin SE6-S1/21) where the HV cable cannot be traced visibly back to the Central Networks RMU to comply with Distribution Safetey Rules.
- Relay protection on Central Networks bus section circuit breaker to grade with customer's 11kV protection.
- Provision must be made for remote emergency tripping of circuit breaker for use by the customer.

1.3.2.8 Arrangement L. Duplicate HV Supply



- This arrangement is applicable where the customer requires an Authorised Supply Capacity up to 12 MVA at 11kV
- The maximum load is based on a single circuit outage at summer maximum continuous cable rating. Where the customer's load profile is known then it may be possible to apply higher cable ratings and an increased Authorised Supply Capacity.
- Maximum summer sustained load using 400mm^2 copper 11kV or 33kV XLPE cables
  - 33kV – 32 MVA
  - 11kV – 12 MVA
  - 6.6kV – 7.3 MVA
- Customer to have emergency tripping facility on the metering circuit breakers 'C'.
- The incoming circuit breakers 'A' may be fitted with directional or unit protection to provide supply security during a fault on one of the incoming cables.
- A pilot cable may be provided to take alarms / indication information to the Primary S/S from the customers substation to Central Networks' Control room where considered necessary.
- If the customer does not require a high level of supply security and the ASC is below 12MW the incoming switches 'A' and bus section 'B' may be isolators. In this case a fault on one circuit will result in both circuits tripping at the Primary Substation. Supply will be restored by manual switching in less than 3 hrs as permitted under Engineering Recommendation P2/5 for loads under 12 MW.
- The Central Networks substation is to be located on or outside the customer's property boundary and have direct access from the public environment.
- Note - Metering on the incoming circuits is no longer permitted by Central Networks. *During abnormal running conditions other customer's load current may circulate through bus section 'B' resulting in metering abnormalities.*

1.4 Secondary Network 11kV & 6.6kV

1.4.1 General Considerations – Secondary Network

The standard Secondary distribution voltage will be 11kV and all new circuits must be capable of 11kV operation. All work undertaken within established 6.6kV systems shall employ dual ratio 11/6.6kV transformers, 11kV cables and 11kV switchgear to facilitate eventual up-rating to 11kV. All references to 11kV in this manual shall equally apply to 6.6kV networks.

Expansion of established 6.6kV systems beyond their existing geographical areas shall only be permitted where there are exceptional circumstances preventing connections being made to an established 11kV network.

The eventual up-rating of Central Networks 6.6kV networks to 11kV will only be carried out when this can be financially or technically justified by Central Networks Asset Development.

11kV networks are supplied from Primary substations which step down the voltage from 66kV or 33kV to 11kV or 6.6kV. Certain Bulk Supply Point substations transform directly from 132kV to 11kV or 6.6kV. All references to Primary substations this section of the manual shall include Bulk Supply Point substations that supply 11kV and 6.6kv networks.

In order to comply with license conditions and to meet supply restoration targets set by the industry regulator all 11kV distribution circuits and plant shall be configured to exceed the minimum security standards of Engineering Recommendation P2/5. Therefore all new connections to the 11kV network shall comply with Section 1.4.5 - 11kV Connectivity Rules.

Network extensions and new connections and shall be carried out using new materials. Refurbished equipment shall only be used to augment, repair or replace existing facilities subject to approval by the Asset Standards Manager.

1.4.2 Connection Strategy

All proposed connections:

- above 1000kVA
- that take the overall load on a ring main above 100% of the circuit rating

shall be referred to the Network Manager for an assessment of the strategic effect on the network.

If the proposal is not approved, the Network Manager shall provide an alternative connection strategy and/or standard supply arrangement acceptable to Central Networks.

Designers should be aware that connections below 1000kVA will have an effect upon the network. In particular the following load thresholds should act as a trigger for an evaluation of the 11kV network by the designer:

- loads above 500 kVA on "Standard 11kV Feeders"
- loads above 200 kVA on "Long 11kV Feeders"
- Disturbing loads such as welders, motors pumps etc.

Where necessary the designer should obtain guidance from the Network Manger.

A 'Long 11kV Feeder' is defined as extending beyond the 15km radius of a Bulk Supply Point or Primary Substation. See Section 4 Network Voltage Policy.

The following shall be considered:

- Network loading
- Supply security
- Overall network operability in line with 11kV and 33kV Connectivity Rules
- The 'fit' with any existing connection strategy for the locality.

1.4.3 11kV Earthing

1.4.3.1 11kV Earth Fault Current

The value of earth fault current on 11kV systems is restricted to a maximum of 3,000 amps by the use of a Neutral Earth Resistors (NER) at 33/11kV and 132/11kV substations. At certain substations the earth fault current is limited to lower values to control Earth Potential Rise. The screens of 11kV cables used on the network must have a one second short circuit rating of at least 3,000 amps.

There are two Arc Suppression Coil trails taking place in Central Networks West. Earth faults are not held indefinitely, after a time delay a permanent earth fault is diverted to the NERs to operate the normal earth fault protection.

1.4.3.2 Earthing of Plant

The Central Networks Earthing Manual specifies the detailed requirements for earthing distribution plant. The main requirements for new installations are summarised below:

- Pole mounted switchgear
    - Manually operated 11kV Air Break Switch Disconnectors. Non-automated remote control ABSDs shall have high level rod operated mechanisms. The equipment steelwork shall not be earthed or bonded to the pole top crossarm. Live local operation is permissible.
    - Very occasionally it is necessary to install or retain a manually operated ABSD on an earthed pole. Live operation is not permissible with earthing installed to ENATS 42-24:Issue 1:1992. Individual earthed ABSDs may be specifically approved for live operation following a bespoke design of the earthing system
    - Existing Pole Mounted 11kV Automated Reclosers. Where these devices have control boxes mounted at ground level they shall be earthed. Live local operation is not permissible with earthing installed to ENATS 42-24:Issue 1:1992.
    - New Pole Mounted 11kV Automated Reclosers shall be installed with the control boxes at high level with the earth lead insulated and ducted to an electrode positioned a

safe distance from the pole. Local live operation is permissible where rod operation facilities exist.

- New Pole Mounted Sectionalisers and Air Break Switch Disconnectors fitted with remote control shall be installed with the control boxes at high level. The equipment steelwork shall not be earthed or bonded to the pole top crossarm. Local Live operation is permissible where rod operation facilities exist.

- The low voltage supply for the control circuits of automated equipment shall be derived from a dedicated transformer on the same pole. The transformer LV neutral shall be directly earthed to the equipment's steelwork. This transformer shall not be used to supply customers. Likewise, transformers supplying customer shall not be used to supply the control box.

- Expulsion Fuses/Links, Automatic Sectionalising Links – Where installed on earthed poles (e.g. transformers and cable terminations) their steelwork shall be bonded to the pole earth. Where installed on un-earthed poles their steelwork shall not be bonded to the pole top cross-arm or earthed.

▪ Distribution substations shall have an HV earth electrode system around the perimeter to provide an equipotential zone around the equipment. The local earth electrode system shall be less than 20 ohms.

▪ Pole mounted transformers, auto reclosers, cable terminations and other plant fitted with surge arresters shall have an HV earth electrode system of less than 10 ohms and shall include a deep driven electrode at the base of the pole acting as a lightning earth.

▪ An Earth Potential Rise (EPR) above 430 volts is classified as a 'Hot' site. An EPR below 430 volts is classified as a 'Cold' site.

▪ Transformers at 'Hot' sites shall have their HV and LV earths segregated. At 'Cold' sites a combined HV and LV earth may be used.

▪ At 'Hot' sites the LV earth electrode shall be segregated by installing it outside the 430 volt EPR contour and connecting it to the transformer star point via insulated cable. This segregation distance depends on the EPR, soil resistivity and physical area of the earth electrode system. This can vary from 5m to 25m for ground mounted substations with a 20 ohm earth. Pole transformers employ a physically larger earth electrode system in order to obtain 10 ohms and the segregation distance can vary from 4m to 43m or more. See Section E5 of the Earthing Manual for typical values.

▪ A site supplied from a 132/11kV or 33/11kV substation can be assumed to be 'Cold' if:

    - the normal and alternative 11kV feed is via an entirely underground cable route. This will route the majority earth fault current back to source via the cable screens rather than the HV earth electrode.

    OR

- the site is in an urban / suburban network that can be defined as a 'Global Earth'. In practice a network consisting of mainly lead covered cables with an area over $10km^2$ may be considered to be a 'Global Earth'.

- Sites that are not part of a 'Global Earth' and have any overhead line in either the normal or alternative 11kV feed shall be considered to be 'Hot'.

- At 'Hot' consumer substations it can be difficult to obtain segregation between the HV and LV earths due to the proximity of the consumer's transformer to the LV switchboard. An earthing specialist shall be commissioned to design each installation.

- Supplies to mobile phone base stations accommodated on 132kV, 275kV & 400kV towers shall be provided in accordance with EA Engineering Recommendation G78. This is essential to prevent dangerous potentials being transferred onto the distribution network during earth faults on the tower. Refere to Central Networks' Application Guide "Supplies to Mobile Phone Base Stations mounted on EHV Towers (G78 Installations)"

1.4.4 11kV Protection

The Central Networks Protection Manual provides detailed information on standard 11kV protection schemes. The main requirements are summarised below.

1.4.4.1 Primary substation circuit breakers

There are five standard protection schemes:

1. Transformer circuit breaker – overhead incoming network.
    a. Neutral Voltage Displacement
    b. IDMT overcurrent and earth fault
    c. Directional overcurrent and earth fault
    d. Inter-trip send to fault thrower
    e. Standby earth fault
    f. Restricted earth fault
    g. Auto Reclose
2. Transformer circuit breaker – underground incoming network.
    a. IDMT overcurrent and earth fault
    b. Directional overcurrent and earth fault
    c. Inter-trip send to source substation via pilot wire.
    d. Standby earth fault
    e. Restricted earth fault

3. Bus Section circuit breaker
    a. IDMT overcurrent and earth fault
4. Feeder circuit breaker – overhead network.
    a. IDMT overcurrent and earth fault
    b. Instantaneous overcurrent and earth fault slugged to 500ms
    c. Sensitive earth fault.
    d. Auto Reclose
5. Feeder circuit breaker – underground network.
    a. IDMT overcurrent and earth fault

1.4.4.2 Secondary substation protection

There are two standard protection schemes:

1. Time Limit Fuse with CT release
    a. Time graded overcurrent
    b. Instantaneous earth fault.
    c. Transformers up to 1000 kVA at 11kV and 500 kVA 6.6kV
2. Merlin Gerin VIP 300 self powered relay
    a. IDMT earth fault and overcurrent
    b. Transformers and loads up to 3,800 kVA at 11kV and 2,280 kVA 6.6kV

1.4.4.3 HV Metered Customer Owned Substations

The protection scheme will depend upon the size of the load and the customer's network configuration. The standard schemes outline in 1.3.3.1 and 1.4.3.2 above shall be used as a basis of design. See section 1.3.2 'HV Metered Supplies' supplies for typical network configurations to HV customers.

The customer should be provided with Section 4.0 of the Central Networks Protection Manual "Guidance for protection of customer owned HV networks". This outlines the issues that the customer should address when designing his system.

1.4.4.4 Padmount transformer protection

A combination of a back-up (partial range) current limiting fuse in series with an under oil expulsions fuse. The combination is 'melt matched' to provide full range protection.

1. Back-up Current Limiting Fuse
    a. Not field replaceable
    b. Covers current range 600 amps to 50,000 amps
    c. Sized to detect faults up to the HV winding only

2. Bay-o-Net under oil expulsion fuse
    a. Field replaceable
    b. Covers current full load to 2,500 amps
    c. Sized to clear LV bus bar zone fault in compliance with ENATS 12-06

1.4.4.5 Pole mounted transformer protection

Individual pole transformers rely upon 11kV circuit protection to detect faults and operate circuit breakers.

The extent of supply interruption may or may not be limited by the inclusion of expulsion fuses or automatic sectionalising links on spurs which operate after a sequence of circuit breaker operations.

Central Networks East - Expulsion fuses are standardised at 50 amp slow blowing and are designed not to melt during instantaneous trips of the source circuit breaker to avoid operation on transient faults. These are intended operate after an auto reclose operation whilst the source protection is set to IDMT.

Central Networks West - Expulsion fuses are sized according to the transformer size.

Automatic Sectionalising Links (ASL) count the number of fault current pulses whilst a multi shot auto reclose circuit breaker operates. On detecting 2 pulses the device registers a permanent fault. During the next dead time of the auto reclose cycle a chemical actuator de-latches the ASL which drops open under gravity. A further close operation of the auto reclose cycle restores supplies to the remaining system. ASLs should not be used on circuits without multi shot auto reclose with at least 3 shots to lock out. All PMARs are multi shot. Modern primary substations circuit breakers can be set to multi shot. Most existing Primary substations have protection that is limited to 2 shots.

All new pole transformers are factory fitted with lightning arresters on the HV and LV side.

15 kV MCOV arresters are fitted between the HV bushings and the transformer tank to protect the HV windings

A single Transient Voltage Clamper is fitted between the LV neutral bushing and the transformer tank to protect the LV winding which is earthed remotely from the transformer steelwork earth.

1.4.5 11kV Circuit Configuration & Loading

1.4.5.1 11kV Ring Mains

11kV networks shall be developed to form open ring mains across either side of the bus sections at primary substations or as interconnectors between two or more primaries to facilitate the provision of alternative supplies or load transfer and management operations. There may be further interconnections between rings depending on the local network configuration. There should not normally be more than 4 ends (i.e. points of HV isolation) to a section of cable or overhead line.

The normal open point should be located to split the load approximately 50/50 over the two halves of the ring. However, it may sometimes be necessary to apply asymmetrical loading to the ring (e.g. 60/40 split) depending on circumstances. No circuit shall be loaded beyond 75% utilisation without the specific approval of the Network Manger. W*here one half of the ring is loaded above 50% then cables ratings based on 75% utilisation need to be used.*

Ring mains shall not be loaded beyond a total of 100% circuit rating without the specific approval of the Network Manger.

Circuit configurations that rely on multiple switching operations in order to facilitate back-feeding will only be permitted with the specific approval of the Network Manager.

Existing circuits are limited to a maximum current of 400 amps by the rating of substation switchgear. Often the rating is lower depending on the size of the cables and/or any current transformers in the circuit. Where necessary, new ring mains can be designed to operate up to 600 amps with the appropriate sized cables and provided all substations have 630 amp switchgear.

Whilst the open ring or interconnector is the preferred arrangement, closed rings and parallel feeders with appropriate protection may be used where approved by Network Manager.

1.4.5.2 Duplicate circuits

Industrial and commercial loads that cannot be accommodated on ring mains shall have a pair of dedicated 11kV cables direct from a Primary or BSP Substation.

Cable ratings on duplicate circuits shall be based on the Summer Sustained Ducted Rating unless the proposed load cycle is known with confidence. See section 3.3.1.5. and Table 3.3.1.5A

Directional or unit protection may be installed to provide a firm supply for a single circuit outage if the customer requires this level of security.

Loads with an authorised supply capacity over 1 MW must have a firm supply to comply with Engineering Recommendation P2/5.

Loads over 12 MW may require three or more firm circuits at 11kV or a 33kV supply as decided by the Network Manager.

1.4.5.3 Standard Equipment and Designs

Standard designs using the equipment contained in Section 3 of the Manual shall normally be used for all network modifications or extensions.

Where standard designs and/or equipment are not suitable for a specific application the Asset Standards Manager may approve the use of a specifically engineered solution with reference to the following documents;

- Central Networks "Local Management Instruction for the Selection and Approval of equipment to be used on the Distribution Network"
- Central Networks "Local Management Instruction for Modification of the Distribution Network"
- Section 2 of this Manual, Network Modification Procedure.

1.4.5.4 Voltage Regulation

Voltage regulation on 11kV & 6.6kV feeders shall be in accordance with Section 4.2.2 of this manual. A power factor of 0.97 should be normally assumed for the calculation. Supplies to large industrial loads may need special consideration if a less favourable power factor is suspected.

Circuit configurations that rely on multiple switching operations in order to maintain voltage during back-feeding will only be permitted with the specific approval of the Network Manager.

When comparing different network design options the circuit copper losses shall form part of the decision making process.

See Tables 3.3.1.5 and 3.3.2.3 for Cable and Overhead Line Regulation and Losses.

1.4.5.5 11kV Cable Applications

Underground cables

All new 11 kV cables shall be laid in black rigid twinwall corrugated ducts to ENATS12-24 with warning tape. Short sections of 11kV cable may be laid direct only where ducts cannot be used such as sharp bends or at jointing positions. Warning tape shall be used in these situations. Warning tape may be omitted where cables are installed in ducts by trenchless cable laying techniques.

Cable ratings on ring mains shall be based on the Winter 5 Day Distribution Rating – 50% Utilisation. Where the ring is asymmetrically loaded (e.g. 65% - 35%) the 75% utilisation rating shall be used.

New ring main cables shall be XLPE Triplex. The ratings shown in Table 3.3.1.4B shall be used which assume two cables leading to a ring main substation, laid in the same trench with the ducts touching. i.e. a group of 2 cables not thermally independent.

The 5 Day Distribution ratings assume a mix of domestic, industrial and commercial loads. If the ring consists of exclusively industrial / commercial load then sustained ratings may have to be used.

Where tee-off connections are permitted by the 11kV Connectivity Rules 185mm^2 Al XLPE Triplex shall be used in urban and suburban areas to cope with system fault level. In rural areas 70mm^2 Al XLPE Triplex may be used where the fault level is below 126MVA.

The first sections of a ring main from a Primary or BSP Substation shall be a minimum of 300 mm^2 XLPE Al Triplex for sufficient distance to for to reduce the load by 650kVA (34 amps @11kV). The remaining parts of the ring main shall be 185 mm^2 XLPE Al Triplex (rated at 366 amps) This ensures an overall ring main rating of 400 amps.

Where the Network Manager specifies a 600 amp ring main this will be specially designed.

Cable ratings on duplicate circuits supplying industrial /commercial loads shall be based on the Summer Sustained Rating unless the proposed load cycle is known with confidence. See section 3.3.1.5. and Table 3.3.1.5A

Tables 3.3.1.4D and 3.3.1.4E contain 5 Day Distribution Ratings – 50% Utilisation for existing 11kV belted Paper Insulated Cables - metric & imperial sizes.

The above ducted ratings of XLPE Triplex cable match the ratings of PICAS belted cable laid direct. However, care must be taken when connecting a ducted XLPE cable to a paper insulated cables. The XLPE cable ratings are obtained at a conductor temperature to 90^{O}C. Paper belted cables are rated at 65^{O}C. There is a danger of transferring excessive heat from the XLPE cable to the paper cable via the transition joint. To overcome this, ducted XLPE cable must be laid direct for a length of at least 1 metre after leaving a duct to allow the conductor temperature to drop to 65^{O}C. (Thermodynamic calculations have demonstrated that a 1 metre length is sufficient reduce the core temperature by 25^{O}C.)

Table 1.4.4.1 11kV Cable Applications	
Size / Type	**Application**
70 mm² Al XLPE Triplex 25mm² wire screen	• Central Networks EAST only • Fault level must be below 6.6kA (126 MVA) • Earth fault level must be below 3.2kA for 1 second. • Tee-off circuits on rural networks up to 52 amps (1 MVA) *P2/5 security standard*
95 mm² Al XLPE Triplex 35mm² wire screen	• Central Networks WEST only • Fault level must be below 8.9A (170 MVA) • Earth fault level must be below 4.5kA for 1 second. • Tee-off circuits on rural networks up to 52 amps (1 MVA) *P2/5 security standard*
185 mm² Al XLPE Triplex 35mm² wire screen	• Fault level must be below 17.4kA (332 MVA) • Earth fault level must be below 4.5kA for 1 second. • Tee-off circuits on all urban networks and where the fault level exceeds rating of 70 mm² or 95 mm²Triplex • Ring Main circuits up to 368 amps • Industrial/Commercial loads up to a firm capacity of 309 amps (5.9 MVA @ 11kV 3.5 MVA @ 6.6kV)
300 mm² Al XLPE Triplex 35mm² wire screen	• Fault level must be below 28.2kA (538 MVA) • Earth fault level must be below 4.5kA for 1 second. • Ring Main circuits up to 489 amps. • Industrial/Commercial loads up to a firm capacity of 403 amps (7.7 MVA @ 11kV 4.6 MVA @ 6.6kV) • High capacity inter-connectors between Primary/Grid Substations • First 1 km from Primary/BSP Substations • Situations where 185 mm² would result in excessive voltage drop.
300 mm² Cu XLPE Triplex 35mm² wire screen	• Earth fault level must be below 4.5kA for 1 second. • Ring Main circuits up to 629 amps. • Multiple runs of cables exiting Primary substations –to offset de-rating • Industrial/Commercial loads up to a firm capacity of 516 amps (9.8 MVA @ 11kV 5.9 MVA @ 6.6kV) • High capacity inter-connectors between Primary/Grid Substations
400 mm² Cu XLPE Triplex 35mm² wire screen	• Earth fault level must be below 4.5kA for 1 second. • Multiple runs of cables exiting Primary substations –to offset de-rating • Industrial/Commercial loads up to a firm capacity of 600 amps (12 MVA @ 11kV 7 MVA @ 6.6kV) • High capacity inter-connectors between Primary/Grid Substations

1.4.5.6 11kV Overhead Line Applications

The ratings of lines built before 1971 are based on 50°C conductor temperature. See tables 3.3.2.2C,D&E in section 3.3.2.2. These lines can be identified by the conductors' imperial sizes.

Lines build after 1971 use metric size conductors and have ratings based on 75°C (Central Networks West) or 60°C (Central Networks East) conductor temperature.

Central Networks West

Overhead line ratings on ring mains shall be based on the Winter Distribution ratings at 75°C conductor temperature. See table 3.3.2.2B in section 3.3.2.2.

Overhead line ratings on duplicate circuits supplying industrial /commercial loads shall be based on the Summer Distribution ratings at 75°C conductor temperature. See table 3.3.2.2B in section 3.3.2.2.

Table 1.4.4.2 11kV Overhead Line Applications – Central Networks West

Size / Type	Application
50 mm² AAAC (Hazel)	• Fault level must be below 4.5kA (86 MVA) * • Ring Main circuits • Tee-off circuits up to 52 Amps (1 MVA) *P2/5 security standard* ** Fault level may be up to 10kA (190 MVA) if protected with NEMA standard 11kV expulsion fuses fitted with arc shortening rods.*
100 mm² AAAC (Oak)	• Fault level must be below 8.9kA (170 MVA). • Interconnectors between Primary Substations • Ring Main circuits • Tee-off circuits where the fault level exceeds the rating of 50 mm² AAAC which cannot be fused.
200 mm² AAAC (Poplar)	• Interconnectors between Primary Substations

Central Networks East

Overhead line ratings on ring mains shall be based on the Winter Distribution ratings at 60°C conductor temperature. See table 3.3.2.2A in section 3.3.2.2.

Overhead line ratings on duplicate circuits supplying industrial /commercial loads shall be based on the Summer Distribution ratings at 60°C conductor temperature. See table 3.3.2.2A in section 3.3.2.2.

Table 1.4.4.3 11kV Overhead Line Applications - Central Networks East

Size / Type	Application

50 mm² ACSR (Rabbit)	• Fault level must be below 4.5kA (86 MVA) * • Tee-off circuits up to 52 Amps (1 MVA) *P2/5 security standard* • Sub ring circuits (e.g. spurs interconnected to improve local security) ** Fault level may be up to 10kA (190 MVA) if protected with NEMA standard 11kV expulsion fuses fitted with arc shortening rods.*
100 mm² ACSR (Dog)	• Fault level must be below 8.9kA (170 MVA). • Tee-off circuits where the fault level exceeds the rating of 50 mm² ACSR which cannot be fused. • Minor diversions of existing 100mm² ACSR lines.
150 mm² ACSR (Dingo)	• Fault level must be below 13.5kA (260 MVA). • Ring Main circuits up to 400 amps (7.6MVA @ 11kV) • Interconnectors between Primary/Grid Substations • Industrial/Commercial loads up to a firm capacity of 7.4 MVA – *two lines at 50% of continuous summer rating with 300 mm² Al XLPE cable sections.*
300 mm² HDA (Butterfly)	• Fault level must be below 23.4kA (450 MVA). • Normally used for 33kV circuits • May be used at 11kV for Industrial/Commercial loads up to a firm capacity of 12.0 MVA – *two lines at 50% of continuous summer rating – 400 mm² Cu XLPE cable sections.*

1.4.6 11kV Connectivity Rules

Under Condition 9 of our Electricity Distribution Licence, Central Networks has a duty to comply with the Distribution Code of England and Wales. Engineering Recommendation P2/5 under this Code sets out the minimum levels of supply security for distribution networks.

P2/5 addresses levels of supply security for distribution networks classified in ranges of group demand only and not individual customers. The application of P2/5 to loads below 1MW results in an open ended restoration time i.e. repair time. A network designed to this minimum requirement would result in customer service levels, (customer minutes lost and time to supply restoration) well below Regulatory targets and customer expectations.

These 11kV Connectivity Rules specify the methods of connecting substations and transformers to the 11kV network to enable:

- the 11kV network to be broken up into sections by switching to enable faults to be localised.
- faulty sections to be isolated and the remaining healthy network sections to be restored to service.
- supplies to customers within faulty sections of 11kV network to be restored by LV back-feeding or mobile generation.
- sections of the network to be isolated for routine work with minimal disruption to customers.

1.4.6.1 Derogations to 11kV Connectivity Rules and/or P2/5

These rules shall not apply to installations designed or installed before 1st July 2004.

Existing networks shall be brought up to these standards during refurbishment or replacement as specified by the Network Manager.

Derogation of these rules at a customer's request, for example to reduce to the cost of a new connection, shall not be permitted unless the intended occupiers of the premises to be supplied are aware of, and accept in writing, the reduced supply security and it's implications. Central Networks will not accept requests for derogations from developers or their agents as they are generally not in a position to fully comprehend the requirements of the future occupiers. Network extensions that fail to meet these requirements shall not be connected to Central Networks' network.

In practice this means:

- Residential housing and Commercial / Industrial estates – at the time the new connection is designed it is unlikely that all or any of the intended occupiers will be known. As it is not possible to seek their approval of a proposed derogation then the 11kV Connectivity Rules shall be applied in full.
- Large individual Industrial / Commercial premises – it may be possible to identify the intended occupier e.g. the client. Written confirmation shall be obtained from that part of the client's business responsible for the future operation of the facility and not just those involved in constructing it. Otherwise the 11kV Connectivity Rules shall be applied in full.
- Derogations to Engineering Recommendation P2/5 will not be agreed by Central Networks without a referral to the industry regulator for a determination.

Where a customer is prepared to pay for a level of supply security exceeding the Central Networks 11kV Connectivity Rules and/or P2/5 this may be provided subject to the solution being technically feasible, does not prejudice the flexible operation and/or security of the network and is approved by the Network Manager.

1.4.6.2 Ground Mounted Substation Rules

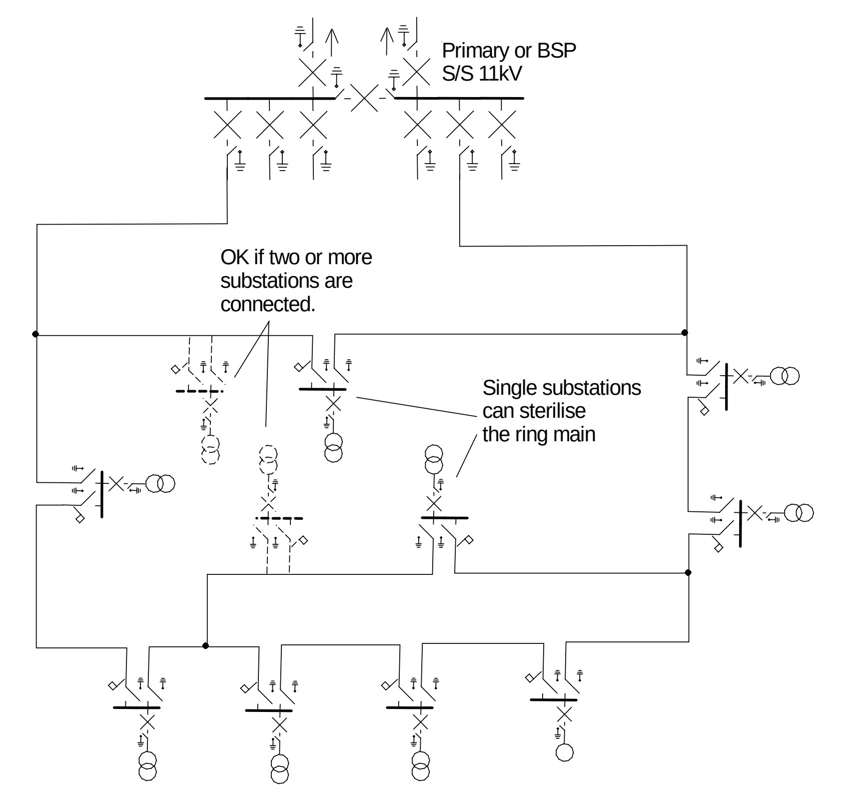
All new substations shall be equipped with 11kV ring main switches.

An earth fault indicator shall be provided on one of the ring switches.

Where connected to an underground or overhead line system the substation shall be ring connected if within 200m of the ring main or spur line. All loads over 1000kVA shall be ring connected regardless of the distance from the ring main.

Tee connected substations shall not be connected to the first cable section from a Primary or BSP substation. Interconnected tee connections may be acceptable provided the interconnection is not to another first section of the same ring main. *Note – the first cable section is defined as the cable to the first ring connected substation or overhead line terminal pole.*

Substations shall not be connected in such a manner that part of the network is sterilised during maintenance work. *e.g. a single substation tee connected across two sections of the same ring main would require part or all of the ring to be shut down for work on the substation.*

	Examples of ring main sterilisation. A single substation requires both side of the ring main to be isolated for maintenance work on that substation. A second substation ensures that isolation is available without interrupting both side of the ring main simultaneously.

Ring connection may be achieved by:

1. Laying two cables in common or separate trenches and looping into an existing ring main.
2. Laying one cable from an existing main or substation and extending via the new substation to link up with another substation or ring main. It may sometimes be necessary to await future developments to complete the ring or interconnector resulting in spurs outside the requirements of the 11kV Connectivity Rules and/or P2/5. Such arrangements should not be undertaken without a connection strategy, approved by the Network Manager, which provides for completion of the ring within a reasonable period. Each case must be judged on merit but in general the aim should be provision within 3 years.
3. Where the ring main is an overhead line it shall be terminated in both directions and the substation cables connected into the ring. If terminal poles are impractical e.g. for wayleave reasons, then two adjacent section poles shall be created leaving a dead span between with the substation cables connected into the ring at each section pole. Under no circumstances shall two cables be connected either side of a single section pole.
4. Where an overhead line spur is the only reasonably practicable connection point the substation shall be ring connected as per '3' in order to provide sectionalising facilities to aid fault localisation and to limit the need for mobile generation. Where the spur is underground cable the substation shall be ring connected into the spur. Future interconnection at the remote end of the spur will enable a full switched alternative supplies to be available without further work to install a second circuit into the substation.

1.4.6.3 Padmount Transformer Rules

Padmount transformers shall not be connected to the first cable section from a Primary or BSP substation. *Note – the first cable section is defined as the cable to the first ring connected substation or overhead line terminal pole.*

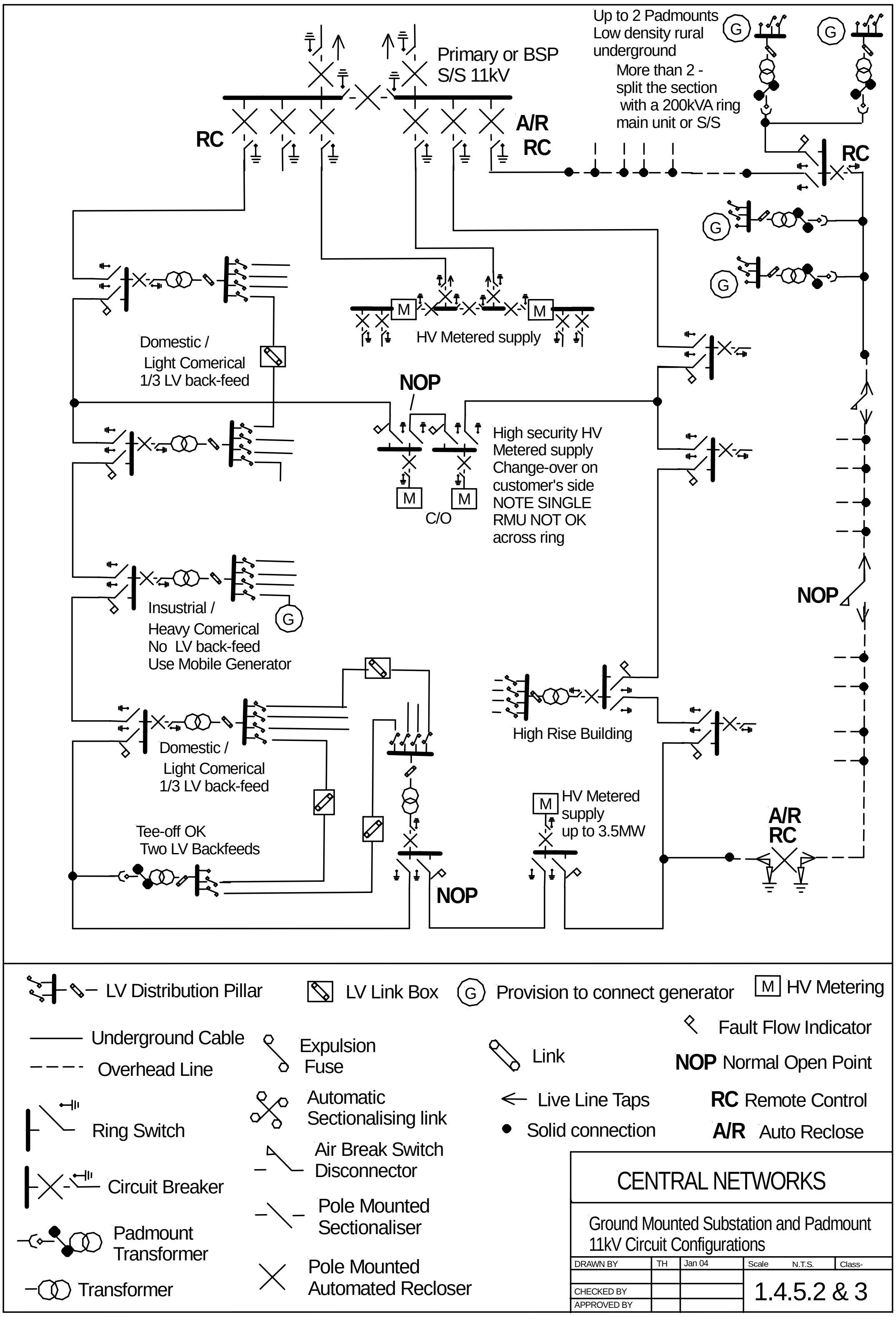
Padmount transformers up to 200 kVA may be tee connected to ring mains or spurs under the following circumstances:

1. Where a full LV back feed is available from a source(s) that can remain on supply whilst the section that the padmount is connected to is isolated. Note that this back-feed will need to come from each of the substations either side of this section so at least one will be available during maintenance work. Maximum of one padmount between switching points.
2. Without LV back-feeds on low customer density rural underground ring mains or spurs subject to the following requirements being met:
    - Maximum of 50 customers and 2 padmounts between switching points
      <u>and</u>
    - An aggregate transformer nameplate capacity of 400kva with a maximum individual 200kva transformer in any group of up to 2 padmounts
      <u>and</u>
    - Customer base is predominately domestic, farming or light industrial/commercial i.e. no individual customers over 140kVA (200amps).
      <u>and</u>
    - There is sufficient space near each padmount to safely park a mobile generator and fuel tank during supply interruptions. (e.g. 100kV generator – 4m x 2.5m plus 2m x 2m for fuel tank)
      <u>or</u>
    - The customers have their own contingencies for supply interruption. e.g. pumping stations, mobile phone base stations etc.

Individual loads over 140kVA shall be supplied from suitably rated compact unit substation connected into the ring main.

Where the proposed number of padmounts will exceed 2 then a compact unit substation instead of a padmount or the section broken up with a free standing ring main unit.

The following drawings show typical circuit layouts using these rules


Primary or BSP
S/S 11kV
RC
A/R
RC
Up to 2 Padmounts
Low density rural
underground
More than 2 -
split the section
with a 200kVA ring
main unit or S/S
RC
G
G
G
G
Domestic /
Light Comerical
1/3 LV back-feed
M
M
HV Metered supply
NOP
High security HV
Metered supply
Change-over on
customer's side
NOTE SINGLE
RMU NOT OK
across ring
M
M
C/O
Insustrial /
Heavy Comerical
No LV back-feed
Use Mobile Generator
G
NOP
High Rise Building
Domestic /
Light Comerical
1/3 LV back-feed
Tee-off OK
Two LV Backfeeds
M
HV Metered
supply
up to 3.5MW
NOP
A/R
RC
LV Distribution Pillar
LV Link Box
G
Provision to connect generator
M
HV Metering
Underground Cable
Overhead Line
Expulsion
Fuse
Link
Fault Flow Indicator
NOP Normal Open Point
Ring Switch
Automatic
Sectionalising link
Live Line Taps
RC Remote Control
Solid connection
A/R Auto Reclose
Air Break Switch
Disconnector
Circuit Breaker
Pole Mounted
Sectionaliser
Padmount
Transformer
Transformer
Pole Mounted
Automated Recloser
CENTRAL NETWORKS
Ground Mounted Substation and Padmount
11kV Circuit Configurations
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APPROVED BY
1.4.5.2 & 3

1.4.6.4 Overhead Line Rules

Few circuits consist wholly of overhead line. The Ground Mounted Substation and Padmount Transformer Rules apply where appropriate in mixed underground/overhead circuits.

Switching devices

The following overhead line switching devises shall be used where defined in these rules:

- Air Break Switch Disconnectors (ABSD) – three phase ganged, manual independent spring assisted high level mechanism, 230MVA fault close, 630 amp load break.

- NEMA Universal Fuse Mounts – single phase un-ganged, 27kV insulators, maximum connected transformer capacity of 500kVA, maximum fault level 190MVA and fitted with either:

  - Expulsion fuse – 50 amp slow blowing with arc shortening rod.

  - Automatic Sectionalising Link (ASL) – 50 amp pickup, 2 pulse

  - Solid link – rated at 8kA for 1 second fault current.

- Live Line Taps – 400 amp rating, used with 95mm^2 aluminium or 70mm^2 copper flexible jumper and connected to the main line via bail clamps.

- Jumpers comprising of the same material as the overhead line or coverd conductor which can be removed to provide an isolation point either by hot glove/stick working or under Permit to Work. Sizes shall be equal to or greater than the overhad line size or 50mm^2 al / 32mm^2 cu for transformer connections.

- Remote controlled equipment, such as Pole Mounted Auto Reclosers, Motor Operated ASBDs, Gas Insulated Switches, are installed at strategic positions on the network as decided by the Network Manger. The provision of such equipment is not covered by these rules. Refer to Section 1.4.7 11kV Network Automation.

Application of switching devices.

1. Air Break Switch Disconnectors shall be installed:

   - To divide ring mains into sections if any of the criteria below are exceeded:
     - A maximum of 1000 kVA of transformer capacity
     - A maximum of 500 customers
     - A maximum of 5 km of ring main

   Additional connections that cause any of the above criteria to be exceeded shall require an additional ABSD installing.

   - On the next pole to a Pole Mounted Auto Recloser or Gas Insulated Switch for use as a point of isolation that complies with the Distribution Safety Rules.

2. Air Break Switch Disconnectors shall be installed on spurs:
    - Of with between 500kVA and 1000kVA of connected transformer capacity.
    - Additional connections that take the capacity over 1000kVA shall require the spur to be converted to a ring main.
    - On spurs with ferroresonance problems. i.e. a mixture of underground cables and transformers that cannot be isolated independently*. e.g. when adding a cable section to a spur not all existing transformers will have local solid links. Rather than install links on a number of transformer the installation of an ABSD may be more economical.*
    - On spurs over 5 spans where the fault level is over 190MVA thus preventing the use of ASLs or fuses
3. Solid links in NEMA universal fuse mounts shall be installed:
    - Only where the fault level is below 190 MVA.
    - Only where the connected transformer capacity is less than 500 kVA
    - On all pole transformers and on all cable spurs to provide isolation facilities during fault localisation. *NB the present use of high speed protection all but eliminates visible damage to transformers and surge arrestors making it difficult to identify faulted plant. Local isolation facilities enable restoration staff carry out further fault localisation within sections of line.*
    - On cables or lines in ferroresonant spurs to enable transformers and cables to be independently isolated. In some circumstances a small number of links may be a more economical option than installing an ABSD.
4. Automatic Sectionalising Links in NEMA universal fuse mounts shall be installed:
    - Only where the fault level is below 190 MVA.
    - Only where the connected transformer capacity is less than 500 kVA
    - On all spur lines at the first pole away from the tee-off or other accessible location before the first transformer where:
        - The spur is downstream of a Pole Mounted Auto Recloser or the Primary Substation circuit breaker fitted with multi-shot auto reclosing with at least 3 shots.

5. Expulsion Fuses in NEMA universal fuse mounts shall be installed:
    - Only where the fault level is below 190 MVA.
    - Only where the connected transformer capacity is less than 500 kVA
    - On all spur lines at the first pole away from the tee-off or other accessible location before the first transformer and where the spur is upstream of the first Pole Mounted Auto Recloser on the circuit and the Primary Substation circuit breaker is not fitted with multi-shot auto reclosing with at least 3 shots.
6. Live Line Taps shall be installed:

- To connect all Pole Mounted Auto Reclosers, Sectionalisers and Remote Controlled Switches to lines to enable routine maintenance to be carried out.
- New ABSDs, Fuses, Links, ASLs, Spurs or Transformers (with links) may initially be connected by live line taps where hot glove/stick connection of jumpers is not reasonably practicable or does not meet live line risk assessment criteria. They should be replaced by jumpers during the next line outage.

7. Jmpers shall be installed:
   - In all equipment not specified above including new ABSDs, Fuses, Links, ASLs, Cable Terminations & Section Poles.

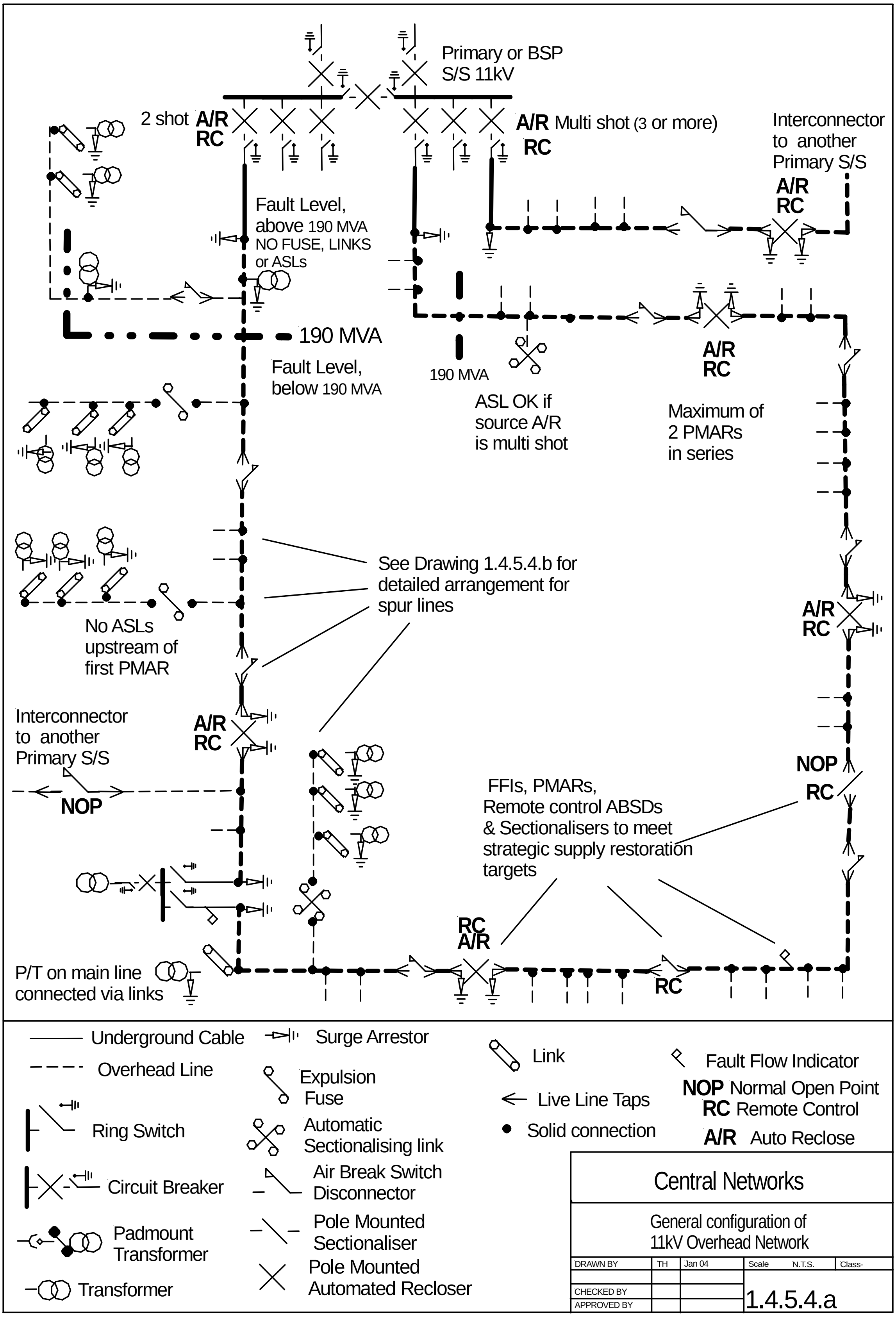
Ferroresonance

Ferroresonance occurs when transformers and cables are switched together by single phase devices. The capacitance of the cable is effectively placed in series with the non-linear inductance of the transformer winding. When one or two phases are made dead the circuit resonates and creates high over-voltages which can damage equipment. In practice the surge arresters fitted to cables and transformers clip the voltage to about 25kV but then quickly overheat and become short circuit for several hours before cooling down and recovering. Re-energising the circuit before the arresters have recovered results in an earth fault.

When the transformers have more than 5% of full load connected to the LV terminals ferroresonance does not occur so the operation of fuses or ASLs on a loaded ferroresonant spur is not a problem.

However, planned work is often done with the LV loads disconnected or being run on mobile generation. Therefore facilities have to be provided to enable transformers and cables to be switched separately.

The following drawings show typical overhead circuit layouts using these rules


Primary or BSP
S/S 11kV
2 shot A/R
RC
A/R Multi shot (3 or more)
RC
Interconnector
to another
Primary S/S
A/R
RC
Fault Level,
above 190 MVA
NO FUSE, LINKS
or ASLs
190 MVA
Fault Level,
below 190 MVA
190 MVA
ASL OK if
source A/R
is multi shot
A/R
RC
Maximum of
2 PMARs
in series
See Drawing 1.4.5.4.b for
detailed arrangement for
spur lines
No ASLs
upstream of
first PMAR
A/R
RC
Interconnector
to another
Primary S/S
A/R
RC
NOP
NOP
RC
FFIs, PMARs,
Remote control ABSDs
& Sectionalisers to meet
strategic supply restoration
targets
P/T on main line
connected via links
RC
A/R
RC
Underground Cable
Overhead Line
Ring Switch
Circuit Breaker
Padmount
Transformer
Transformer
Surge Arrestor
Expulsion
Fuse
Automatic
Sectionalising link
Air Break Switch
Disconnector
Pole Mounted
Sectionaliser
Pole Mounted
Automated Recloser
Link
Live Line Taps
Solid connection
Fault Flow Indicator
NOP Normal Open Point
RC Remote Control
A/R Auto Reclose
Central Networks
General configuration of
11kV Overhead Network
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Class-
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APPROVED BY
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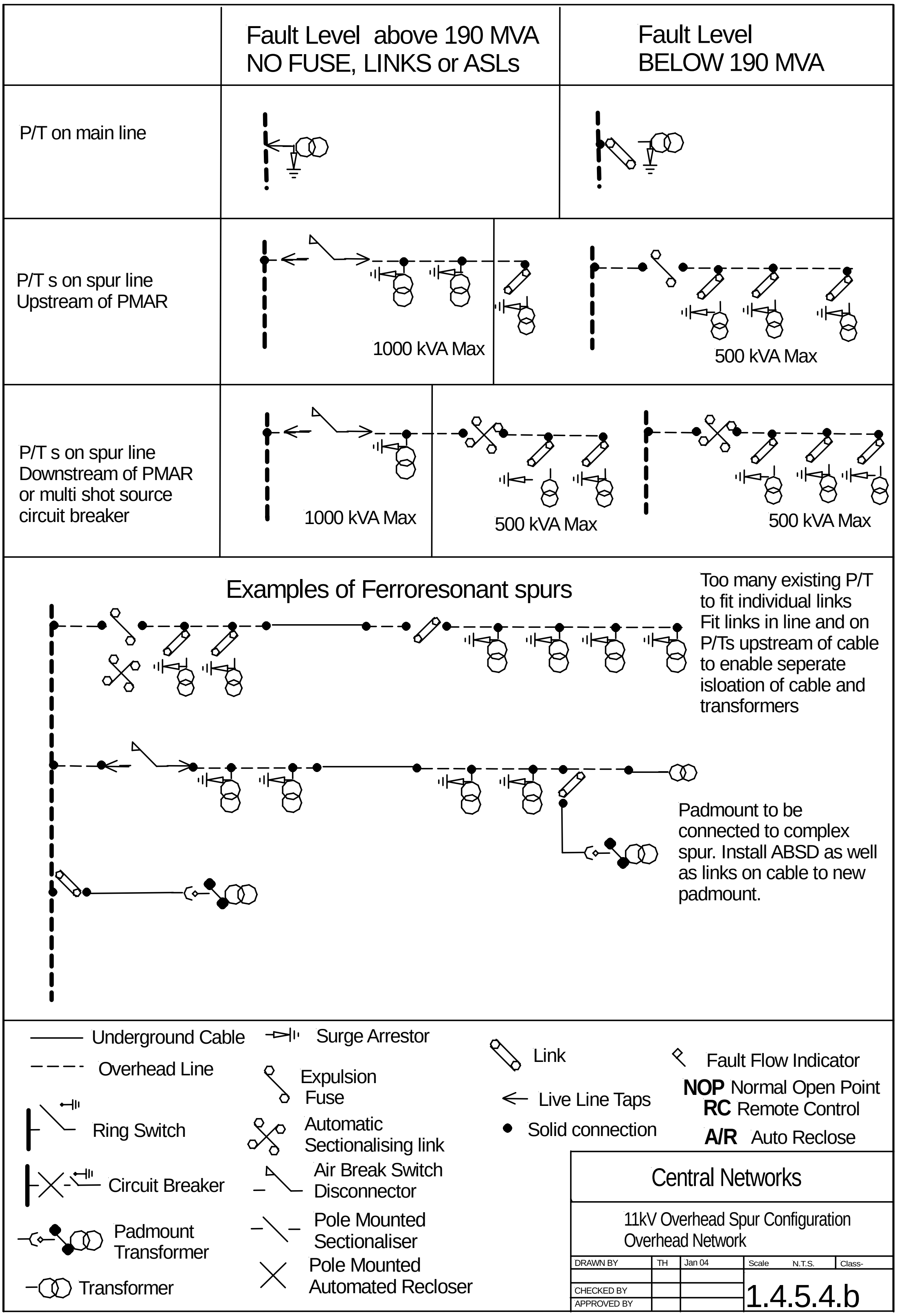
Fault Level above 190 MVA
NO FUSE, LINKS or ASLs
Fault Level
BELOW 190 MVA
P/T on main line
P/T s on spur line
Upstream of PMAR
1000 kVA Max
500 kVA Max
P/T s on spur line
Downstream of PMAR
or multi shot source
circuit breaker
1000 kVA Max
500 kVA Max
500 kVA Max
Examples of Ferroresonant spurs
Too many existing P/T to fit individual links
Fit links in line and on P/Ts upstream of cable to enable seperate isloation of cable and transformers
Padmount to be connected to complex spur. Install ABSD as well as links on cable to new padmount.
Underground Cable
Overhead Line
Ring Switch
Circuit Breaker
Padmount
Transformer
Transformer
Surge Arrestor
Expulsion
Fuse
Automatic
Sectionaling link
Air Break Switch
Disconnector
Pole Mounted
Sectionaliser
Pole Mounted
Automated Recloser
Link
Live Line Taps
Solid connection
Fault Flow Indicator
NOP Normal Open Point
RC Remote Control
A/R Auto Reclose
Central Networks
11kV Overhead Spur Configuration
Overhead Network
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1.4.6.5 LV Back-feeds and Mobile Generation

Ground Mounted Substations

Where technically possible sufficient LV back-feeds shall be provided to ground mounted substations ensuring that during back-feeding:

The maximum regulation on the LV network being back-feed does not exceed

- 12% of 230v when supplied from "Standard 11kV Feeders".
- 10% of 230 volts when supplied from "Long 11kV Feeders

assuming 33% of the design ADMD. *i.e. routine work planned for times of light load. The ring main connection allows for full HV restoration for 11kV cable faults.*

and

- The maximum loop impedance on the LV network does not exceed
  - 0.52 ohms on non-electric heating networks
  - 0.38 ohms on electric heating networks
  - 0.19 ohms on commercial / industrial networks

These values will ensure that cut-out fuses will operate with 5 seconds as required under the current edition of BS7671.

The remaining risk of LV cable faults clearing in over 100 seconds is deemed to be acceptable as the network will be under close technical supervision during the course of the work.

Where the LV back-feed cannot be designed to meet these criteria then there must be sufficient space and access for a mobile generator to be parked and connected. Note that *generators over 100 kVA are delivered and parked on the trailer of an articulated lorry.*

Typical 200kVA generator used for supply restoration. Larger sizes have a separate fuel tank.

Padmount Transformers

Padmount Transformers on low density rural underground networks need not have LV back-feeds where provision is technically impossible. Mobile generator access must be available to restore supplies during cable faults and for planned work where justified.

Where technically possible sufficient LV back-feeds shall be provided to padmount transformers ensuring that during back-feeding:

The maximum regulation on the LV network being back-feed does not exceed

- 12% of 230v when supplied from "Standard 11kV Feeders".
- 10% of 230 volts when supplied from "Long 11kV Feeders

assuming 100% of the design ADMD. *Because the padmount is tee connected the LV back feed could be required at times of maximum load due to an 11kV cable fault.*

and

- The maximum loop impedance on the LV network does not exceed
  - 0.52 ohms on non-electric heating networks
  - 0.38 ohms on electric heating networks

These values will ensure that cut-out fuses will operate with 5 seconds as required under the current edition of BS7671.

The remaining risk of LV cable faults clearing in over 100 seconds is deemed to be acceptable as the network will be under close technical supervision during the course of the work.

If necessary both LV cables should have separate back-feeds to avoid feeding through the bus-bars.

If the above criteria cannot be met then a 200 kVA ring main substation shall be installed.

Pole mounted transformers

Pole Mounted Transformers need not have LV back-feeds where provision is technically impossible. Mobile generator access must be available to restore supplies during transformer faults and for planed work where justified.

Where technically possible sufficient LV back-feeds shall be provided to padmount transformers ensuring that during back-feeding:

The maximum regulation on the LV network being back-feed does not exceed

- 12% of 230v when supplied from "Standard 11kV Feeders".
- 10% of 230 volts when supplied from "Long 11kV Feeders

assuming 33% of the design ADMD if the spur is totally overhead or 100% if there is underground cable in the spur. *Most transformer faults occur during the summer in lightning storms. Cable faults may occur at times of maximum load.*

<u>and</u>

- The maximum loop impedance on the LV network does not exceed
    - 0.52 ohms on non-electric heating networks
    - 0.38 ohms on electric heating networks
    - 0.19 ohms on commercial / industrial networks

These values will ensure that cut-out fuses will operate with 5 seconds as required under the current edition of BS7671.

The remaining risk of LV cable faults clearing in over 100 seconds is deemed to be acceptable as the network will be under close technical supervision during the course of the work.

Where there is more than one LV cable connected to the Pole Transformer each will require a back-feed as Pole Transformers are not equipped with transformer LV isolators.

If the above criteria cannot be met then mobile generator access must be available to restore supplies during transformer or cable faults and for planned work where justified.

A 'Long 11kV Feeder' is defined as extending beyond the 15km radius of a Bulk Supply Point or Primary Substation. See Section 4 Network Voltage Policy.

1.4.7 Physical Siting of 11kV Substations, Cables & Lines

All references to substations in this section shall also include switching stations and padmount transformers.

1.4.7.1 Location and Operational Access to Substations

Substations shall be sited at ground level and have 24 hour access available from the public environment by using the Central Networks standard operational key.

- Compact Unit Substations up to 1000 kVA and ring main + metering units shall normally be housed in the standard Central Networks Glass Reinforced Plastic (GRP) housing with approved explosion relief features. A plot of land 4m x 4m is required.

- Developers may opt to provide a free standing brick build housing to Central Networks' specification employing a GRP roof with approved explosion relief features. A plot of land 4m x 4m is required. Substations shall not be attached to houses or garages.

- Substations shall not normally be situated inside customer's premises or built into the wall of a building without the permission of the Networks Manger. Where this is unavoidable the allocated space must provide certain clearances around the equipment for operational access, maintenance and internal arc relief. For compact unit substations and ring main units these clearances are;

    - Equipment side/rear to wall – 750mm *- maintenance & internal arc relief*

    - Front – 1000mm or less if towards fully opening doors – *operational requirement*

    - Min ceiling height of 2.1m but at least 500mm clearance above the switchgear – *to comply with the internal arc relief requirement s of ENATS 41-36*

- Substations shall not be situated on roofs or in basements.

- Substations shall not normally be installed inside residential buildings. See section 1.4.7.5.

- Substations supplying LV networks without LV back-feeds shall have suitable space available within 25 metres to safely park and connect mobile generation of the required capacity.

In high density urban situations these rules may be relaxed at the discretion of Network Manager. However, developers are expected to make provision for substations at an early stage of the design work.

The Construction Design & Management Regulations require the designer to consider the entire life cycle of an installation including construction, use, maintenance and eventual demolition. Substations inside customer's property cannot be immediately disconnected from the network upon notification that the supply is longer required as network alterations have to be planned and executed to joint out the substation. There have been a number of *instances where third parties have been injured whilst interfering with high voltage equipment located inside the boundary of a vacated property. The Health and Safety Executive have been critical of having live high voltage equipment inside vacated premises. Placing the Central Networks 11kV switchgear on or outside the boundary fence enables Central Networks to make all equipment inside the property dead by switching upon notification that the supply is no longer in use.*

1.4.7.2 Routing of 11kv Overhead Lines

Overhead lines represent a potential hazard to members of the public and workers from accidental contact. Overhead line routes shall be planned bearing in the mind the type of use, or foreseeable use, to which the land is or may be put.

Central Networks follows the requirements of ENATS 43-8 'Overhead Line Clearances'. Road clearances are applied to agricultural land in recognition of the size of agricultural equipment now in common use. See Section 3 of the Overhead Line Manual Volume 1 for further information.

High Load Routes

Certain roads are designated as High Load Routes by the Department of Transport. These require a ground clearance of 7.1m in order to accommodate vehicles up to 6.1m high. See ENATS 43-08 section 6.1.

When planning a line to cross a road the designer shall establish whether or not it is a designated high road route and specify the clearance appropriately.

Customer & Network Operations maintains the list of the high load routes and line crossings within Central Networks.

Un-insulated 11kV overhead Lines

Un-insulated overhead lines shall not be routed across land used for:

Public recreation including;

- Playing fields
- Car parks
- Caravan / camping sites
- Lakes, rivers and canals
- Gardens of residential dwellings.
- Woods / forests
- Any sites identified as being used for recreation with or without the owner's permission.

Work activities other than farming including;

- Factory yards, loading bays etc.
- Commercial vehicle parking areas
- Hopyards, orchards, garden centres
- Commercial wood/forests
- Any sites identified as being a unacceptable hazard to workers

Routing overhead lines across farmland

A risk assessment must be carried out and any unacceptable locations must be avoided. Examples include:

- Locations where regular loading /unloading activities take place
- Fields where portable irrigation pipes are regularly used
- Any locations identified as being a potential hazard to farm workers

Pole mounted transformers and switchgear.

- Live jumpers may be as low as 4.3m from ground level – such equipment must be placed where accidental contact is judged to be unlikely.
- Free standing (cable supplied) pole transformers shall not normally be used as locations unsuitable for overhead line are unlikely to be suitable for low level exposed live terminals.
- Overhead line Wayleave terminations – these are often prompted by a change use of the land. Pole transformers should not be retained as free standing transformers unless it is clear that the new use of the land does not place persons at an unacceptable risk.

Vehicular Access

The Working at Height Regulations require that a safe method access is provided to tall structures.

The Health & Safety Executive's preferred hierarchy of access is

1. Mobile elevated work platform (MEWP)
2. Ladders
3. Free climbing with permanent attachment for fall arrest equipment
4. Free climbing by first person to install temporary fall arrest equipment.

Options 2 to 4 are only acceptable where vehicular access for a MEWP is not possible on existing overhead lines constructed before the Working at Height Regulations came into force.

All new overhead lines must be constructed along routes accessible to a four wheel drive MEWP.

Hazard reduction

Where un-insulated overhead lines represent an unacceptable risk the following alternatives are available in order of preference;

1. Underground cable
3. Covered Conductor.
4. Large cross section bare conductors – risk assessment

1. Underground cable
    a. This option eliminates the risk of accidental contact with exposed live equipment.
    b. May not be economically viable or practicable in certain situations such as river / canal crossings.
    c. May not be an environmentally acceptable solution through woodland where damage to tree roots may occur during cable trenching.
    d. Not suitable in commercial forests where excavations during harvesting and re-planting may represent an unacceptable risk of cable damage.

2. Covered Conductor.

    e.g. BLX, SAX, PAS, Amokraft.

    a. This is NOT fully insulated. Covered conductor itself is not designed to protect persons from accidental contact. Contact with trees can be maintained for a few hours or days depending on the insulation type.
    b. Every 2nd or 3rd pole top has exposed live connections for Arc Protection Devices (arcing horns known as APDs). These prevent the line being burnt down by direct lightning strikes. These may be omitted within wooded areas where direct strikes will occur to trees rather than the line.
    c. May be used to cross rivers, dykes, canals and small lakes. This is primarily to reduce fault incidence caused by water-fowl strikes. Covered conductor may reduce, but not eliminate, the hazard of electrocution resulting from accidental contact by fishing rods / boat masts. APDs must not be installed on the poles either side of the crossing or on access routes to the water where contact could be made with the exposed live APDs. **Warning signs must be displayed and fishing/boating activities must be restricted in proximity to covered conductor lines to exactly the same standards as bare wire overhead lines.**
    d. **Must not be used** alongside rivers, canals dykes, canals, lakes and other leisure areas as the primary method of protecting the public.
    e. Available up to 185mm^2 i.e. equivalent to 150mm^2 O/H line.
3. Large cross section conductors

a. Covered conductor systems are not available for conductors over 185mm^2.

b. New heavy duty lines, such as 200 mm^2 or 300mm^2, should be routed to avoid, or be under-grounded in, areas of high risk where reasonably practicable.

c. Where river, canal, dykes crossing are unavoidable then a risk assessment should be made taking into account the frequency and type of activities at risk. The crossing should preferably be at right angles but no more 30^0 to minimise the length exposure of the un-insulated line to a minimum. Taller poles shall be used where these can mitigate the risk. The Overhead Line Manual Volume 1 Section 3 "Overhead Line Clearances" Table 6 lists clearances across certain named waterways in the Central Networks East area as agreed with the British Waterways Board.

1.4.7.3 Routing of 11kV Underground Cables

Underground cables are vulnerable to damage by persons excavating and may then be a source of danger due to the explosive release of energy during failure. However, cables need to be excavated and worked on from time to time for routine repairs, networks extensions, replacement etc. Cables shall be laid in black rigid twinwall corrugated ducts to ENATS 12-24 and identified with warning tape at the depths specified in the Central Networks Cables, Cable Laying and Accessories Manual, Section 3, "Cable Laying Technical Requirements".

Preferred routes

Underground cable routes shall be planned bearing in the mind the type of use, or foreseeable use, to which the land is or may be put.

The preferred options for cable routes are along the footpaths and across roads of public highway.

Routes should not be planned along carriageway unless other alternative are not reasonably practicable. Where possible joints should be located off the carriageway by diverting the duct line into suitable locations.

Where a route is across private land is unavoidable then a Permanent Easement must be obtained.

Routes to avoid

Areas of land and natural features have legal protection due to their environmental character or sensitivity. Such designations include Sites of Special Scientific Interest (SSSI), National Nature Reserves, Special Areas of Conservation and Scheduled Ancient Monuments. See Section 8. "Environmental Requirements" for more information.

Special precautions are needed when digging near trees to avoid damage to tree roots. Hand digging may make a shorter route through trees more expensive than a longer route to avoid them.

Routes through commercial forests should be avoided. Mechanical equipment used to harvest and re-plant trees exposed the cable to accidental contact. The lack of permanent features to act as tie-in points makes meaningful recording of the route and future use of plans difficult.

Routes across agricultural land should avoid locations where excavation may be predicted e.g. gate posts. When crossing ditches the laying depth should be increased to keep the cable well below ditch clearing excavations. It should also be ascertained if the landowner carries out sub-soil ploughing to un-compact the soil. Where necessary an increased laying depth should be agreed.

1.4.7.4 Earth Potential Rise

At hot sites there may be issues relating to the proximity of Central Networks earthing to third part equipment, buildings, fencing etc. which could be affected by transfer potentials during earth faults on the Central Networks 11kV network.

Also, Central Networks 11kV & LV equipment may be affected by transferred potentials from the earths of higher voltage installations in the proximity. (e.g. 33kV, 132kV, 275kV, 400kV circuits and railway 25kV supplies).

The Earthing Manual shall be consulted and where reasonably practicable the substation shall be sited in a position where a standard earthing design will be safe. Where necessary an earthing consultant shall be engaged to design a specific earthing system for that location.

1.4.7.5 Environmental Constraints

Noise

Substations shall not normally be installed inside residential buildings. Low frequency vibrations from transformers will be transmitted through the building foundations and become apparent to residents at periods of low ambient noise. Where it is unavoidable, typically in high density urban areas, Central Networks may permit a substation to be installed inside provided the transformer foundations are acoustically isolated from the building foundation.

Escape of Insulating Oil

All proposed substations shall be individually assessed to ascertain the environmental risk, if any, associated with its immediate surrounding environment. The key point being to identify any potential for pollution of controlled waters in the event of an oil release and thus determine the need for control measures.

Control measures include:

- Siting the substation in a less sensitive location – preferred option.
- Using a bunded foundation to contain escaping oil
- Use of an environmentally benign alternative to mineral oil approved by Central Networks.

Refer to Section 8 Environmental Requirements for further information.

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Water and Gas

The Electricity Safety, Quality, and Continuity Regulations 2002 Regulation 3(4) require generators and distributors to take precautions to prevent, so far as is reasonably practicable, danger due to the influx of water, or any noxious or explosive liquid or gas, into any enclosed space, arising from the installation or operation of their equipment.

Environments affected by this regulation include customers' premises, e.g. basements and stairwells, and generators' and distributors' own premises, e.g. substations and cable basements.

Examples of substances that may cause danger or disruption to the public supply of electricity include:

- water due to burst mains, flash floods or fire fighting activities
- methane leaking from gas pipes in the ground
- leakage of SF6 from switchgear displacing air

New substations shall not be placed below ground level.
All cables ducts into substations shall be sealed.
Equipment designed specifically for submersible operation may be used to replace existing underground substations only.

1.4.7.6 Substation Legal Requirements

Please refer to the Central Networks Wayleaves and Property Policy and Procedures Manual - Freehold / Leasehold Acquisitions section. Note that this Manual is confidential to Central Networks. Information from this manual may be released to third parties where relevant to the work being undertaken.

1.4.8 11kV Network Automation

The term Network Automation includes equipment that either:

1. Autonomously carries out a sequence of pre-planned switching operations in the event of a supply failure to isolate faulty network and re-connect healthy sections.

and/or

2. May be operated by remote control from the distribution network control centre.

The use of autonomous automation is generally confined to auto changer schemes on 33kV and/or 11kV transformer circuit breakers at Primary Substations supplied from incompatible sources than cannot be permanently paralleled. Certain high voltage customers also have auto changeover scheme installed.

Remote control of network plant is employed on the 33kV & 11kV network to reduce customer interruptions and restoration times.

The Networks Manager will specify which locations shall be provided with remote control in order meet strategic customer service level targets.

Pole Mounted Auto Reclosers (PMAR)

These are installed in circuits with a maximum of two in series on each half of a ring main. Fault discrimination is achieved by definite time grading. The Primary substation circuit breaker instantaneous relay is slugged to 400 ms, the first PMAR to 200ms and the second to 50ms. The normal open point is fitted with either a PMAR or other remote controlled device. See the Central Networks Protection manual for more details.

Whilst initial fault interruption is carried out automatically by a PMAR tripping, supplies to healthy sections between PMARs are restored by the distribution control engineer using remote control and local operational staff.

PMARs cannot be used as a Point of Isolation under the Distribution Safety Rules. An ABSD must be situated on an adjacent pole to provide isolation.

Remote controlled switchgear

Certain makes and types of switchgear can have motorised actuators and communications equipment fitted which enables remote control via radio link.

Current options are:

- Power Isolators Rapier Air break Switch Disconnector (ABSD) fitted with double acting spring mechanism and motor drive control box. The connection rod from the drive motor is fitted with a mechanical de-coupling devise that enables the Rapier ABSD to be used as a Point of Isolation under the Distribution Safety Rules.

- Merlin Gerin / NuLec RL27 overhead line gas insulated switch with motor drive control box. The RL27 cannot be used as a Point of Isolation under the Distribution Safety Rules. An ABSD must be situated on an adjacent pole to provide isolation.

- Merlin Gerin Ringmaster range of 11kV switchgear may have motor control actuators fitted and are pre-wired to accept the control box. The motor actuators are easily removable to enable the switchgear be used as a Point of Isolation under the Distribution Safety Rules.

- Certain makes of other switchgear, such as the Long & Crawford T3FG3 and T4GF3 may be retrospectively fitted with motor control actuators. There are several makes of motor actuator available. They must be capable of being mechanically disconnected to enable the switchgear be used as a Point of Isolation under the Distribution Safety Rules.

1.5 Primary Network 33kV

The 33kV section is under preparation and will be included in due course.

1.5.1 33kV General Considerations

1.5.2 33kV Earthing

1.5.3 33kV Protection

1.5.4 33kV Circuit Configurations

1.5.5 33kV Connectivity Rules

1.5.6 Physical Siting of 33kV Substations and Equipment

1.5.7 33kV Network Automation

1.6 Grid Network 132kV

The 132kV section is under preparation and will be included in due course.

1.6.1 General Considerations at 132kV

1.6.2 132kV Earthing

1.6.3 132kV Protection

1.6.4 132kV Circuit Configurations

1.6.5 132kV Connectivity Rules

1.6.6 Physical Siting of 132kV Substations and Equipment

2. Network Modification Procedure

2.1 Introduction

This section of the Network Design Manual is aligned to comply with the requirements of the Powergen Engineering Minimum Standard 017 Plant Modification Procedure. It is implemented in Central Networks by the Local Management Instruction for Modification of the Distribution Network.

In an electricity distribution network the installation, replacement or disconnection of transformers, cables, overhead lines and switchgear etc. can have safety and operational implications.

This procedure applies to actions that:

- Reduce or increase network impedance
- Reduce or increase earth electrode resistance
- Reduce or increase protection clearance times
- Change equipment technology
- Change the application of approved equipment from approved standard arrangements/applications.
- Any other actions that are identified as possible threats to the continued safe and reliable operation of Distribution Network.

This procedure does not apply to:

- Actions that are identified by a suitably experienced and qualified professional engineer as having no implications to the continued safe and reliable operation of Distribution Network.
- Actions that were taken before the first publication date of this Manual.

Principles

- For the continued safe and reliable operation of the network all modifications and extensions must be designed and implemented in a manner that that takes into account their effect on the existing network.
- Where effects on the Distribution Network's safety case are identified they are brought to the attention of a suitably experienced and qualified Professional Engineer for resolution.
- All Central Networks business streams, contractors and consultants making network modifications shall ensure that they have access to suitably qualified Professional Engineers, experienced in distribution system design to provide first line technical support to Project Managers, Contract Managers and Instructed Persons and to liaise with the Assets Manager's technical specialists.

- Where routine design work is delegated to 'Instructed Persons' then their design procedures / tools must be capable of identifying and highlighting issues that need to be referred to a Professional Engineer.
- Pre-approved standard designs, equipment and applications are to be used wherever possible on the distribution network. Any deviation from these standards must be pre-authorised by the Asset Standards Manager.

The following wording is taken from the Powergen Minimum Engineering Standard 017:

"For the continued safe operation of plant and equipment, all modifications must be designed and implemented in a manner that is consistent with the original design intent. This has long been recognised in the nuclear side of the power industry, where formal procedures exist to ensure that proposed modifications are checked to ensure that they do not breach the safety case.

The danger that can result from inadequate attention to plant modification practices have been dramatically demonstrated by disasters in many countries around the world. For example, the incident on the Flixborough chemical plant, UK, in 1974, killed 28 people and injured a further 36. The disaster was formally attributed to "the introduction into a well designed and constructed plant of a modification which destroyed its integrity".

It is therefore essential that adequate formal procedures are drawn up and implemented within the Company, to ensure that modifications are designed, constructed, tested and maintained to a standard that is the same as, or better than, the plant being modified."

2.2 Implications of Network Modifications

2.2.1 Cause and Effect Mechanisms

Cause and effect mechanisms include:

Cause	How	Effect	Down stream Implications
1 Reduced network impedance	Install additional or larger plant or circuits. Paralleling of plant or circuits. Reinforcement of circuits.	Increased fault level Increased earth fault current Reduced LV loop impedance	Over-stress plant, cables and lines. General protection grading issues Increased Earth Potential Rise Possible rise above 16kA max PSCC
2 Increased network impedance	Remove plant or circuits. Install smaller plant or circuits. Un-paralleling of plant or circuits.	Reduced fault level Reduced earth fault current Increased LV loop impedance	Increased Protection times Increased earth fault clearance times or operation of SEF instead of IDMT Increased S/S LV fuse clearance times Cut-out fuse clearance times may no longer comply with the current edition of BS7671 Reduced quality of supply – more flicker

Continued			
Cause	**How**	**Effect**	**Down stream Implications**
3 Increased earth electrode resistance	Disconnection of lead covered cables / replacement by plastic sheath cables Disconnection of earth electrode e.g. disposal of part of a substation site. Insert O/H line into U/G circuit - no metallic earth path to source. Replace lead covered LV cables with CNE cable	Reduced earth fault current Increased Earth Potential Rise Loss of separate earth conductor	Increased earth fault clearance times. Operation of SEF instead of IDMT Safe voltage / time criteria may be exceeded. S/S or equipment may become 'hot' Non PME customers may be affected
4 Increased protection clearance times	Remove plant or circuits. Install smaller plant or circuits. Un-paralleling of plant or circuits. Insert additional protection stages – slug upstream protection	Increased duration of overcurrent Increased duration of earth fault current	Over-stress plant, cables and lines. Safe voltage / time criteria for touch and step potentials may be exceeded. General protection grading issues
5 Decreased protection clearance times	Lower protection settings Insert additional protection stages – fast or instantaneous protection	Reduced duration of fault current	Failure to grade with downstream protection – extended interruption. Minimal damage to plant making fault identification difficult
6 Change of equipment Technology or the application of equipment	Replace old pole transformer for new one fitted with HV & LV surge arresters. As above but LV cable is lead covered – HV earth was remotely earthed. Oil filled switchgear in basement S/S replaced by SF6 gear 132kV Gas Insulated Switchgear (GIS) installed. Other new technologies	Lightning impulses transferred to LV neutral. HV / LV earth segregation will be compromised when the deep earth is installed Risk of leaked gas pooling – suffocation risk Small earth system – high EPR High frequency earthing issues Previous design assumptions may not be valid	Must have 10 ohm HV deep earth and 20 ohm segregated LV earth to keep with safe levels . Earthing must be modified to provide HV LV segregation. Control measures required or re-site above ground Special earthing design needed. Thorough design and risk assessment required.

2.2.2 Examples of Implications

Examples include:

a) Installation of new 132/33kV, 132/25kV, 132/11kV or 33/11kV substation:
   - i) Increased 3 phase fault level on the network.
   - ii) Over-stress 33kV and 11kV switchgear at existing substations
   - iii) Protection schemes & settings may need altering
   - iv) Increased earth fault current
   - v) Increased Earth Potential Rise (EPR) – Primary may become 'Hot' or 'hotter' – increase in 650v and 430v contours – effect on telephones at S/S and local houses.
   - vi) Transfer of increased EPR onto 11kV cable screens – distribution S/S may become 'hot'.
   - vii) The EPR rise at secondary substations may require that HV and LV earths to be segregated.
   - viii) Raised fault level on 11kV circuits– Over-stress Secondary S/S switchgear and/or exceed Air Break Switch Disconnector fault close capabilities. Small size 11kV cables may become over-stressed.

b) Increase transformer size at existing 132/33kV, 132/25kV, 132/11kV or 33/11kV substation:
   - i) In addition affecting other parts of the network as in 1 above, plant at substation may be effected by increased 3 phase fault level
   - ii) Protection may be effected
   - iii) Increased earth fault level may increase the substation's EPR
   - iv) Transformer tails, switchgear and CTs may be overloaded

c) Disconnect lead covered cables or replace with plastic sheathed cable.
   - i) Increase in overall earth resistance which and may cause the EPR to rise at substations.
   - ii) The EPR rise at secondary substations may require that HV and LV earths to be segregated.
   - iii) Lead covered LV cables replaced or reinforced with CNE cables will have PME implications.
   - iv) Replacement of cable with a cable of smaller cross sectional area will increase the LV network loop impedance. LV fuse clearance criteria must be checked.

d) Replace part of an underground circuit with overhead line.
   - i) On HV cables the metal sheath may have formed an important route for earth fault current. EPR may be raised at substations.
   - ii) The EPR rise at secondary substations may require that HV and LV earths to be segregated.
   - iii) Lead covered LV cables replaced or reinforced with ABC O/H line will have PME implications.

iv) Replacement of cable with an overhead line of smaller cross sectional area will increase the LV network loop impedance. LV fuse clearance criteria must be checked.

e) Replace a bare wire overhead line with ABC.
   i) The mechanical duty on the poles and stays will change – any undersized components must be replaced with the correct size.
   ii) The ABC may have a higher loop impedance than some of the larger copper conductors on the network. This will increase the LV network loop impedance. LV fuse clearance criteria must be checked.

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f) Replace switchgear, transformer, cables or LV pillar at an existing site.
   i) Operator's standing position may have altered in relation to the earthing system. Safe touch, step and transferred potentials cannot be assumed. Earthing system must be re-evaluated and brought up to modern standards
   ii) Replacement of lead covered cables with plastic sheathed cables will raise the EPR.
   iii) The EPR rise at secondary substations may require that HV and LV earths to be segregated
   iv) Lead covered LV cables replaced with CNE cables will have PME implications.
   v) Replacement of existing pole transformers with new units fitted with HV & LV lightning protection will require earthing to be brought up to modern specification to control the magnitude of the lightning impulse transferred to the LV network. Existing lead covered LV cable may have to be replaced with plastic sheath cable to get HV / LV earth separation.
   vi) Replacement of distribution transformers with a lower KVA rating will increase the LV network loop impedance. LV fuse clearance criteria must be checked.

3. Standard Equipment Ratings and Data

3.1 General

This section contains the standard equipment types, ratings, circuit sizes and data that shall be used for network design and construction. This equipment shall be applied within its capabilities and limitations as part of standard network designs.

Where standard designs and/or equipment are not suitable for a specific application it will be necessary to engineer a bespoke solution with reference to the following documents:

- Central Networks "Local Management Instruction for the Selection and Approval of Equipment to be used on the Distribution Network"
- Central Networks "Local Management Instruction for Modification of the Distribution Network"
- Section 2, Network Modification Procedure of this Manual.

The data tables in this section include both standard and legacy equipment to facilitate design calculations involving the extension and/or modification of the existing network. Standard equipment is denoted by a tick in the column "Central Networks New Build Size".

Detailed equipment specifications are contained in:

- Central Networks "Plant Specification Manual"
- Central Networks "Cables, Cable Laying and Accessories Manual"
- Central Networks "Overhead Line Manual Volumes1 & 2 "

3.2 Low Voltage Network Ratings and Data

3.2.1 LV Underground Cables

3.2.1.1 Single Phase LV Service Cables

Central Networks East

Hybrid CNE Cable: Solid aluminium core, singles phase, XLPE insulated, concentric bare copper neutral/earth wires forming a combined neutral/earth conductor (CNE), 600/1000 volt, PVC sheathed overall, to specification BS 7870-3.1:1996 and ENATS 09-7 Table 2 (XLPE variant).

As detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.1

Service Cables - Central Networks East	
Size / Type	**Use**
25 mm^2 Hybrid	Public Lighting - PME
35 mm^2 Hybrid	Single phase services up to 90 amps - PME - single and looped domestic houses - single light commercial properties

Central Networks West

Hybrid Concentric Neutral HCN Cable: Solid aluminium core, singles phase, XLPE insulated, concentric bare copper neutral/earth wires forming a combined neutral/earth conductor (CNE), 600/1000 volt, PVC sheathed overall.

Copper Concentric Neutral CCN Cable: Stranded copper core, singles phase, XLPE insulated, concentric bare copper neutral/earth wires forming a combined neutral/earth conductor (CNE), 600/1000 volt, PVC sheathed overall.

Copper Split Concentric CNE Cable: Stranded copper core, singles phase, XLPE insulated, concentric bare copper earth wires, insulated neutral wires forming a Separate neutral/earth conductor (SNE), 600/1000 volt, PVC sheathed overall.

Service Cables - Central Networks West	
Size / Type	**Use**
10 mm^2 Al HCN	Street lighting PME
25 mm^2 Al HCN	House services PME
35 mm^2 Al HCN	House services PME
25 mm^2 Cu CCN	House services PME
35 mm^2 Cu CCN	House services PME
16 mm^2 Cu Split Concentric	Street lighting Non- PME
25 mm^2 Cu Split Concentric	House services Non- PME
35 mm^2 Cu Split Concentric	House services Non- PME

3.2.1.2 Three Phase LV Cables

Central Networks East

Wavecon CNE Cable: Three phase, three core, solid aluminium conductor, XLPE insulated, single rubber bedding, copper wire waveform concentric forming a combined neutral/earth conductor (CNE), rated voltage 0.6/1 kV, PVC sheathed overall, to specification BS 7870-3.40:2001 (Implementation of HD 603)

NB Prior to year 2000 the type of CNE cable used in Central Networks East had aluminium waveform concentric neutral/earth conductors. This type of cable is known as Alpex. The electrical parameters of Wavecon and Alpex are identical.

As detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.1

Central Networks West

Hybrid Concentric Neutral HCN Cable: Three phase, three core, solid aluminium conductor, XLPE insulated, single rubber bedding, copper wire helical concentric forming a combined neutral/earth conductor (CNE), rated voltage 0.6/1 kV, PVC sheathed overall

Wavecon CNE Cable: Three phase, three core, solid aluminium conductor, XLPE insulated, single rubber bedding, copper wire waveform concentric forming a combined neutral/earth conductor (CNE), rated voltage 0.6/1 kV, PVC sheathed overall, to specification BS 7870-3.40:2001 (Implementation of HD 603)

Table 1.3.1.2

LV Cables - Central Networks East & West		Continuous Rating (Summer) AMPS	
Size / Type	**Use**	**Laid Direct**	**Ducted**
35 mm^2 Wavecon / HCN	3 phase services	132	106
95 mm^2 Wavecon	3 phase services & LV mains	245	201
185 mm^2 Wavecon	3 phase services & LV mains	355	292
300 mm^2 Wavecon	3 phase services & LV mains	470	382

The above ratings assume:

- Maximum conductor temperature 90^{O}C
- Ground temp 15^{O}C
- Soil Thermal Resistivity 1.2 ^{O}C m/W
- 1 cable laid in the trench.
- Laid direct
- 125 mm duct
- Laid 450mm deep to top of cable / duct

3.2.1.3 Transformer Tails (Distribution Substation)

Single core, solid aluminium sectoral conductor, XLPE insulated, aluminium wire armoured, 600/1000 volt, PVC sheathed overall, to specification BS5467:1997.

As detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.1

Transformer Tails (Distribution Substation	
Size / Type	**Use**
4 x 600 mm^2 1 per phase + 1 neutral	315 kVA or 500 kVA Transformers to LV pillar.
7 x 600 mm^2 2 per phase + 1 neutral	800 kVA or 1000 kVA Transformers to LV pillar.

These cables are for use in distribution substations only and do not have to comply with the current edition of BS7671 "Requirements for Electrical Installations". They shall not be used on customer owned installations.

3.2.1.4 Transformer Tails (Large LV Industrial Supplies)

The LV tails from the substation LV Air Circuit Breaker to the customer's switchgear are owned by the customer and must comply with the current edition of BS7671 'Requirements for Electrical Installations'

Section 1.3.1.11 Arrangement F. 11kV extension, 500 to 1000kVA substation & LV Air Circuit Breaker suggests combinations of cables and transformer sizes based on these tables.

The following tables have been calculated from the current edition of BS7671 for cables laid in covered trenches. The customer's electrical contractor should refer to the current edition of BS7671 to confirm that these sizes are adequate for the proposed method of installation.

Note: the tables, methods and columns refer to the tables in the current edition of BS7671

Table 3.2.1.4.A

Single Core Copper 70^{o}C thermoplastic (PVC) non-magnetic armour Table 4D3A of BS7671 ARMOURS BONDED AT BOTH ENDS

Size	Table 4D3A Rating Amps	Table 4B3 correction factor for cables in covered trenches (methods 18 & 19)			Current rating per core Amps			Total Capacity Amps		
	Method 12 Horizontal flat spaced column 10	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase
185 mm^2	490	0.77	0.7	0.65	377	343	319	377	686	957
240 mm^2	566	0.76	0.69	0.63	430	391	357	430	782	1071
300 mm^2	616	0.74	0.68	0.62	456	419	382	456	838	1146
400 mm^2	674	0.73	0.66	0.6	492	445	404	492	890	1212
500 mm^2	721	0.72	0.64	0.58	519	461	418	519	922	1254
630 mm^2	771	0.71	0.63	0.57	547	486	439	547	972	1317
800 mm^2	824	0.7*	0.62*	0.56*	577	511	461	577	1022	1383
1000 mm^2	872	0.69*	0.61*	0.55*	602	532	480	602	1064	1440

- Values for cables over 630 mm^2 extrapolated from table 4B3 of the current edition of BS7671

Table 3.2.1.4.B										
Single Core Copper 90^{O}C thermosetting (XLPE) non-magnetic armour Table 4E3A of BS7671 ARMOURS BONDED AT BOTH ENDS										
Size	Table 4E3A Rating Amps	Table 4B3 correction factor for cables in covered trenches (methods 18 & 19)			Current rating per core Amps			Total Capacity Amps		
	Method 12 Horizontal flat spaced column 10	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase
185 mm^2	618	0.77	0.7	0.65	476	433	402	476	866	1206
240 mm^2	715	0.76	0.69	0.63	543	493	450	543	986	1350
300 mm^2	810	0.74	0.68	0.62	599	551	502	599	1102	1506
400 mm^2	848	0.73	0.66	0.6	619	560	509	619	1120	1527
500 mm^2	923	0.72	0.64	0.58	665	591	535	665	1182	1605
630 mm^2	992	0.71	0.63	0.57	704	625	565	704	1250	1695
800 mm^2	1042	0.7*	0.62*	0.56*	729	646	584	729	1292	1752
1000 mm^2	1110	0.69*	0.61*	0.55*	766	677	611	766	1354	1833

* Values for cables over 630 mm^2 extrapolated from table 4B3 of the current edition of BS7671

Table 3.2.1.4.C										
Single Core Copper 70^{O}C Thermoplastic (PVC) Table 4D1A of BS7671 UNARMOURED (or ARMOURED and EARTHED at ONE END ONLY)										
Size	**Table 4D1A Rating Amps**	**Table 4B3 correction factor for cables in covered trenches (methods 18 & 19)**			**Current rating per core Amps**			**Total Capacity Amps**		
	Method 12 Horizontal flat spaced column 10	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase
185 mm2	521	0.77	0.7	0.65	401	365	339	401	730	1017
240 mm2	615	0.76	0.69	0.63	467	424	387	467	848	1161
300 mm2	709	0.74	0.68	0.62	525	482	440	525	964	1320
400 mm2	852	0.73	0.66	0.6	622	562	511	622	1124	1533
500 mm2	982	0.72	0.64	0.58	707	628	570	707	1256	1710
630 mm2	1138	0.71	0.63	0.57	808	717	649	808	1434	1947
800 mm2	1265	0.7*	0.62*	0.56*	886	784	708	886	1568	2124
1000 mm2	1420	0.69*	0.61*	0.55*	980	866	781	980	1732	2343

- Values for cables over 630 mm2 extrapolated from table 4B3 of the current edition of BS7671

Table 3.2.1.4.D										
Single Core Copper 90^{O}C Thermosetting (XLPE) Table 4E1A of BS7671										
UNARMOURED (or ARMOURED and EARTHED at ONE END ONLY)										
Size	**Table 4E1A Rating Amps**	**Table 4B3 correction factor for cables in covered trenches (methods 18 & 19)**			**Current rating per core Amps**			**Total Capacity Amps**		
	Method 12 Horizontal flat spaced column 10	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase	1 core per phase	2 cores per phase	3 cores per phase
185 mm2	651	0.77	0.7	0.65	501	456	423	501	912	1269
240 mm2	769	0.76	0.69	0.63	584	531	484	584	1062	1452
300 mm2	886	0.74	0.68	0.62	656	602	549	656	1204	1647
400 mm2	1065	0.73	0.66	0.6	777	703	639	777	1406	1917
500 mm2	1228	0.72	0.64	0.58	884	786	712	884	1572	2136
630 mm2	1423	0.71	0.63	0.57	1010	896	811	1010	1792	2433
800 mm2	1581	0.7*	0.62*	0.56*	1107	980	885	1107	1960	2655
1000 mm2	1775	0.69*	0.61*	0.55*	1225	1083	976	1225	2166	2928

* Values for cables over 630 mm2 extrapolated from table 4B3 of the current edition of BS7671

Table 3.2.1.4.E										
Four Core Copper 70^{O}C Thermoplastic (PVC) Table 4D4A of BS7671										
STEEL WIRE ARMOURED and EARTHED at BOTH ENDS										
Size	**Table 4D4A Rating Amps**	**Table 4B3 correction factor for cables in covered trenches (methods 18 & 19)**			**Current rating per core Amps**			**Total Capacity Amps**		
	Method 13 Horizontal flat spaced column 5	2 cables in parallel column 4	3 cables in parallel column 5	4 cables in parallel column 7	2 cables	3 cables	4 cables	2 cables	3 cables	4 cables
120 mm^2	290	0.75	0.69	0.68	218	200	197	435	600	789
150 mm^2	332	0.74	0.67	0.67	246	222	222	491	667	890
185 mm^2	378	0.73	0.65	0.65	276	246	246	552	737	983
240 mm^2	445	0.71	0.63	0.63	316	280	280	632	841	1121
300 mm^2	510	0.69	0.62	0.62	352	316	316	704	949	1265

400 mm^2	590	0.67	0.59	0.6	395	348	354	791	1044	1416

Table 3.2.1.4.F

Four Core Copper 90^{O}C Thermosetting (XLPE) Table 4E4A of BS7671

STEEL WIRE ARMOURED and EARTHED at BOTH ENDS

Size	Table 4E4A Rating Amps	Table 4B3 correction factor for cables in covered trenches (methods 18 & 19)			Current rating per core Amps			Total Capacity Amps		
	Method 13 Horizontal flat spaced column 5	2 cables in parallel column 4	3 cables in parallel column 5	4 cables in parallel column 7	2 cables	3 cables	4 cables	2 cables	3 cables	4 cables
120 mm^2	353	0.75	0.69	0.68	265	244	240	530	731	960
150 mm^2	406	0.74	0.67	0.67	300	272	272	601	816	1088
185 mm^2	463	0.73	0.65	0.65	338	301	301	676	903	1204
240 mm^2	546	0.71	0.63	0.63	388	344	344	775	1032	1376
300 mm^2	628	0.69	0.62	0.62	433	389	389	867	1168	1557
400 mm^2	728	0.67	0.59	0.6	488	430	437	976	1289	1747

3.2.1.5 LV Underground Cable Data Tables

Size mm^2	Application	New build size	Resistance Phase R W / km	Resistance Neutral R W / km	Reactance Phase jX W / km	Reactance Neutral jX W / km	Continuous Rating (Summer) Laid Direct AMPS	Continuous Rating (Summer) Ducted AMPS
4 mm^2cu	Street Lighting		4.52	4.8	0.054		53	44
25 mm^2 Hybrid	Street Lighting	✓	1.180	1.240	0.043		115	94
35 mm^2Hybrid	1 Ø service	✓	0.851	0.900	0.041		140	115
35 mm^2 HCN	3 Ø service	✓	0.939	0.939	0.076	0.015	132	106
35 mm^2 Wavecon	3 Ø service	✓	0.939	0.939	0.076	0.015	132	106
95 mm^2 Wavecon	Main/Service	✓	0.320	0.320	0.075	0.016	245	201
185 mm^2 Wavecon	Main/Service	✓	0.164	0.164	0.074	0.014	355	292
300 mm^2 Wavecon	Main/Service	✓	0.100	0.164	0.073	0.011	470	382
600 mm^2XLPE single core	Transformer Tails	✓	0.0515	0.2	0.088	0.088	See Cables Cable Laying & Accessories Manual section 2.1.3	
35 mm^2 Alpex	3 Ø service		0.939	0.939	0.076	0.015	132	106
70 mm^2Alpex	Main/Service		0.443	0.443	0.076	0.015	196	159
120 mm^2Alpex	Main/Service		0.253	0.253	0.073	0.015	265	223
185 mm^2Alpex	Main/Service		0.164	0.164	0.074	0.014	355	292
300 mm^2Alpex	Main/Service		0.100	0.164	0.073	0.011	470	382
Consac – Paper Insulated Aluminium Sheathed						*based on Alpex*		
70 mm^2 Consac	Main/Service		0.433	0.433	0.061	*0.015*	185	150
95 mm^2 Consac	Main/Service		0.320	0.320	0.069	*0.015*	220	180
120 mm^2 Consac	Main/Service		0.253	0.253	0.069	*0.015*	250	210
150 mm^2 Consac	Main/Service		0.206	0.206	0.068	*0.015*	280	235
185 mm^2 Consac	Main/Service		0.165	0.165	0.068	*0.014*	320	265
240 mm^2 Consac	Main/Service		0.125	0.125	0.068	*0.014*	370	310
300 mm^2 Consac	Main/Service		0.100	0.100	0.068	*0.014*	420	350
PILC - Paper Insulated Lead Covered								
4/35 mm^2al	Main/Service		0.868	0.868	0.075	0.075	125	105
4/95 mm^2al	Main/Service		0.320	0.320	0.070	0.070	225	185
4/185 mm^2al	Main/Service		0.164	0.164	0.068	0.068	330	275
4/300 mm^2al	Main/Service		0.100	0.164	0.067	0.067	430	360
0.1 in^2 al	Main/Service		0.456	0.456	0.073	0.073	185	150
0.15 in^2 al	Main/Service		0.312	0.312	0.070	0.070	225	185
0.2 in^2 al	Main/Service		0.234	0.234	0.069	0.069	270	220
0.25 in^2 al	Main/Service		0.187	0.187	0.069	0.069	310	255
0.3 in^2 al	Main/Service		0.152	0.152	0.068	0.068	350	290
0.5 in^2 al	Main/Service		0.092	0.092	0.067	0.067	450	375
0.0225 in^2 cu	Main/Service		1.258	1.258	0.086	0.086	100	83
0.04 in^2 cu	Main/Service		0.703	0.703	0.079	0.079	140	115
0.06 in^2 cu	Main/Service		0.463	0.463	0.076	0.076	175	140
0.1 in^2 cu	Main/Service		0.276	0.276	0.073	0.073	240	195
0.15 in^2 cu	Main/Service		0.188	0.188	0.070	0.070	290	240
0.2 in^2 cu	Main/Service		0.142	0.142	0.069	0.069	345	285
0.25 in^2 cu	Main/Service		0.113	0.113	0.069	0.069	395	325
0.3 in^2 cu	Main/Service		0.092	0.092	0.068	0.068	445	385
0.4 in^2 cu	Main/Service		0.068	0.068	0.068	0.068	520	430

Resistance values are DC at 20^{0}C	Maximum Conductor temperature:- - Wavecon & Alpex 90^{0}C (XLPE) - Hybrid 70^{0}C (PVC) - PILC and Consac 80^{0}C	Depth of lay 0.45m Ground temperature 15 ^{0}C (Summer) Soil thermal resistivity 1.2 ^{0}C m/w (Summer)

3.2.2 LV Overhead Lines

3.2.2.1 Main and Service Lines

Aerial Bundled Conductor (ABC) to ENATS 43-12,13 &14

As detailed in Central Networks Overhead Line Manual Section 6

Size / Type	Use
2 x 35 mm^2 ABC	1 phase services up to 100 Amps
4 x 35 mm^2 ABC	3 phase services 100 Amps
4 x 95 mm^2 ABC	3 phase services up to 135kVA LV mains up to 228 Amps

3.2.2.2 Pole Transformer Tails

Aerial Bundled Conductor (ABC) to ENATS 43-12,13 &14

As detailed in Central Networks Overhead Line Manual Section 6

Stranded copper core, red PVC insulated, brown PVC sheathed to Basec ref 61817 and BS 6004

Size / Type	Use
2 x 95 mm^2 ABC (cores 2 & 3 left disconnected)	1 phase Pole Transformers up to 50 kVA
4 x 95 mm^2 ABC <u>or</u> 4 x 70 mm^2 Cu PVC/PVC	3 phase Pole Transformers up to 100 kVA
4 x 120 mm^2 Cu PVC/PVC	3 phase Pole Transformers 200 kVA
7 x 120 mm^2 Cu PVC/PVC	3 phase Pole Transformers 315 kVA – 2 way LV fuse cabinet

3.2.2.3 LV Overhead Line Data Tables

Size	Application	New build size	Resistance		Reactance		Continuous Rating	
			Phase R W /km	Neutral R W /km	Phase jX W /km	Neutral jX W /km	AMPS	AMPS
Aerial Bundled Conductor							**Pole Top**	**Under-eaves**
2/25 ABC	1 Ø service		1.200	1.200	0.086	0.086	119	109
2/35 ABC	1 Ø service	✓	0.868	0.868	0.086	0.086	144	133
4/35 ABC	3 Ø service	✓	0.868	0.868	0.086	0.086	120	114
4/50 ABC			0.641	0.641	0.083	0.083	144	140
4/70 ABC			0.443	0.443	0.080	0.080	180	-
4/95 ABC	Main	✓	0.320	0.320	0.077	0.077	228	191
4/120 ABC			0.253	0.253	0.075	0.075	300	270
Cu PVC/PVC Pole Transformer Tails						**Cleated to pole *** * Table 4D1A BS 7671 column 11		
70 mm²	Trans tails	✓	0.268	0.268	-	-	254	-
120 mm²	Trans tails	✓	0.153	0.153	-	-	382	-
185 mm²	Trans tails				-	-	480	-
240 mm²	Trans tails				-	-	569	-
Open wire – metric sizes							**Winter**	**Summer**
50 HDA 4w			0.542	0.542	0.297	0.297	185	154
100 HDA 4w			0.270	0.270	0.276	0.276	288	240
Open wire – imperial sizes								
0.025 cu 4w	= 16mm²		1.083	1.083	0.347	0.347	122	102
0.04 cu 4w	= 25mm²		0.681	0.681	0.305	0.305	162	135
0.05 cu 4w	= 32mm²		0.541	0.541	*0.297*	*0.297*	190	159
0.06 cu 4w	= 38mm²		0.439	0.439	0.293	0.293	220	184
0.1 cu 4w	= 64mm²		0.272	0.272	0.289	0.289	283	236
0.15 cu 4w	= 96mm²		0.183	0.183	0.278	0.278	363	303
Open wire – SWG sizes								
No 6 cu	= 0.03 in² or 18mm²		*0.975*	*0.975*	*0.337*	*0.337*	*129*	*103*
No 5 cu	= 0.035 in² or 22mm²		*0.800*	*0.800*	*0.319*	*0.319*	*148*	*118*
No 4 cu	= 0.04 in² or 27mm²		*0.640*	*0.640*	*0.303*	*0.303*	*167*	*133*
No 3 cu	= 0.05 in² or 32mm²		*0.540*	*0.540*	*0.297*	*0.297*	*185*	*148*
No 2 cu	= 0.06 in² or 38mm²		*0.439*	*0.439*	*0.293*	*0.293*	*209*	*167*
No 1 cu	= 0.071 in² or 45mm²		*0.390*	*0.390*	*0.292*	*0.292*	*233*	*186*
1/0 cu	= 0.082 in² or 53mm²		*0.360*	*0.360*	*0.291*	*0.291*	*258*	*206*
2/0 cu	= 0.095 in² or 61mm²		*0.286*	*0.286*	*0.290*	*0.290*	*283*	*226*
3/0 cu	= 0.109 in² or 70mm²		*0.250*	*0.250*	*0.288*	*0.288*	*309*	*247*

Resistance values are DC at 20 °C

ABC ratings are based on ERA Report 90/0386 July 1990
Maximum conductor temperature 75 °C
Ambient temperature 25 °C
Wind speed 0.5m/s
Solar radiation 1kW/m²

ABC ratings are based on ERA Report 90/0386 July 1990
Maximum conductor temperature 75 °C
Ambient temperature 25 °C
Wind speed 0.5m/s
Solar radiation 1kW/m²

Open wire ratings are based on;
Maximum conductor temperature 50 °C
Ambient temperature 20 °C Summer, 5 °C Winter

Data shown in italics for Open Wire SWG sizes has been extrapolated from Open Wire Imperial Size data.

3.2.3 LV Switchgear

3.2.3.1 Service Cut-outs

LV service cut-outs shall be as detailed in the Central Networks ant Specification Manual Section 3G.

Street lighting cut-outs shall be to BS 7654.

Single and three phase cut-outs (up to 100A) shall be to BS 7657.

Three phase cut-outs shall accept BS 88 part 5 fuses

Size / Type	**Use**
1 phase 25 amp to BS 7654:1997 (A1)	Street lamp services plus loop to other street lamps
1 phase 100 amp to BS 7657 (B2A)	1 phase services up to 100 amps plus loop to second domestic property
3 phase 100 amp to BS 7657 (B3)	3 phase services 100 amps (loop to second cut-out forbidden)
3 phase 400 amp (D1)	3 phase services 400 amps for aluminium CNE cables up to 185mm^2 (loop to second cut-out forbidden)
3 phase 600 amp (D2)	3 phase services 600 amps for aluminium CNE cables up to 300mm^2 (loop to second cut-out forbidden)

3.2.3.2 LV Distribution Cabinets

LV fuse cabinets / pillars and metering/protection cubicles free-standing or transformer mounted shall be in accordance with ENATS 37-2 Issue 3 and as detailed in the Central Networks Plant Specification Manual Section 3G.

Size / Type Figures in brackets refer to Plant Specification Manual	**Use**
600 Amp 1phase Fuse carrier (E1)	
300 Amp 1 phase Fuse carrier (E2)	Single phase 50 kVA padmount transformer
400 Amp 2 way (3.6) incl: 1 x 400 Amp transformer links 2 x 400 Amp outgoing feeder ways 1 x 400 Amp generator connection	Three phase 100 kVA & 200 kVA padmount transformer
500 Amp 2 way (3.1) incl: 1 x 500 Amp transformer links 2 x 500 Amp outgoing feeder ways 3 x incoming CTs & MDIs	200 kVA transformer • LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 225 kVA
800 Amp 4 way (3.3) incl: 1 x 800 Amp transformer links 4 x 630 Amp outgoing feeder ways 3 x incoming CTs & MDIs	315 kVA transformer • LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 300 kVA
1600 Amp 4 way (3.4) incl: 1 x 1600 Amp transformer links 4 x 630 Amp outgoing feeder ways 3 x incoming CTs & MDIs	500 kVA transformer • LV Network supplying mixed loads • Single or double direct services for industrial / commercial loads up to 600 kVA
1600 Amp 5way(3.5) incl: 1 x 1600 Amp transformer links 5 x 630 Amp outgoing feeder ways 3 x incoming CTs & MDIs	800 or 1000 kVA transformer • LV Network supplying mixed loads • Single or double direct services for industrial / commercial loads up to 600 kVA
800 Amp ACB cabinet (6.4) incl: 1 x 800 Amp transformer links 1 x 800 Amp Air Circuit Breaker 1 x 630 Amp outgoing feeder ways 3 x incoming 800/5A CTs & MDIs 1 x Micrologic Trip Unit	500 KVA transformer 250 to 500 kVA LV metered supply to single customer from plus feed out onto local LV network
1250 Amp ACB cabinet (6.5) incl: 1 x 1250 Amp transformer links 1 x 1250 Amp Air Circuit Breaker 1 x 500 Amp outgoing feeder ways 3 x incoming 1200/5A CTs & MDIs 1 x Micrologic Trip Unit	800 KVA transformer 501 to 800 kVA LV metered supply to single customer plus feed out onto local LV network
1600 Amp ACB cabinet (6.6) incl: 1 x 1600 Amp transformer links 1 x 1600 Amp Air Circuit Breaker 1 x 630 Amp outgoing feeder ways 3 x incoming 1600/5A CTs & MDIs 1 x Micrologic Trip Unit	1000 KVA transformer 801 to 1000 kVA LV metered supply to single customer plus feed out onto local LV network
2500 Amp ACB cabinet (6.7) incl: 1 x 2500 Amp transformer links 1 x 2500 Amp Air Circuit Breaker 1 x 630 Amp outgoing feeder ways 3 x incoming 2500/5A CTs & MDIs 1 x Micrologic Trip Unit	1500 KVA transformer *DISCONTINUED* 1001 to 1500 kVA LV metered supply to single customer plus feed out onto local LV network

3.2.3.3 Underground Network Boxes

See Plant Specification Manual

LV 2 Way Underground Link Box.	Inter-connectors between substations for back-feeding purposes. Sub fusing point for network extensions where earth loop impedance is high.
LV 4 Way Underground Link Box.	Inter-connectors between substations for back-feeding purposes. Where economical use over multiple 2-way link boxes can be justified.

3.2.3.4 Pole Mounted LV Switchgear

Single pole LV fuse units for mounting on wood poles shall be to BS7656 and shall accept BS 88 part 5 fuses with 88mm centres as detailed in the Central Networks Plant Specification manual Section 3G.

Three pole ABC Network switches and ABC Service Box shall be as detailed in the Central Networks Overhead Line Manual Vol 1 Section 6

Size / Type Figures in brackets refer to Plant Specification and O/H Line Manuals	**Use**
1ph 400 amp to BS7656 and suitable for BS88 fuse links with 82mm centres. Item (F1) in Plant Specification Manual	• Controlling LV circuits supplied from pole transformers • Open points on lines rated above 245 Amps
250 Amp ABC Network Switch with size NH00 245 amp links (Item LV220 in Overhead Line Manual Vol 1)	• Reconnecting ABC circuits on-load after temporary disconnection • Open points on ABC lines.
ABC Service Box (Item LV221 in Overhead Line Manual Vol 1)	• Connecting from 4 to 12 services at a single pole • Wall box to transitions from 35 CNE to ABC or Hybrid under-eaves services.

3.3 Secondary Network 11kV Ratings and Data

3.3.1 11kV Cables

3.3.1.1 11 kV Network Cables

11kV Triplex: Solid circular aluminium conductor (SAC), Cross Linked Polyethylene (XLPE) insulation, copper wire screen, red MDPE over-sheath, three single cores laid up in trefoil formation to specification BS7870 Part 4.10:1999 & IEC 502 as detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.2

The standard sizes to be used in Central Networks are:

- 70 mm^2 aluminium XLPE Triplex , 25mm^2 wire screen (East)
- 95 mm^2 aluminium XLPE Triplex , 35mm^2 wire screen (West)
- 185 mm^2 aluminium XLPE Triplex , 35mm^2 wire screen
- 300 mm^2 aluminium XLPE Triplex , 35mm^2 wire screen

The following sizes are used for special applications :

- 300 mm^2 copper XLPE Triplex , 35mm^2 wire screen
- 400 mm^2 copper XLPE Triplex , 35mm^2 wire screen

For applications refer to Section 1.4.4.1

3.3.1.2 Transformer 11kV Tails

Single core, circular stranded copper conductor, extruded conductor screen, XLPE insulation, helical copper wire screen (35mm^2), red MDPE oversheath 6350/11000v cable to BS 7870-4.10:1999 as detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.2.

The standard sizes to be used in Central Networks are:

- 400 mm^2 copper XLPE single core , 35mm^2 wire screen
- 630 mm^2 copper XLPE single core , 35mm^2 wire screen

Transformer Nameplate Rating		CER Winter		CER Summer		Tails per phase	Current per core	
		MVA	Amps	MVA	Amps		Winter	Summer
4/8 MVA	11kV	8	420	6.5	341	1 x 400 mm^2	420	341
6/12 MVA	11kV	12	628	9.5	498	1 x 400 mm^2	628	498
12/24 MVA	11kV	24	1257	19	996	2 x 400 mm^2	628	498
20/40 MVA	11kV	40	2096	32	1676	3 x 630 mm^2	698	558
6/12 MVA	6.6kV	12	1044	9.5	826	2 x 400 mm^2	522	413
12/24 MVA	6.6kV	24	2088	19	1653	3 x 630 mm^2	696	551
20/40 MVA	6.6kV	40	3580	32	2784	Special design requires 3500 amp s/gear		

These combinations of cable are based on the Sustained Ratings of the cables installed to the configurations shown in Table 3.3.1.5 G employing single point screen bonding.

The winter and summer ratings of the cables match or exceed the respective winter and summer Certified Emergency Ratings of the transformers. Other configurations may not provide the full transformer rating – consult the Assets Manager if site conditions prevent these configurations from being used.

3.3.1.3 Cable Rating Criteria

Current ratings of 11kV cables are determined from Engineering Recommendation P17 'Current Ratings Guide for Distribution Cables'

Three types of rating are employed in Central Networks:

- 5 Day Distribution Rating (5 day cyclic rating)
- Cyclic (Continuous) rating
- Sustained (Continuous) rating

Paper Insulated Cables

The ratings for paper insulated cables are based on the tables contained in Engineering Recommendation P17 parts 1 & 2.

Central Networks East has traditionally used belted cables for which P17 prescribes a maximum conductor temperature of 65^{0}C.

Central Networks West has traditionally used screened cables for which P17 prescribes a maximum conductor temperature of 70^{0}C.

XLPE Insulated Cables

The ratings for XLPE cables have been calculated using the 'CRATER' spreadsheet developed by EA Technology Ltd. Version 1.0 Feb 2004. This tool uses Engineering Recommendation P17 Part 3 calculation criteria but some results differ slightly from the P17 tables. Explanations are provided in the 'CRATER' user manual.

P17 prescribes a maximum conductor temperature of 90^{0}C for XLPE cables. This value is applied to Central Networks East & West.

'CRATER' is capable of calculating a wider range of installation circumstances than can be contained in tables. e.g. various laid direct and duct configurations, multiple circuits, spacing, soil types etc.

Some common multiple cable configurations have been included in the tables. However, where large multiple runs are being designed, e.g. congested exits from Primary Substations, the Equipment Specialists in Asset Standards will be able to provide guidance using 'CRATER'.

Duct type - important note.

The ratings that 'CRATER' calculates for cables installed in corrugated polyethylene duct (e.g. Ridgiduct) are significantly lower than for smooth wall ducts. EATL STP Project S0389 Report No 5617 identified that trapped air in the closed sections of the corrugations insulates 65% of the effective duct length. The report calculated that the overall thermal resistivity of corrugated polyethylene duct varies from 4.3 to 13.2 ^{0}Cm/W depending on whether the outside corrugations are filled with soil or air. 'CRATER' applies an average value of 8.7 ^{0}Cm/W when 'Ridgiduct' is selected.

Appendix D of Report 5617 details the method of calculating the thermal resistivity of Ridgiduct. The figure of 4.3 ^{0}Cm/W was calculated assuming soils with a resistivity of 1.2 ^{0}Cm/W (as used in summer calculations). Re-calculating using the winter soil thermal resistivity of 0.9 ^{0}Cm/W lowers the overall thermal resistivity of 3.7 ^{0}Cm/W. This compares with 1.2 ^{0}Cm/W for earthenware ducts, 2.5 ^{0}Cm/W for polyethylene ducts and 5.0 ^{0}Cm/W for PVC ducts. For the purpose of Central Networks cables ratings it is assumed that the outer corrugations will fill with fine soil or silt after laying and a thermal resistivity of less than 5.0 ^{0}Cm/W will be attained in practice. Therefore the ducted cable ratings in this Manual have been calculated in 'CRATER' by selecting PVC duct 126.3mm I/D 134.6mm O/D to represent Ridgiduct. For this assumption to remain valid it is essential that Ridgiduct are bedded in material that contains elements small enough to fill the corrugations. The Central Networks Cable, Cable Laying an Accessories Manual provides guidance on backfill materials.

5 Day Distribution Rating

This is a cyclic rating that assumes the cable forms part of an open ring on a Primary Substation or an interconnector between Primaries feeding average domestic, small industrial and commercial loads in average environmental conditions.

The cable is normally carrying only 50% of the load prior to being required to supply the second half of the ring in an emergency, such as a cable fault.

The rating can also be based on the cable carrying 75% of the load prior to an emergency. This has been employed in certain urban networks where 4 circuits have been arranged such that 3 healthy circuits can each pick up 25% of the load of a faulted circuit by multiple switching operations. New circuits or existing circuits presently operating at 50% utilisation shall not be run at 75% utilisation without approval of the Network Manager.

The 5 Day Distribution Rating tables for XLPE cables have 50% and 75% utilisation ratings. Tables are provided for

- Un-grouped cables – single cable without the possibility of being heated by an adjacent cable on the same ring main.
- Group of 2 cables – this assumes two cables of a ring main in the same trench connected to a distribution substation. During emergency feeding both cables run to their 5 Day Distribution rating to supply the rest of the ring.
- Multiple groups of cable - this assumes the entire group normally runs to 50% utilisation. During emergency feeding one of the group runs to its 5 Day Distribution rating.

Distribution Ratings depend on the load being cyclic in nature so that heating during periods of high load is followed by periods of cooling during low load. For calculation purposes the shape of the load curve is express as a value called Load Loss Factor. The Distribution Ratings in P17 are based on 'Load

Curve G' (Loss Load Factor =5.061) which is shown later in this section together with the method of calculation the Loss Load Factor for actual load curves.

Cyclic Ratings

These are similar to the 5 day Distribution ratings but assume that the loading condition is maintained indefinitely and so take into account long term heating of the soil. The Cyclic ratings published are based on Engineering Recommendation P17 – 'Load Curve G' (Loss Load Factor = 5.061). They are not suitable for industrial and large commercial loads unless adjusted to reflect the actual Loss Load Factor. Refer to the Assets Manager for further information.

Cyclic ratings are applicable to ring mains supplying average domestic, small industrial and commercial loads in average environmental conditions where anticipated repair times are in excess of 5 days.

Sustained Ratings

Cables supplying only industrial and large commercial loads, where loads close to maximum demand are sustained for long periods, do not benefit form periodic cooling during light load periods.

Sustained Ratings, corrected for ambient ground temperature, are therefore appropriate for these loads. Summer ratings will normally be used unless there is firm evidence of seasonal load variation. Note that commercial summer loads are often equal to or higher than winter loads due to air conditioning.

Sustained Ratings are used for the secondary tails of 132/11kV & 33/11kV transformers which can be called upon to carry their Certified Emergency Rating for periods greater than 5 days.

As transformer tails are often used in combinations of 2 or 3 per phase for great care has to be used during installation to ensure that the correct grouping/spacing is used to ensure that the Certified Emergency Rating of the transformer is achievable and not limited by the 11kV cables.

Section 3.3.1.2 11kV Transformer Tails – states the combinations and sizes to be used for each transformer size. These are based on the ratings of the cables installed to the configurations shown in Table 3.3.1.5F employing single point screen bonding.

The Loss Load Factor for Sustained Ratings is 1.0 and the Utilisation Factor is 100%.

Ratings used in GIS

The 11kV cable ratings used in the Central Networks Graphical Information Systems (GIS) system diagrams are based on:

Central Networks East:

- Cyclic Rating, Group of 2, Winter, Table 3.3.1.5 B
- 5 day Distribution Rating 50% utilisation, Group of 2 Winter Table 3.3.1.4 B
- Sustained Rating, Ungrouped, Summer, Table 3.3.1.5 A

Both laid direct and ducted ratings used.

The Central Networks East 11kV System Diagram displays cable rating in the following format:

334 (368) = Cyclic rating (5 day distribution rating)

[309 (309)] = Sustained Summer rating – Note the square brackets denote a contrained cable rating.

Caution - XLPE cable to Paper cable joints

Caution should be exercised when using XLPE cable in existing paper insulated networks. The rating of paper insulated cable is based on a conductor temperature of 70^{0}Cfor screen cables and 65^{0}C for belted cables. For XLPE it is based on 90^{0}C.

For example: On the face of it 185 mm^2 XPLE in a duct has the same rating to a 185 mm^2 belted PICAS laid direct.

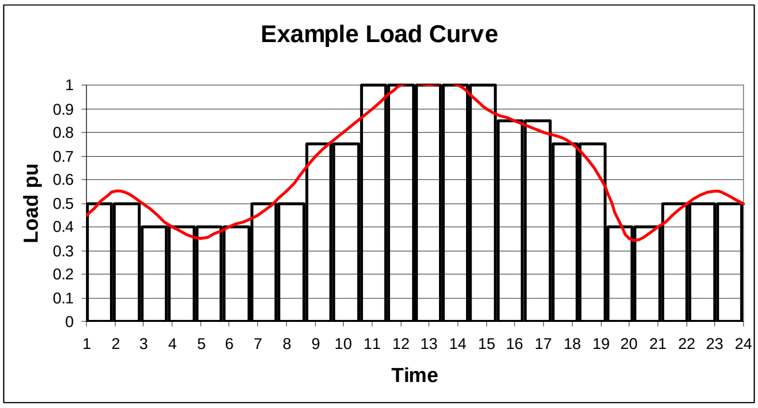
However, at a joint between the ducted XLPE cable and the lid direct PICAS cable 90^{0}C conductor temperature of the XLPE cable core would transfer through the joint and overheat the PICAS cable, possibly resulting in joint failure.

To avoid this the XLPE cable must be laid direct for a distance of one metre before jointing to a paper insulated cable to allow the core temperature to drop to 65^{0}C.

Calculation of Loss Load Factor

An approximate value of Loss Load Factor can be calculated by the following method:

- Draw an the actual load curve under consideration making maximum demand equal to 1 and other levels in proportion.
- Approximate this to a series of rectangles with height representing an average proportion of the maximum demand over a period and width representing the length of that period.



The Loss Load Factor

= Sum of the square of the per unit loads x durations divided by 24 hours

= $(0.5^2 \text{ x}(2+2+3) + 0.4^2 \text{ x}(4+2) + 0.75^2 \text{ x}(2+2) + 1^2 \text{ x}(5) + 0.85^2 \text{ x}(2)) \div 24$

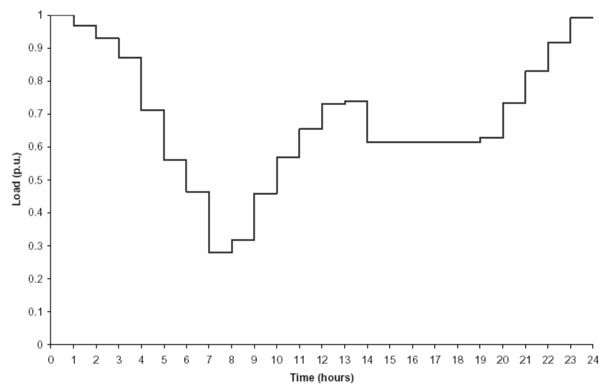
= (0.25x7 + 0.16x6 + 0.5625x4 + 1x5 + 0.7225x2) ÷ 24

= (1.75 + 0.96 + 2.25 + 5 + 1.445) ÷ 24 = 11.405 ÷ 24

= 0.475

Load Curve G

This is the standard load curve that was used to generate the cyclic and distribution ratings given in P17, Parts 1, 2 and 3. The loss load factor for this curve is 0.5061.



Load Curve G gives a Loss Load Factor of 0.5061 and this is assumed in the 5 Day Distribution rating in this Manual.

3.3.1.4 11kV Cable 5 day Distribution Rating Tables

5 day Distribution limited time current ratings for 11kv cables in open rings across a primary or interconnector between primaries.

- Values for normal domestic/small commercial loads and average environmental conditions
- Ambient ground temperature 10°C Winter, 15°C Summer.
- Soil thermal resistivity 0.9 °C m/W Winter, 1.2 °C m/W Summer.
- Soil Thermal Diffusivity of $5 \times 10^{-7} \times (g/0.9)\ m^2/s$ where g is the soil thermal resistivity in ^{0}Cm/W
- Loss Load Factor 0.5 Load Curve G
- Maximum conductor temperature of
  - 65^{0}C for belted paper insulation (Central Networks East)
  - 70^{0}C for screened paper insulation (Central Networks West)
  - 90^{0}C for XLPE insulation. (Central Networks East & West)
- Depth of 600mm to the top of the cable or duct
- No account taken of soil drying out. (Not applicable to Distribution ratings)
- Where 'Off Peak' loads predominate a correction factor of 0.97 should be applied.
- The 5 day Distribution limited time rating can be applied for the duration of an emergency lasting not more than 5 days assuming cable carrying only 50% of load before the emergency. (or 75% in the table for 75% utilisation)
- Duct sections less than 15m long can be assumed to be laid direct.

The following 5 Day Distribution Ratings tables are provided:

Table 3.3.1.4 A	11kV XLPE Cables - Ungrouped - 5 Day Distribution Rating - 50% & 75% Utilisation
Table 3.3.1.4 B	11kV XLPE Cables – Group of 2 - 5 Day Distribution Rating - 50% & 75% Utilisation
Table 3.3.1.4 C	11kV XLPE Cable - Multiple Groups - 5 Day Distribution Rating - 50% & 75% Utilisation
Table 3.3.1.4 D	11kV Belted Paper Cables – 5 Day Distribution Rating - 50% & 75% Utilisation Ungrouped - Metric sizes
Table 3.3.1.4 E	11kV Belted Paper Cables – 5 Day Distribution Rating - 50% & 75% Utilisation Ungrouped - Imperial sizes
Table 3.3.1.4 F	11kV Screened Paper Cables – 5 Day Distribution Rating - 50% & 75% Utilisation Ungrouped - Metric sizes
Table 3.3.1.4 G	11kV Screened Paper Cables – 5 Day Distribution Rating - 50% & 75% Utilisation Ungrouped - Imperial sizes
Table 3.3.1.4 H	De-rating factors for Grouped Paper Cables

Table 3.3.1.4 A		**Central Networks East & West**							
11kV XLPE Cables – **Ungrouped - 5 Day Distribution Rating**									
CABLE		**WINTER Amps**				**SUMMER Amps**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**
70 mm^2	Al Triplex	292	284	216	213	260	253	208	205
95 mm^2	Al Triplex	346	337	257	253	309	300	247	243
150 mm^2	Al Triplex	445	433	330	325	396	385	317	312
185 mm^2	Al Triplex	507	494	376	370	451	439	360	355
240 mm^2	Al Triplex	592	576	439	432	525	511	420	413
300 mm^2	Al Triplex	672	654	499	492	595	579	476	469
300 mm^2	Cu Triplex	866	842	642	632	766	745	612	602
400 mm^2	Cu Triplex	989	962	818	796	873	850	766	746
95 mm^2	Al 3-Core	310	305	239	236	283	278	231	228
185 mm^2	Al 3-Core	457	450	353	348	342	409	339	335
300 mm^2	Al 3-Core	613	603	473	467	556	547	454	448
300 mm^2	Cu 3-Core	792	780	616	608	718	707	590	583

The above ratings have been calculated on 'Crater V3.0 Oct 2004'

Assumptions:

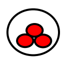
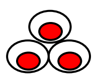
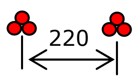
- Max 90^{O}C conductor temp
- Winter - soil temp 10^{O}C , Thermal resistivity 0.9 m ^{O}C/W
- Summer - soil temp 15^{O}C , Thermal resistivity 1.2 m ^{O}C/W
- Screens bonded at both ends
- Laid 600mm deep to top of cable / duct
- 1 cable laid in the trench.
- Laid direct 
- 125 mm duct up to 300mm^2 
- 3 x 125 mm duct for 400mm^2 

Table 3.3.1.4 B									**Central Networks East & West**
11kV XLPE Cables – **Group of 2 - 5 Day Distribution Rating**									
CABLE		**WINTER Amps**				**SUMMER Amps**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**
70 mm²	Al Triplex	283	267	211	203	250	238	202	193
95 mm²	Al Triplex	335	316	251	241	296	281	239	228
150 mm²	Al Triplex	430	404	323	308	379	358	307	292
185 mm²	Al Triplex	489	459	368	350	430	406	349	331
240 mm²	Al Triplex	570	534	430	407	500	472	407	384
300 mm²	Al Triplex	646	605	489	462	566	534	462	435
300 mm²	Cu Triplex	832	779	629	595	728	686	593	559
400 mm²	Cu Triplex	949	887	796	750	828	780	739	696
95 mm²	Al 3-Core	300	286	235	228	271	260	225	218
185 mm²	Al 3-Core	442	418	346	333	399	379	331	317
300 mm²	Al 3-Core	593	558	464	445	533	504	442	422
300 mm²	Cu 3-Core	767	721	604	580	689	651	574	549

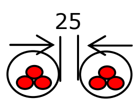
The above ratings have been calculated on 'Crater V3.0 Oct 2004'

Assumptions:

- Max 90^{o}C conductor temp
- Winter - soil temp 10^{o}C , Thermal resistivity 0.9 m ^{o}C/W
- Summer - soil temp 15^{o}C , Thermal resistivity 1.2 m ^{o}C/W
- Screens bonded at both ends
- Laid 600mm deep to top of cable / duct
- 2 cables laid in the trench.
- Laid direct



- 125 mm duct up to 300mm²



- 3 x 125 mm duct for 400mm²

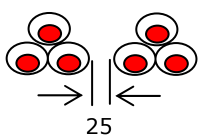
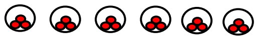
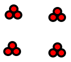
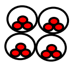
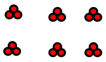
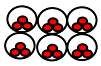
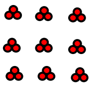
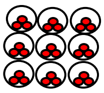
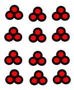
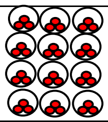


Table 3.3.1.4 C	**Central Networks East & West**

11kV XLPE Cable - **Multiple Groups - 5 Day Distribution Rating**						
			Winter amps		**Summer amps**	
Formation	**Utilisation**		**50%**	**75%**	**50%**	**75%**
	Size	**Type**				
 6 circuits	185 mm^2	Al Triplex	443	352	383	309
	300 mm^2	Al Triplex	582	457	500	401
	300 mm^2	Cu Triplex	749	589	643	515
	400 mm^2	Cu Triplex	852	667	730	582
 6 circuits	185 mm^2	Al Triplex	342	284	323	263
	300 mm^2	Al Triplex	454	369	427	341
	300 mm^2	Cu Triplex	584	475	549	438
	400 mm^2	Cu Triplex	736	582	671	531
 4 circuits	185 mm^2	Al Triplex	461	379	393	328
	300 mm^2	Al Triplex	605	493	514	426
	300 mm^2	Cu Triplex	767	626	661	548
	400 mm^2	Cu Triplex	873	709	751	620
 4 circuits	185 mm^2	Al Triplex	350	304	331	283
	300 mm^2	Al Triplex	465	398	438	370
	300 mm^2	Cu Triplex	598	512	562	475
	400 mm^2	Cu Triplex	745	612	683	561
 6 circuits	185 mm^2	Al Triplex	434	328	374	288
	300 mm^2	Al Triplex	569	425	489	372
	300 mm^2	Cu Triplex	733	548	628	479
	400 mm^2	Cu Triplex	833	619	712	540
 6 circuits	185 mm^2	Al Triplex	340	271	319	250
	300 mm^2	Al Triplex	451	352	421	324
	300 mm^2	Cu Triplex	580	453	541	417
	400 mm^2	Cu Triplex	721	543	655	494
 9 circuits	185 mm^2	Al Triplex	411	328	352	249
	300 mm^2	Al Triplex	538	368	459	321
	300 mm^2	Cu Triplex	692	474	590	413
	400 mm^2	Cu Triplex	786	535	668	466
 9 circuits	185 mm^2	Al Triplex	326	241	304	221
	300 mm^2	Al Triplex	433	311	401	285
	300 mm^2	Cu Triplex	557	400	515	366
	400 mm^2	Cu Triplex	686	472	621	428
 12 circuits	185 mm^2	Al Triplex	396	256	338	224
	300 mm^2	Al Triplex	517	330	440	288
	300 mm^2	Cu Triplex	665	425	565	370
	400 mm^2	Cu Triplex	755	479	640	416
 12 circuits	185 mm^2	Al Triplex	322	224	292	201
	300 mm^2	Al Triplex	426	289	387	259
	300 mm^2	Cu Triplex	540	366	497	332
	400 mm^2	Cu Triplex	660	420	595	378

- Laid Direct - 150mm spacing between cables
- 125 mm ducts touching
- Laid 600mm deep to top of cable / duct
- Max 90OC conductor temp
- For other combinations contact the Assets Manager

Table 3.3.1.4 D									**Central Networks East**
11kV Belted Paper Cables – **5 Day Distribution Rating** **Ungrouped** - Metric sizes - Max 65^{O}C conductor temp									
CABLE		**WINTER Amps**				**SUMMER Amps**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**
95 mm^2	Al PICAS	245	239	190	185	220	214	178	174
185 mm^2	AL PICAS	370	360	290	282	329	320	272	265
240 mm^2	Cu PICAS	545*	531	436*	425	485*	473	409*	399
300 mm^2	Al PICAS	490	478	395	385	436	425	371	362
95 mm^2	Al SWA	260	253	200	195	234	228	188	183
185 mm^2	Al SWA	390	380	300	292	347	338	282	275
300 mm^2	Al SWA	525	512	410	400	467	455	385	375

Assumptions:

- Max 65^{O}C conductor temp
- Winter - soil temp 10^{O}C , Thermal resistivity 0.9 m ^{O}C/W
- Summer - soil temp 15^{O}C , Thermal resistivity 1.2 m ^{O}C/W
- Laid 600mm deep to top of cable / duct

Table 3.3.1.4 E									**Central Networks East**
11kV Belted Paper Cables – **5 Day Distribution Rating** **Ungrouped** - Imperial sizes - Max 65^{O}C conductor temp									
CABLE		**WINTER Amps**				**SUMMER Amps**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**
0.06 in^2	Al SWA	145	141	115	112	132	129	109	106
0.1 in^2	Al SWA	195	190	155	151	175	171	145	141
0.15 in^2	Al SWA	250	244	195	190	225	219	183	178
0.2 in^2	Al SWA	300	293	235	229	270	263	221	215
0.25 in2	Al SWA	345	336	270	263	311	303	254	248
0.3 in^2	Al SWA	390	380	310	302	347	338	290	283
0.4 in^2	Al SWA	470	458	370	361	418	408	348	339
0.5 in^2	Al SWA	530	517	420	410	471	459	395	385
0.0225 in^2	Cu SWA	102	100	90	88	93	91	85	83
0.04 in^2	Cu SWA	145	141	115	112	132	129	109	106
0.06 in^2	Cu SWA	185	180	150	146	168	164	142	139
0.10 in^2	Cu SWA	255	249	205	200	230	224	192	187
0.15 in^2	Cu SWA	320	312	255	249	288	281	240	234
0.2 in^2	Cu SWA	385	375	305	297	347	338	285	278
0.25 in^2	Cu SWA	440	429	350	341	396	386	329	321
0.3 in^2	Cu SWA	500	488	400	390	445	434	375	366
0.4 in^2	Cu SWA	595	580	475	463	530	517	498	486
0.5 in^2	Cu SWA	670	653	535	522	596	581	560	546

Assumptions:

- Max 65^{O}C conductor temp
- Winter - soil temp 10^{O}C , Thermal resistivity 0.9 m ^{O}C/W
- Summer - soil temp 15^{O}C , Thermal resistivity 1.2 m ^{O}C/W
- Laid 600mm deep to top of cable / duct

Table 3.3.1.4 F									**Central Networks West**
11kV Screened Paper Cables – **5 Day Distribution Rating** **Ungrouped** - Metric sizes - Max 70^{O}C conductor temp									
CABLE		**WINTER Amps**				**SUMMER Amps**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**
95 mm^2	Al PICAS	270	263	205	200	240	234	193	187
185 mm^2	AL PICAS	400	390	310	302	356	347	291	284
300 mm^2	Al PICAS	530	517	420	410	472	460	395	385
185 mm^2	Cu PICAS	540	527	410	400	481	469	385	375
300 mm^2	Cu PICAS	719	701	555	541	640	624	521	508
95 mm^2	Al SWA	286	279	215	210	257	251	202	197
185 mm^2	Al SWA	420	410	320	312	374	365	301	294
300 mm^2	Al SWA	567	553	435	424	505	492	409	399

Assumptions:

- Max 70^{O}C conductor temp
- Winter - soil temp 10^{O}C , Thermal resistivity 0.9 m ^{O}C/W
- Summer - soil temp 15^{O}C , Thermal resistivity 1.2 m ^{O}C/W
- Laid 600mm deep to top of cable / duct

Table 3.3.1.4 G									**Central Networks West**
11kV Screened Paper Cables – **5 Day Distribution Rating** **Ungrouped** - Imperial sizes - Max 70^{O}C conductor temp									
CABLE		**WINTER Amps**				**SUMMER Amps**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**	**50%**	**75%**
0.06 in^2	Al SWA	160	156	125	122	146	142	118	115
0.1 in^2	Al SWA	220	215	170	166	198	193	160	156
0.15 in^2	Al SWA	275	268	215	210	248	242	202	197
0.2 in^2	Al SWA	330	322	255	249	297	290	240	234
0.25 in^2	Al SWA	375	366	295	288	338	330	277	270
0.3 in^2	Al SWA	425	414	335	327	383	373	315	307
0.4 in^2	Al SWA	510	497	400	390	454	443	376	367
0.5 in^2	Al SWA	570	556	450	439	507	494	423	412
0.0225 in^2	Cu SWA	116	113	101	98	106	103	96	94
0.04 in^2	Cu SWA	165	161	130	127	150	146	143	139
0.06 in^2	Cu SWA	210	205	165	161	191	186	182	177
0.10 in^2	Cu SWA	285	278	220	215	257	251	242	236
0.15 in^2	Cu SWA	355	346	280	273	320	312	301	293
0.2 in^2	Cu SWA	420	410	330	322	378	369	355	346
0.25 in^2	Cu SWA	480	468	375	366	432	421	406	396
0.3 in^2	Cu SWA	545	531	430	419	491	479	462	450
0.4 in^2	Cu SWA	645	629	510	497	547	533	514	501
0.5 in^2	Cu SWA	720	702	570	556	641	625	603	589

Assumptions:

- Max 70^{O}C conductor temp
- Winter - soil temp 10^{O}C , Thermal resistivity 0.9 m ^{O}C/W
- Summer - soil temp 15^{O}C , Thermal resistivity 1.2 m ^{O}C/W
- Laid 600mm deep to top of cable / duct

3.3.1.5 11kV Cable Sustained & Cyclic Rating Tables

- Values are for average environmental conditions
- Ambient ground temperature 10°C Winter 15°C Summer.
- Soil thermal resistivity 0.9°C m/w Winter, 1.2°C m/w Summer
- Loss Load Factor 0.5 Load Curve G (applicable to Cyclic ratings only)
- Maximum conductor temperature of
  - 65^{O}C for belted paper insulation (Central Networks East)
  - 70^{O}C for screened paper insulation (Central Networks West)
  - 90^{O}C for XLPE insulation. (Central Networks East & West)
- For other conditions including cables in air or clipped to wall use Engineering Recommendation P17 tables with all appropriate correction factors. The EA Technology Ltd 'CRATER' spreadsheet is available to carry out these calculations for XLPE cables.
- Duct sections less than 15m long can be assumed to be laid direct.

The following Sustained & Cyclic Ratings tables are provided:

Table 3.3.1.5 A	11kV XLPE Cables Sustained & Cyclic Rating – Ungrouped
Table 3.3.1.5 B	11kV XLPE Cables Sustained & Cyclic Rating – Group of 2
Table 3.3.1.5 C	11kV Belted Paper Cables - Sustained Rating & Cyclic Rating – Ungrouped – Metric Sizes
Table 3.3.1.5 D	11kV Belted Paper Cables - Sustained Rating & Cyclic Rating – Ungrouped – Imperial Sizes
Table 3.3.1.5 E	11kV Screened Paper Cables - Sustained Rating & Cyclic Rating – Ungrouped – Metric Sizes
Table 3.3.1.5 F	11kV Screened Paper Cables - Sustained Rating & Cyclic Rating – Ungrouped – Imperial Sizes
Table 3.3.1.5 G	Transformer 11kV XLPE Tails Sustained Ratings

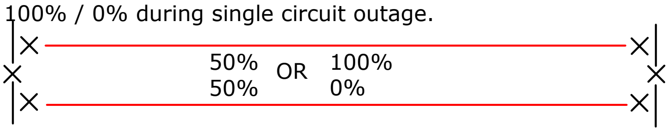
Table 3.3.1.5 A **Central Networks East & West**

11kV XLPE Cables - **Sustained & Cyclic Ratings**
Ungrouped - Max 90^{O}C conductor temp

CABLE		WINTER				SUMMER			
		Laid Direct		Ducted		Laid Direct		Ducted	
	Utilisation	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic
70 mm^2	Al Triplex	246	276	196	212	214	243	181	199
95 mm^2	Al Triplex	292	327	233	252	253	288	214	237
150 mm^2	Al Triplex	371	420	297	323	321	368	273	303
185 mm^2	Al Triplex	421	477	337	367	363	419	309	344
240 mm^2	Al Triplex	487	555	391	427	420	486	357	400
300 mm^2	Al Triplex	550	630	442	485	474	551	403	453
300 mm^2	Cu Triplex	705	810	567	623	606	707	516	580
400 mm^2	Cu Singles*	798	922	674	764	686	804	601	699
2 x 185 mm^2	Al Triplex**	336 + 336	385 + 385	293 + 293	317 + 317	287 + 287	330 + 330	264 + 264	294 + 294
2 x 300 mm^2	Al Triplex **	433 + 433	502 + 502	382 + 382	418 + 418	370 + 370	428 + 428	342 + 342	382 + 382
95 mm^2	Al 3-Core	268	298	219	234	236	268	203	221
185 mm^2	Al 3-Core	389	437	319	344	342	393	294	324
300 mm^2	Al 3-Core	514	584	424	460	451	523	389	431
300 mm^2	Cu 3-Core	662	755	550	598	580	675	504	560

The above ratings have been calculated on 'Crater V3' and assume:

- Circuits should take separate routes if possible
- The cables are NOT grouped – they may be laid in the same trench but not fully loaded simultaneously – e.g. parallel feeders to customer substation sharing the load 50% / 50% or 100% / 0% during single circuit outage.



- Laid direct – 120mm between the cable centres
- 125mm ducts 25mm apart
- Screens bonded at both ends
- Laid 600mm deep to top of cable / duct

*400 mm^2 Singles – laid direct in trefoil,
- ducted in 3 separate ducts

** 2 x 185/300 Al Triplex per circuit
600mm cover to top cables
800mm cover to lower cables

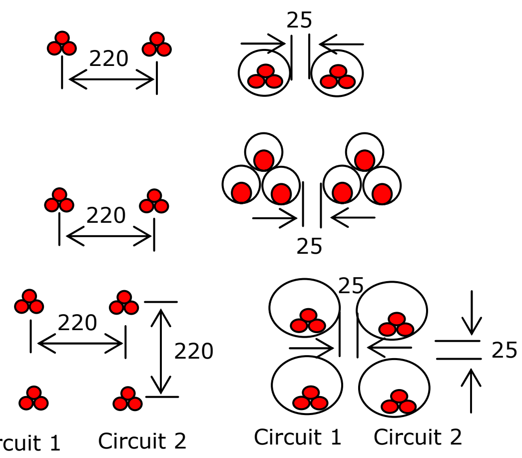
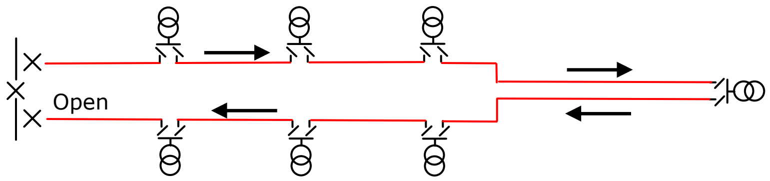


Table 3.3.1.5 B		**Central Networks East & West**							
11kV XLPE Cables - **Sustained & Cyclic Ratings** **Group of 2** - Max 90°C conductor temp									
CABLE		**WINTER**				**SUMMER**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**
70 mm^2	Al Triplex	212	245	176	196	183	215	160	182
95 mm^2	Al Triplex	250	290	208	231	215	253	185	211
150 mm^2	Al Triplex	315	368	264	295	270	321	234	267
185 mm^2	Al Triplex	355	416	298	334	305	363	264	302
240 mm^2	Al Triplex	409	482	345	388	351	419	304	350
300 mm^2	Al Triplex	460	544	388	438	394	472	342	395
300 mm^2	Cu Triplex	589	699	498	563	504	607	437	507
400 mm^2	Cu Singles*	664	793	553	675	567	687	486	608
2 x 185 mm^2	Al Triplex**	302 + 302	364 + 364	237 + 237	285 + 285	258 + 258	316 + 316	209+ 209	256 + 256
2 x 300 mm^2	Al Triplex **	390 + 390	475 + 475	306 + 306	369 + 369	333 + 333	411 + 411	268 + 268	331 + 331
95 mm^2	Al 3-Core	233	268	192	212	201	235	175	197
185 mm^2	Al 3-Core	333	388	277	307	287	340	252	285
300 mm^2	Al 3-Core	434	510	365	407	374	448	330	376
300 mm^2	Cu 3-Core	553	651	474	530	482	579	427	488

The above ratings have been calculated on 'Crater V3' and assume:

- Theses ratings are for cables installed on a ring main. Whilst for most of the ring they run seperatly they do run togther where they loop in and out of the ring man substation in the same trench. During abnormal feeding they are both subject to the full ring main load.



- #Laid direct – 150mm between the cables
- 125mm ducts – touching
- Screens bonded at both ends
- Laid 600mm deep to top of cable / duct

*400 mm^2 Singles – laid direct in trefoil,
- ducted in 3 separate ducts

** 2 x 185/300 Al Triplex per circuit
600mm cover to top cables
800mm cover to lower cables

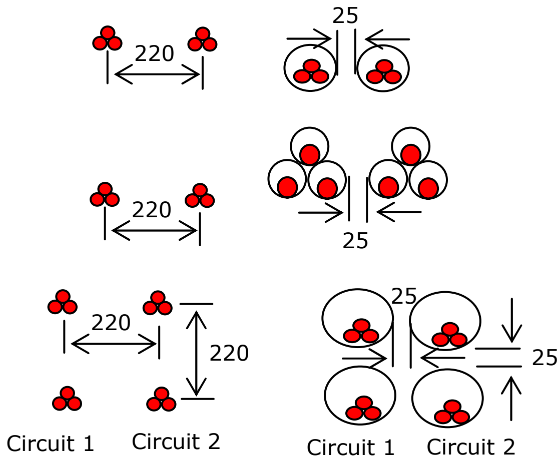


Table 3.3.1.5 C									**Central Networks East**
11kV Belted Paper Cables –**Sustained & Cyclic Ratings** **Ungrouped** – Metric Sizes - Max 65^{O}C conductor temp									
CABLE		**WINTER**				**SUMMER**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**
95 mm^2	Al PICAS	205	230	170	181	185	207	160	169
185 mm^2	AL PICAS	300	340	250	273	270	303	230	256
240 mm^2	Cu PICAS	441*	501*	375*	406*	393*	446*	352*	380*
300 mm^2	Al PICAS	390	446	335	363	355	397	305	341
95 mm^2	Al SWA	220	244	180	190	195	220	170	179
185 mm^2	Al SWA	320	359	260	282	285	319	240	265
300 mm^2	Al SWA	420	478	350	377	380	425	315	354

* Mathematically derived from aluminium values (no manufacturer's data)

Table 3.3.1.5 D									**Central Networks East**
11kV Belted Paper Cables - **Cyclic & Sustained Rating** **Ungrouped** – Imperial Sizes - Max 65^{O}C conductor temp									
CABLE		**WINTER**				**SUMMER**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**	**Sustained**	**Cyclic**
0.06 in^2	Al SWA	128	138	105	110	116	125	99	105
0.10 in^2	Al SWA	168	183	140	147	151	165	131	138
0.15 in^2	Al SWA	213	235	174	185	191	212	163	174
0.20 in^2	Al SWA	252	279	207	221	227	251	194	208
0.25 in^2	Al SWA	286	321	235	254	258	289	221	239
0.3 in^2	Al SWA	320	359	270	288	285	319	252	270
0.4 in^2	Al SWA	381	432	315	344	339	385	296	324
0.5 in^2	Al SWA	424	482	353	386	377	429	332	363
0.0225 in^2	Cu SWA	93	99	85	89	85	90	80	84
0.04 in^2	Cu SWA	129	138	106	112	117	125	100	106
0.06 in^2	Cu SWA	163	176	137	144	148	160	129	136
0.10 in^2	Cu SWA	219	240	185	144	198	216	173	182
0.15 in^2	Cu SWA	272	301	227	242	245	271	214	228
0.2 in^2	Cu SWA	323	358	268	287	291	323	251	268
0.25 in^2	Cu SWA	365	409	305	329	329	368	286	309
0.3 in^2	Cu SWA	410	460	348	372	365	409	326	349
0.4 in^2	Cu SWA	482	547	404	442	429	488	423	463
0.5 in^2	Cu SWA	536	610	449	492	477	542	470	515

Table 3.3.1.5 E									Central Networks West
11kV Screened Paper Cables –**Sustained & Cyclic Ratings** **Ungrouped** – Metric Sizes - Max 70°C conductor temp									
CABLE		**WINTER**				**SUMMER**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic
95 mm^2	Al PICAS	224	251	182	195	199	223	172	183
185 mm^2	AL PICAS	324	368	267	288	288	328	250	271
300 mm^2	Al PICAS	419	482	353	386	373	430	332	363
185 mm^2	Cu PICAS	437	497	353	381	390	443	331	358
300 mm^2	Cu PICAS	568	654	466	511	506	582	438	479
95 mm^2	Al SWA	237	266	191	204	213	239	180	192
185 mm^2	Al SWA	340	386	275	298	303	344	259	280
300 mm^2	Al SWA	448	516	365	400	399	460	344	376

Table 3.3.1.5 F									Central Networks West
11kV Screened Paper Cables - **Cyclic & Sustained Rating** **Ungrouped** – Imperial Sizes - Max 70°C conductor temp									
CABLE		**WINTER**				**SUMMER**			
		Laid Direct		**Ducted**		**Laid Direct**		**Ducted**	
	Utilisation	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic
0.06 in^2	Al SWA	138	150	113	119	126	137	106	112
0.10 in^2	Al SWA	187	207	150	162	168	186	141	152
0.15 in^2	Al SWA	231	256	187	202	208	231	176	190
0.20 in^2	Al SWA	274	307	222	237	247	276	209	223
0.25 in^2	Al SWA	308	345	254	274	277	311	238	258
0.3 in^2	Al SWA	344	391	285	312	310	352	268	293
0.4 in^2	Al SWA	408	464	336	368	363	413	316	346
0.5 in^2	Al SWA	450	519	374	410	401	461	351	385
0.0225 in^2	Cu SWA	104	113	93	99	95	103	88	94
0.04 in^2	Cu SWA	144	157	117	125	131	143	129	137
0.06 in^2	Cu SWA	181	197	149	157	164	180	164	173
0.10 in^2	Cu SWA	242	268	194	209	218	242	213	230
0.15 in^2	Cu SWA	298	330	244	263	269	298	262	283
0.2 in^2	Cu SWA	349	391	287	307	314	352	309	330
0.25 in^2	Cu SWA	394	442	323	349	354	397	349	378
0.3 in^2	Cu SWA	441	501	366	400	398	452	393	430
0.4 in^2	Cu SWA	516	587	428	469	438	498	432	473
0.5 in^2	Cu SWA	569	655	473	519	506	583	500	549

Table 3.3.1.5 G						
Transformer 11kV XLPE Tails **Sustained** Ratings						
Formation	**Size**	**Type**	**Winter amps**		**Summer amps**	
A In trefoil – 1 core per phase R YB	400 mm²	Cu Singles	821	798	706	686
	630 mm²	Cu Singles	1046	1006	897	861
B Laid singly – 1 core per phase – 2D spacing between cores R Y B	400 mm²	Cu Singles	885	785	759	671
	630 mm²	Cu Singles	1155	968	988	824
C Laid singly – 1 core per phase - ducts touching R Y B	400 mm²	Cu Singles	778	655	701	586
	630 mm²	Cu Singles	1010	808	906	718
D In trefoil – 2 cores per phase - 300mm spacing R YB R YB	400 mm²	Cu Singles	700	681	598	581
	630 mm²	Cu Singles	884	850	754	724
E Laid singly – 2 cores per phase - ducts touching R YB R YB	400 mm²	Cu Singles	659	563	579	494
	630 mm²	Cu Singles	848	694	743	606
F In trefoil – 3 cores per phase - 300mm spacing R YB R YB R YB	400 mm²	Cu Singles	620	603	528	513
	630 mm²	Cu Singles	779	749	662	636
G Laid singly – 3 cores per phase - ducts touching R YB R YB R YB	400 mm²	Cu Singles	579	495	505	431
	630 mm²	Cu Singles	743	608	645	527

Cable screens bonded to earth at one end only – NORMAL ARRANGMENT

Cable screens bonded to earth at both ends – DO NOT USE

The current ratings are given for each core. For the total capacity of multiple cores per phase multiply the rating by the number of cores.

Transformer Nameplate Rating		CER Winter		CER Summer		Tails per phase	Current per core	
		MVA	Amps	MVA	Amps		Winter	Summer
6/12 MVA	11kV	12	628	9.5	498	1 x 400 mm²	628	498
12/24 MVA	11kV	24	1257	19	996	2 x 400 mm²	628	498
20/40 MVA	11kV	40	2096	32	1676	3 x 630 mm²	698	558
6/12 MVA	6.6kV	12	1044	9.5	826	2 x 400 mm²	522	413
12/24 MVA	6.6kV	24	2088	19	1653	3 x 630 mm²	696	551
20/40 MVA	6.6kV	40	3580	32	2784	Special design		

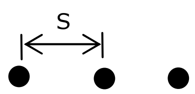
EATL 'CRATER' Spreadsheet settings used for Transformer Tail Ratings							
	Common settings						
Cable Characteristics							
Cable type	Copper wire screen BS 7870-4.10 (11kV)						
Conductor	Copper stranded						
Conductor size mm^2	400 & 630						
Insulation type	XLPE						
Sheath type	Polyethylene						
Colour of Sheath	N/A						
Cu Wire Screen area mm^2	35 mm^2						
Bonding arrangement	Single point & Solid, No Transposition as required						
Operating Conditions							
Environment	In soil						
Drying out of soil	No Account taken						
Conductor temp	90 ^{O}C						
Soil Temp	10 ^{O}C Winter 15 ^{O}C Summer						
Soil Thermal Resistivity	0.9 m^{O}C/W Winter 1.2 m^{O}C/W Winter						
Soil depth	600 mm						
Loss Load Factor	1.0 (set to 1.0 so that Dist/Cyclic/Sust rating are equal)						
Utilisation %	100% (set to 100% so that Dist/Cyclic/Sust rating are equal)						
Limited Time days	N/A						
Cable Grouping	See below						
Soil Thermal diffusivity	5.0E-07x(0.9/g)^0.8						
Soil depth measured to	Top surface						
	Arrangement						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Cable grouping	No	No	No	Yes	Yes	Yes	Yes
Cable & Duct configuration							
Single cores flat 2D Spacing between centres		Y					
Single core in trefoil	Y			Y		Y	
Three ducts flat touching			Y				
Three ducts flat 2D spacing							
Three ducts trefoil					Y		Y
One duct 3 singles in trefoil							
Duct Characteristics							
Duct type	Ridgiduct						
Duct size	125mm ID 148mm OD						
Grouping							
Grouping – trefoils flat	N/A	N/A	N/A	Y	Y	Y	
Grouping -trefoils tiered	N/A	N/A	N/A				Y
Spacing mm	N/A	N/A	N/A	300	225	300	225
No of Trefoils				2	2	3	3
				The Distribution rating as displayed on the 'Grouped' result screen is equal to the Sustained rating because Loss Load Factor is 1.0 & Utilisation is 100%			

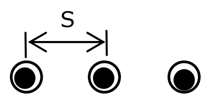
3.3.1.6 11kV Paper Cables - Grouping Correction Table

Where multiple cables are installed in close proximity (i.e. grouped) the heat dissipation is reduced thus de-rating the cables. The following table may be used to calculate the degree of de-rating of grouped legacy cables.

Table 3.3.1.6A

De-rating factors for Grouped Paper Cables
5 Day Distribution Rating, Cyclic and Sustained





Soil Thermal Resistivity °Cm/W	S Spacing of cables mm	Laid Direct					Ducted				
		Number of Cables in Group					Number of Cables in Group				
		2	3	4	5	6	2	3	4	5	6
0.9 Winter	150	0.97	0.93	0.91	0.89	0.88	0.98	0.96	0.95	0.94	0.93
	300	0.98	0.95	0.94	0.92	0.92	0.99	0.97	0.96	0.95	0.95
	450	0.98	0.96	0.95	0.94	0.94	0.99	0.98	0.97	0.97	0.96
	600	0.98	0.97	0.96	0.96	0.95	0.99	0.98	0.98	0.97	0.97
1.2 Summer	150	0.96	0.92	0.90	0.88	0.86	0.98	0.95	0.94	0.92	0.91
	300	0.97	0.94	0.93	1.91	0.90	0.98	0.96	0.95	0.94	0.94
	450	0.98	0.96	0.95	0.93	0.93	0.99	0.97	0.96	0.96	0.95
	600	0.98	0.96	0.96	0.95	0.94	0.99	0.98	0.97	0.97	0.96

Soil Thermal Resistivity °Cm/W	S Spacing of cables mm	Formation of Cables					Formation of Ducts				
		3 (S)	4	6	9	12	3	4	6	9	12
0.9 Winter	150	0.93	0.9	0.85	0.78	0.73	0.96	0.94	0.91	0.87	0.83
	300	0.94	0.92	0.88	0.82	0.77	0.97	0.95	0.93	0.89	0.86
	450	0.95	0.93	0.89	0.84	0.79	0.97	0.96	0.94	0.9	0.87
	600	0.95	0.94	0.9	0.85	0.8	0.97	0.96	0.94	0.91	0.88
1.2 Summer	150	0.92	0.89	0.83	0.76	0.7	0.95	0.93	0.89	0.84	0.8
	300	0.94	0.91	0.86	0.8	0.74	0.96	0.94	0.91	0.86	0.82
	450	0.94	0.92	0.88	0.82	0.77	0.96	0.95	0.92	0.88	0.84
	600	0.94	0.93	0.89	0.83	0.78	0.96	0.95	0.93	0.89	0.85

Based on Engineering Recommendation P17 Table 10

For other values of Soil Resistivity please refer to P17

3.3.1.7 11kV Paper Cables - Loss Load Factor Correction Table

The 5 Day Distribution ratings in Section3.3.1.4 and the Cyclic ratings in Section 3.3.1.5 are based on 'Load Curve G' which has a Loss Load factor of 0.5 representing a typical mixed industrial/commercial/residential distribution feeder load.

Where the load mix is predominantly industrial/commercial the Loss Load Factor is often significantly higher thus de-rating the cables to a value closer to the Sustained ratings.

The following factors can be used to assess the capability of legacy cables to safely accommodate industrial/commercial loads.

Table 3.3.1.6B

De-rating factors for Variation in Loss Load Factors
Paper Cables - 5 Day Distribution & Cyclic Ratings

Soil Resistivity °Cm/W	Loss Load Factor over 24 hr Period	Laid Direct		Ducted	
		Belted	Screened	Belted	Screened
0.9 Winter	0.45 – 0.5	1.0	1.0	1.0	1.0
	0.5 – 0.55	0.98	0.98	0.99	0.99
	0.55 – 0.6	0.97	0.97	0.98	0.98
	0.6 - 0.65	0.96	0.95	0.97	0.97
	0.65 – 0.7	0.94	0.94	0.96	0.96
	0.7 – 0.75	0.93	0.93	0.96	0.95
	0.75 – 0.8	0.92	0.91	0.95	0.95
	0.8 – 0.85	0.91	0.90	0.94	0.94
	0.85 – 0.9	0.90	0.89	0.93	0.93
	0.9 – 0.95	0.89	0.88	0.93	0.92
	0.95 – 1.0	0.88	0.87	0.92	0.91
1.2 Summer	0.45 – 0.5	1.0	1.0	1.0	1.0
	0.5 – 0.55	0.98	0.98	0.99	0.99
	0.55 – 0.6	0.96	0.96	0.98	0.98
	0.6 – 0.65	0.95	0.95	0.96	0.96
	0.65 – 0.7	0.93	0.93	0.95	0.95
	0.7 – 0.75	0.92	0.92	0.94	0.94
	0.75 – 0.8	0.91	0.91	0.93	0.93
	0.8 – 0.85	0.90	0.89	0.92	0.92
	0.85 – 0.9	0.88	0.88	0.92	0.91
	0.9 – 0.95	0.87	0.86	0.91	0.90
	0.95 – 1.0	0.86	0.85	0.90	0.89

Based on Engineering Recommendation P17 Table 13

For lower values of Loss Load Factor please refer to P17

3.3.1.8 11kV Cable Electrical Data Tables

CABLE		1 sec S/C rating		Resistance		Reactance		% Volt drop	Losses at 1MVA Note 1
Size	Type	Core kA	Screen kA	R W /km DC @ 20°C	% (100MVA base)	jX W /km	% (100MVA base)	% per km per MVA	KW per km
70 mm²	Al Triplex	6.6	3.2	0.443	36.61	0.125	10.33	0.356	3.445
95 mm²	Al Triplex	8.9	4.5	0.320	26.45	0.119	9.835	0.258	2.488
150 mm²	Al Triplex	14.1	4.5	0.206	17.02	0.112	9.256	0.167	1.602
185 mm²	Al Triplex	17.4	4.5	0.164	13.55	0.108	8.926	0.133	1.275
240 mm²	Al Triplex	22.5	4.5	0.125	10.33	0.104	8.595	0.102	0.972
300 mm²	Al Triplex	28.2	4.5	0.100	8.26	0.101	8.347	0.083	0.778
300 mm²	Cu Triplex	42.9	4.5	0.060	4.96	0.0961	7.94	0.052	0.467
400 mm²	Cu singles	57.2	4.5	0.047	3.88	0.095	7.851	0.042	0.365
630 mm²	Cu singles	90.1	4.5	0.0283	2.34	0.089	7.355	0.029	0.220
300 mm²	Al PICAS	23.4	23.4	0.100	8.26	0.077	6.35	0.082	0.778
240 mm²	Cu PICAS	28.6	4.5	0.0754	6.23	0.078	6.45	0.062	0.586
185 mm²	Al PICAS	14.4	14.4	0.164	13.55	0.080	6.61	0.132	1.275
95 mm²	Al PICAS	7.4	7.4	0.320	26.44	0.087	7.19	0.257	2.488
300 mm²	Al SWA	*23.4*		0.100	8.26	0.077	6.35	0.082	0.778
185 mm²	Al SWA	*14.4*		0.164	13.55	0.080	6.61	0.132	1.275
95 mm²	Al SWA	*7.4*		0.320	26.44	0.087	7.19	0.257	2.488
0.5 in²	Al SWA	*23.4*		0.0923	7.63	0.0742	6.13	0.075	0.718
0.3 in²	Al SWA	*14.4*		0.152	12.56	0.0778	6.43	0.123	1.182
0.15 in²	Al SWA	*7.4*		0.312	25.78	0.0839	6.93	0.251	2.426
0.10 in²	Al SWA	*5.0*		0.456	37.68	0.0897	7.41	0.366	3.546
0.3 in²	Cu SWA	*23.4*		0.0920	7.60	0.0778	6.43	0.075	0.715
0.2 in²	Cu SWA	*14.4*		0.142	11.73	0.082	6.78	0.115	1.104
0.15 in²	Cu SWA	*11.5*		0.188	15.54	0.0839	6.93	0.152	1.462
0.10 in²	Cu SWA	*7.4*		0.276	22.81	0.0897	7.41	0.222	2.146
0.06 in²	Cu SWA	*4.5*		0.463	38.26	0.0962	7.95	0.372	3.600
0.04 in²	Cu SWA	*2.9*		0.703	58.10	0.102	8.43	0.564	5.466
0.0225 in²	Cu SWA	*1.8*		1.258	103.96	0.114	9.42	1.009	9.782

Derived from:-

%Volt Drop = $(\sqrt{((0.97R\%)^2 + (0.24X\%)^2)}) / 100$

assuming 0.97 p.f. load, Voltage = 11kV

Losses = $I^2 \times R$ (where I = 50.91 Amps for 1MW at 11.0 kV and 0.97 pf)

Note 1 Losses at any other load cab be calculated from :
Loss = Loss at 1MVA x (Actual Load in MVA)^2

1 sec S/S ratings for imperial cables shown in italics have been extrapolated from drawing DPM 423 in the EMEB Distribution Planning Manual

3.3.2 11kV Overhead Lines

3.3.2.1 11kV Conductors

Normal applications: 11kV unearthed bare wire construction shall be to ENATS 43-40 as detailed in Central Networks Overhead Manual Volume 1.

Special applications e.g. wooded areas, protection of water-fowl, recreational areas: 11kV unearthed covered conductor construction shall generally be to ENATS 43-40 and ENATS 43-119,120,121. There is no Central Networks standard for covered conductor lines – refer to the Technology & Standards Manager for guidance.

Steelwork and fittings shall generally be to ENATS 43-95 and as detailed in Central Networks' Overhead Manual Volume 2.

The standard sizes to be used in are:

Central Networks West

- 50 mm^2 AAAC 'Hazel' (All Aluminium Alloy Conductor)
- 100 mm^2 AAAC 'Oak' (All Aluminium Alloy Conductor)
- 200 mm^2 AAAC 'Poplar' (All Aluminium Alloy Conductor)

Central Networks East

- 50 mm^2 ACSR 'Rabbit' (Aluminium Core Steel Reinforced)
- 100 mm^2 ACSR 'Dog' (Aluminium Core Steel Reinforced)
- 150 mm^2 ACSR 'Dingo' (Aluminium Core Steel Reinforced)
- 300 mm^2 HDA 'Butterfly' (Hard Drawn Aluminium)

For applications refer to Section 1.4.4.2

3.3.2.2 11kV Conductor Distribution Rating Tables

Continuous current ratings are based on Engineering Recommendation P27 and calculated using the EA Technology Ltd Overhead Line Calculator Spreadsheet. (NB. Cyclic ratings are not applicable to overhead lines).
Maximum conductor temperature 50 ^{O}C pre line built before 1971
Maximum conductor temperature 60 ^{O}C pre line built after 1971 in Central Networks East
Maximum conductor temperature 75 ^{O}C pre line built after 1971 in Central Networks West

Exceedance (excursion time) of 0.001%
Wind speed 0.5m/s
Solar radiation nil
Ambient temperature:

20 ^{O}C Summer	(May June, July, August)
9 ^{O}C Spring /Autumn	(March, April / Sept, Oct, Nov)
2 ^{O}C Winter	(Dec, Jan, Feb)

Table 3.3.2.2A New Lines and Lines Built After 1971 60 °C Conductor Temperature (Central Networks East standard)						
(New build standard shown bold)				Summer	Autumn Spring	Winter
Size	Type	Code	Stranding	Amps	Amps	Amps
Bare Conductors						
40 mm^2	ACSR	Ferret	6/1/3.0 mm	156	175	186
50 mm^2	**ACSR**	**Rabbit**	**6/1/3.35 mm**	**181**	**203**	**215**
100 mm^2	**ACSR**	**Dog**	**6/4.72 & 7/1.57 mm**	**286**	**318**	**338**
150 mm^2	**ACSR**	**Dingo**	**18/1/3.35 mm**	**386**	**432**	**458**
150 mm^2	ACSR	Wolf	30/7/2.59	396	443	470
175 mm^2	ACSR	Lynx	30/2/2.79	437	489	518
50 mm^2	AAAC	Hazel	7/3.30 mm	188	221	224
100 mm^2	AAAC	Oak	7/4.65 mm	297	333	353
150 mm^2	AAAC	Ash	19/3.48 mm	393	440	467
200 mm^2	AAAC	Poplar	37/2.87 mm	474	531	562
300 mm^2	AAAC	Upas	37/3.53 mm	626	700	742
50 mm^2	HDA	Ant	7/3.10 mm	186	209	222
100 mm^2	HDA	Wasp	7/4.39 mm	295	331	351
300 mm^2	**HDA**	**Butterfly**	**19/4.65 mm**	**622**	**695**	**737**
Covered Conductors						
50 mm^2	XLPE CC	HazelCC AL3	7/3.30 mm	201	225	239
50 mm^2	BLX / PAS	50CC AL2	7/compacted	168	188	200
120 mm^2	BLX / PAS	120CC AL2	19/compacted	300	336	356
185 mm^2	BLX / PAS	185CC AL2	34min/compacted	394	441	467
50 mm^2	BLX / PAS	50CC AL3	7/compacted	178	200	212
120 mm^2	BLX / PAS	120CC AL3	19/compacted	310	347	369
185 mm^2	BLX / PAS	185CC AL3	34min/compacted	411	460	488
Engineering Recommendation P27 calculations carried out on EA Technology Ltd Spreadsheet: Bare conductors – OHRAT2 (version 5th May 2004) ANATS 43-122 Appemdix B1 Covered Conductors - OHRATv3.01 (version 7th July 2004)						

Table 3.3.2.2B New Lines and Lines Built After 1971 75 ^{O}C Conductor Temperature (Central Networks West standard)						
(New build standard shown bold)				**Summer Amps**	**Autumn Spring Amps**	**Winter Amps**
Size	**Type**	**Code**	**Stranding**			
Bare Conductors						
40 mm^2	ACSR	Ferret	6/1/3.0 mm	181	197	206
50 mm^2	ACSR	Rabbit	6/1/3.35 mm	209	228	238
100 mm^2	ACSR	Dog	6/4.72 & 7/1.57 mm	329	359	375
150 mm^2	ACSR	Dingo	18/1/3.35 mm	447	485	507
150 mm^2	ACSR	Wolf	30/7/2.59	459	498	521
175 mm^2	ACSR	Lynx	30/2/2.79	507	550	575
50 mm^2	**AAAC**	**Hazel**	**7/3.30 mm**	**219**	**238**	**249**
100 mm^2	**AAAC**	**Oak**	**7/4.65 mm**	**345**	**375**	**392**
150 mm^2	AAAC	Ash	19/3.48 mm	457	496	518
200 mm^2	**AAAC**	**Poplar**	**37/2.87 mm**	**551**	**598**	**626**
300 mm^2	AAAC	Upas	37/3.53 mm	729	790	826
50 mm^2	HDA	Ant	7/3.10 mm	216	235	246
100 mm^2	HDA	Wasp	7/4.39 mm	343	372	390
300 mm^2	HDA	Butterfly	19/4.65 mm	723	785	820
Covered Conductors						
50 mm^2	XLPE CC	HazelCC AL3	7/3.30 mm	233	253	265
50 mm^2	BLX / PAS	50CC AL2	7/compacted	194	211	221
120 mm^2	BLX / PAS	120CC AL2	19/compacted	348	378	395
185 mm^2	BLX / PAS	185CC AL2	34min/compacted	457	496	519
50 mm^2	BLX / PAS	50CC AL3	7/compacted	207	225	235
120 mm^2	BLX / PAS	120CC AL3	19/compacted	360	391	409
185 mm^2	BLX / PAS	185CC AL3	34min/compacted	477	518	541
Engineering Recommendation P27 calculations carried out on EA Technology Ltd Spreadsheet: Bare conductors – OHRAT2 (version 5th May 2004) ANATS 43-122 Appemdix B1 Covered Conductors - OHRATv3.01 (version 7th July 2004)						

Table 3.3.2.2C Lines Built Before 1971 50 ^{O}C Conductor Temperature						
Aluminium				Summer	Autumn	Winter
Size	Type	Code	Stranding	Amps	Spring Amps	Amps
0.02 in^2	ACSR	Squirrel	6/1/.083 in	86	100	109
0.025 in^2	ACSR	Gopher	6/1/.093 in	100	116	126
0.03 in^2	ACSR	Weasel	6/1/.102 in	113	131	141
0.04 in^2	ACSR	Ferret	6/1/.118 in	136	159	171
0.05 in^2	ACSR	Rabbit	6/1/.132 in	158	184	198
0.06 in^2	ACSR	Mink	6/1/.144 in	178	205	223
0.075 in^2	ACSR	Raccoon	6/1/.161 in	207	239	257
0.1 in^2	ACSR	Dog	6/.186 & 7/.062 in	252	289	310
0.15 in^2	ACSR	Dingo	18/1/.132 in	337	391	421
0.15 in^2	ACSR	Wolf	30/7/.102 in	346	401	431
0.175 in^2	ACSR	Lynx	30/2/2.79 in	382	442	476
0.025 in^2	AAAC	Almond	7/.092 in	105	122	132
0.03 in^2	AAAC	Cedar	7/.100 in	117	136	146
0.04 in^2	AAAC	Fir	7/.116 in	142	165	178
0.05 in^2	AAAC	Hazel	7/.130 in	165	191	206
0.06 in^2	AAAC	Pine	7/.142 in	186	215	232
0.075 in^2	AAAC	Willow	7/.160 in	215	250	269
0.1 in^2	AAAC	Oak	7/.183 in	259	301	324
0.15 in^2	AAAC	Ash	7/.137 in	343	397	428
0.175 in^2	AAAC	Elm	19/.148 in	380	440	474
0.2 in^2	AAAC	Poplar	37/.113 in	414	479	515
0.3 in^2	AAAC	Upas	37/.139 in	545	631	679
0.05 in^2	HDA	Ant	7/0.122 in	163	189	204
0.1 in^2	HDA	Wasp	7/0.173 in	258	299	322
0.3 in^2	HDA	Butterfly	19/0.183 in	542	628	675
0.4 in^2	HDA	Centipede	37/0.149 in	852	924	966
Engineering Recommendation P27 calculations carried out on EA Technology Ltd Spreadsheet OHRAT2 (version 5th May 2004						

Table 3.3.2.2D Lines Built Before 1971 50 °C Conductor Temperature						
Copper (Imperial sizes)				Summer	Autumn Spring	Winter
Size	Type	Metric eq	Stranding	Amps	Amps	Amps
0.017 in²	Cad cu	13 mm²	3/0.93" 3/2.36mm	78	90	97
0.0225 in²	Cad cu	17 mm²	7/.069" 7/1.75mm	89	104	112
0.025 in²	Cad cu	19 mm²	7/.073" 7/1.85mm	96	111	120
0.025 in²	Cad cu	19 mm²	3/.112" 3/2.84mm	99	115	124
0.04 in²	Cad cu	31 mm²	7/.093" 7/2.36mm	132	153	165
0.05 in²	Cad cu	38 mm²	3/.158" 3/4.01mm	156	181	195
0.05 in²	Cad cu	38 mm²	7/.103" 7/2.62mm	151	175	189
0.075 in²	Cad cu	60 mm²	7/.127" 7/3.23mm	197	229	247
0.1 in²	Cad cu	80 mm²	7/.146" 7/3.71mm	237	275	296
0.15 in²	Cad cu	113 mm²	7/.179" 7/4.55mm	312	362	390
0.15 in²	Cad cu	110 mm²	19/.109" 19/2.77mm	314	364	392
0.175 in²	Cad cu	110 mm²	19/.118" 19/3.00mm	347	402	433
0.022 in²	Cu	15 mm²	7/.064" 7/1.63mm	89	103	111
0.025 in²	Cu	16 mm²	3/.104" 3/2.64mm	98	114	123
0.04 in²	Cu	27 mm²	3/.131" 3/3.37mm	135	157	169
0.05 in²	Cu	33 mm²	3/.147" 3/3.73mm	154	179	193
0.075 in²	Cu	49 mm²	3/.180" 3/4.57mm	202	234	252
0.075 in²	Cu	48 mm²	7/.116" 7/2.95mm	192	223	241
0.1 in²	Cu	65 mm²	7/.136" 7/3.45mm	236	274	295
0.15 in²	Cu	110 mm²	19/.109" 19/2.77mm	342	397	427
0.2 in²	Cu	130 mm²	19/.116" 19/2.95mm	364	422	454
Engineering Recommendation P27 calculations carried out on EA Technology Ltd Spreadsheet OHRAT2 (version 5th May 2004						

Table 3.3.2.2E Lines Built Before 1971 50 °C Conductor Temperature						
Solid Copper (SWG sizes)				Summer	Autumn Spring	Winter
Size	Type	Metric eq	Diameter	Amps	Amps	Amps
No 6 cu	SWG	18.6 mm²	4.88 mm	*103*	120	*129*
No 5 cu	SWG	22.8 mm²	5.38 mm	*118*	137	*148*
No 4 cu	SWG	27.3 mm²	5.89 mm	*133*	155	*167*
No 3 cu	SWG	32.2 mm²	6.4 mm	*148*	171	*185*
No 2 cu	SWG	38.6 mm²	7.01 mm	*167*	194	*209*
No 1 cu	SWG	45.6 mm²	7.62 mm	*186*	216	*233*
1/0 cu	SWG	53.2 mm²	8.23 mm	*206*	239	*258*
2/0 cu	SWG	61.4 mm²	8.84 mm	*226*	263	*283*
3/0 cu	SWG	70.1 mm²	9.45 mm	*247*	287	*309*
SWG values calculated on EATL spreadsheet OHRAT" (5th May 2004 version) – approx only – based on equivalent cross section 7 strand conductor as there is no option for solid conductor.						

3.3.2.3 11kV O/H Line Data Tables

Conductor		1 sec S/C rating		Resistance		Reactance		% Volt drop	Losses at 1MVA Note 1
Size	**Type**	**kA**	**MVA**	**R W /km**	**% (100MVA)**	**jX W /km**	**% (100MVA)**	**per km per MVA**	**per km per MVA**
Metric									
40 mm^2	ACSR Ferret	3.6	69	0.677	55.95	0.408	33.72	0.549	5.264
50 mm^2	ACSR Rabbit	4.4	86	0.543	44.88	0.395	32.64	0.442	4.222
50 mm^2	AAAC Hazel			0.550	45.45	0.351	29.01	0.446	4.277
100 mm^2	ACSR Dog	8.9	170	0.273	22.56	0.378	31.24	0.231	2.123
100 mm^2	AAAC Oak			0.277	22.89	0.351	29.01	0.233	2.154
150 mm^2	ACSR Dingo	13.5	260	0.182	15.04	0.335	27.69	0.160	1.415
150 mm^2	ACSR Wolf			0.183	15.12	0.335*	27.69	0.161	1.423
150 mm^2	AAAC Ash								
175 mm^2	ACSR Lynx								
200 mm^2	AAAC Poplar			0.139	11.49	0.325	26.86	0.129	1.081
300 mm^2	HDA Butterfly	23.4	450	0.0892	7.37	0.316	26.12	0.095	0.694
300 mm^2	HDA Upas			0.0916	7.57	0.316*	26.12	0.097	0.712
50 mm^2	HazelCC AL3			0.55		0.351*			
50 mm^2	BLX 50CC AL2			0.72		0.351*			
120 mm^2	BLX 120CC AL2			0.288		0.343*			
185 mm^2	BLX 185CC AL2			0.188					
50 mm^2	BLX 50CC AL3			0.61		0.351*			
120 mm^2	BLX 120CC AL3			0.272		0.343*			
185 mm^2	BLX 185CC AL3			0.176					
						* extrapolated values			
Imperial									
0.0225 in^2	Cad cu			1.350*	111.6	0.38*	31.41	1.085	10.50
0.025 in^2	Cu eq	1.7	32	1.100	90.90	0.375	30.99	0.956	9.090
0.04 in^2	Cu eq	3.6	69	0.691	57.10	0.360	29.75	0.625	5.710
0.05 in^2	Cu eq	4.4	86	0.549	45.37	0.353	29.17	0.510	4.537
0.075 in^2	Cu eq	*6.8*	*130*	0.378	31.24	0.343	28.36	0.371	3.124
0.1 in^2	Cu eq	8.9	170	0.276	22.81	0.333	27.52	0.287	2.281
0.15 in^2	Cu eq	13.5	260	0.184	15.21	0.320	26.44	0.211	1.521
SWG									
No 6 cu	= 18.6 mm^2			*0.975*	*80.58*	*0.375*	*30.99*	*0.785*	*7.581*
No 5 cu	= 22.8 mm^2			*0.800*	*66.12*	*0.360*	*29.75*	*0.645*	*6.220*
No 4 cu	= 27.3 mm^2			*0.640*	*52.89*	*0.360*	*29.75*	*0.518*	*4.976*
No 3 cu	= 32.2 mm^2			*0.540*	*44.63*	*0.353*	*29.17*	*0.439*	*4.199*
No 2 cu	= 38.6 mm^2			*0.439*	*36.28*	*0.343*	*28.36*	*0.358*	*3.413*
No 1 cu	= 45.6 mm^2			*0.390*	*32.23*	*0.343*	*28.36*	*0.320*	*3.032*
1/0 cu	= 53.2 mm^2			*0.360*	*29.75*	*0.343*	*28.36*	*0.296*	*2.799*
2/0 cu	= 61.4 mm^2			*0.286*	*23.64*	*0.333*	*27.52*	*0.239*	*2.224*
3/0 cu	= 70.1 mm^2			*0.250*	*20.66*	*0.320*	*26.44*	*0.210*	*1.944*

The values for SWG conductors are approximations only.

Derived from:-
%Volt Drop = (√ ((0.97R%)^2 + (0.24X%)^2)) / 100

assuming 0.97 p.f. load, Voltage = 11kV

Losses = I ^{2} x R (where I = 50.91 Amps for 1MW at 11.0 kV and 0.97 pf)

Note 1 Losses at any other load cab be calculated from :
Loss = Loss at 1MVA x (Actual Load in MVA)^2

Data in italics is extrapolated from adjacent values.

3.3.3 11 kV / LV Transformers

3.3.3.1 Ground Mounted Transformers

Ground mounted transformers shall generally be in accordance with ENATS 35-1 and as detailed in the Central Networks' Plant Specification Manual Section 3F. Free-standing and as part of Compact Unit Substation (CUS)

Free-standing and as part of Compact Unit Substation (CUS)	
Size / Type	**Use**
200 kVA CUS with 11kV RMU 500A 2 way LV Pillar	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 225 kVA
315 kVA CUS with 11kV RMU & 800A 4 way LV Pillar	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 300 kVA
500 kVA CUS with 11kV RMU & 1600A 4 way LV Pillar	• LV Network supplying mixed loads • Single or double direct services for industrial / commercial loads up to 600 kVA
800 kVA CUS with 11kV RMU & 1600A 4 way LV Pillar	• LV Network supplying mixed loads • Single or double direct services for industrial / commercial loads up to 600 kVA
500 kVA CUS with 11kV RMU & LV 1250A ACB cabinet	• 301 to 500 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located next to public highway
800 kVA CUS with 11kV RMU & LV 1250A ACB cabinet	• 501 to 800 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located next to public highway
1000 kVA CUS with 11kV RMU & LV 1600A ACB cabinet	• 801 to 1000 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located next to public highway
1500 kVA CUS with 11kV RMU & LV 2500A ACB cabinet	• 1000 to 1500 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located next to public highway
500 kVA CUS with 11kV feeder switch & LV 1250A ACB cabinet	• 301 to 500 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located remotely from RMU
800 kVA CUS with	• 501 to 800 kVA LV metered supply to single customer from plus feed

11kV feeder switch & LV 1250A ACB cabinet	out onto local LV network • Substation located remotely from RMU
1000 kVA CUS with 11kV feeder switch & LV 1600A ACB cabinet	• 801 to 1000 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located remotely from RMU
1500 kVA CUS with 11kV feeder switch & LV 2500A ACB cabinet	• 1000 to 1500 kVA LV metered supply to single customer from plus feed out onto local LV network • Substation located remotely from RMU

3.3.3.2 Padmount Transformers

Padmount transformers shall generally be in accordance with ANSI C57-12-25/26 and as detailed in the Central Networks Plant Specification Manual Section 3F.

Size / Type	Use
50 kVA single phase padmount with one feeder way	• LV Network supplying mixed loads • Single phase loads up to 50kVA
100 kVA three phase padmount with two feeder ways	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 110 kVA
200 kVA three phase padmount with two feeder ways	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 225 kVA

3.3.3.3 Pole Mounted Transformers

Pole mounted transformers shall generally be in accordance with ENATS 35-1 and as detailed in the Central Networks Plant Specification Manual Section 3F.

Size / Type	Use
25 kVA single phase 2 wire	• Single direct service for domestic / farming load up to 25 kVA
50 kVA single phase 2 wire	• LV Network supplying mixed loads • Single phase loads up to 50 kVA
100 kVA single phase 3 wire	• LV Network supplying mixed loads • 480/240v split phase loads up to 100 kVA
50 kVA three phase	Single direct service for domestic load or pumping station up to 50 kVA • Must not be used for unbalanced loads as negatve phase sequence voltage may damage motors.
100 kVA three phase	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 100 kVA
200 kVA three phase	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 200 kVA
315 kVA three phase	• LV Network supplying mixed loads • Single direct service for industrial / commercial load up to 315 kVA

3.3.3.4 11kV/LV Transformer Data Tables

Transformers							
Size / Type	**Pole or Ground Mounted**	**New build size**	**R ohms**	**jX ohms**	**Max Fe Losses W**	**Max Cu Losses W**	**Max Cyclic loading**
100 kVA ANSI Padmount	GM	✓	0.0271	0.0401	200	1500	150%
200 kVA ANSI Padmount	GM	✓	0.0074	0.0258	370	1600	150%
25 kVA ENATS	PM		0.2080	0.2660			130%
50 kVA ENATS	PM	✓	0.0876	0.1440			130%
100 kVA ENATS	PM	✓	0.0371	0.0810	175	1700	130%
200 kVA ENATS	PM	✓	0.0158	0.0406	275	3000	130%
200 kVA ENATS	GM	✓	0.0158	0.0406	275	3000	130%
300 kVA ENATS	GM		0.0095	0.0277			130%
315 kVA ENATS	GM	✓	0.0090	0.0268	425	5100	130%
315 kVA ENATS	PM		0.0090	0.0268	425	5100	130%
500 kVA ENATS	GM	✓	0.0051	0.0171	600	7000	130%
750 kVA ENATS	GM		0.0031	0.0115			130%
800 kVA ENATS	GM	✓	0.0029	0.0107	1500	10000	130%
1000 kVA ENATS	GM	✓	0.0022	0.0086	1800	13300	130%
1500 kVA ENATS	GM		0.0013	0.0067			130%
50 kVA 1Ø ANSI Padmount	GM	✓	0.0182	0.0206	170	750	150%
16 kVA 1Ø ENATS	PM		0.1074	0.139			130%
25 kVA 1Ø ENATS	PM	✓	0.0612	0.0944			130%
50 kVA 1Ø ENATS	PM	✓	0.0266	0.0496	110	800	130%
100 kVA 2Ø ENATS	PM		0.0165	0.0255			130%

Note –impedances are referred to the LV side of the transformer

3.3.4 11kV Switchgear

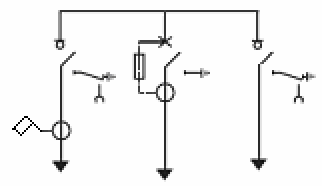
3.3.4.1 11kV Distribution Substation Switchgear

11kV Distribution Switchgear shall generally be in accordance with ENATS 41-36 with more specific technical design information, as detailed in the Central Networks Plant Specification Manual.

This secondary switchgear includes RMUs (Transformer mounted and free-standing), Metering units, Multi-panel boards for consumer s/s including extensible circuit breakers, switch disconnectors etc.

Table 3.3.4.1 1 of 7

Central Networks Contract Reference	Schneider designation	Lucy designation	Application

RMU2-CC/TLF
 	
Free standing ring main equipment with 200A circuit breaker with cable box.
 	
TLF Protection
Non extensible
630 amp switch disconnectors
Fault flow indicator & CTs on left ring switch
	Merlin Gerin Ringmaster
	
	RN2c-T1/21
	
	
		Lucy Sabre
		
		VRN2A
			• Ring feed substations with free standing equipment.
			• Switchgear replacement.
			• Transformer protection up to
			  • 1000 kVA@*11kV*
			  • *500 kVA 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using CT operated trip coils with provision for time limit fuses (TLF)
			
			Tee-off CB must not be used to feed circuits with a direct 11kV back-feed – earth switch is limited to 3.15kA fault level.

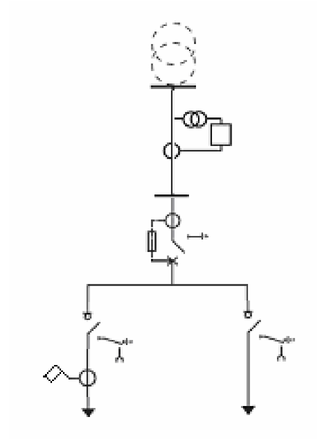
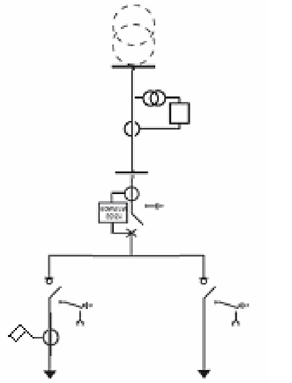
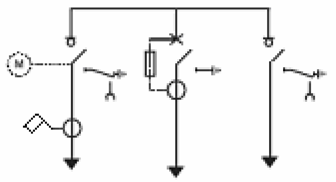
RMU2-DC/TLF
 	
Free standing ring main equipment with 200A circuit breaker complete with directly mounted 11kV metering unit.
 	
TLF Protection
Non extensible
630 amp switch disconnectors
Fault flow indicator & CTs on left ring switch
	Merlin Gerin Ringmaster
	
	RN2c-T1/21 + MU2-M2/16
	
	
		Lucy Sabre
		
		VRN2A + AIMU
			• Consumer Substations.
			• Transformer protection up to
			  • 1000 kVA@*11kV*
			  • *500 kVA 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using CT operated trip coils with provision for time limit fuses (TLF)
			
			Tee-off CB must not be used to feed circuits with a direct 11kV back-feed – earth switch is limited to 3.15kA fault level.
			
			Specify :
			VT Voltage – 11kV or 6.6kV
			CT Ratio – 100/50/5

Table 3.3.4.1 2 of 7			

RMU2-DC/REL
 	
Free standing ring main equipment with 200A circuit breaker complete with with directly mounted 11kV metering unit.
 	
Self Powered relay.
Non extensible
630 amp switch disconnectors
Fault flow indicator &
CTs on left ring switch
	Merlin Gerin Ringmaster
	
	RN2c-T2/21 + MU2-M3/16
	
	
		Lucy Sabre
		
		VRN2A + AIMU
			• Consumer Substations.
			• Transformer protection up to
			  • 3.8 *MVA@11kV*
			  • *2.3 MVA @ 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using Self Powered relay
			
			Tee-off CB must not be used to feed circuits with a direct 11kV back-feed – earth switch is limited to 3.15kA fault level.
			
			Specify :
			VT Voltage – 11kV or 6.6kV
			CT Ration – 200/100/5

RMU2-CC/AUTO/TLF/EFCT/1ACT
 	
Free standing ring main equipment with 200A circuit breaker with cable box.
 	
1 actuator. For automation use (c/w RTU)
 	
TLF Protection
Non extensible
630 amp switch disconnectors
Fault flow indicator &
CTs on left ring switch
	Merlin Gerin Ringmaster
	
	RN2C-T1/21 T200E-4MI-GPU
	
	
		Lucy Sabre
		
		VRN2A-FS
			• Automated Ring feed substations with free standing equipment.
			• Switchgear repalcement.
			• Transformer protection up to
			  • 1000 kVA@*11kV*
			  • *500 kVA 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using CT operated trip coils with provision for time limit fuses (TLF)
			
			Tee-off CB must not be used to feed circuits with a direct 11kV back-feed – earth switch is limited to 3.15kA fault level.

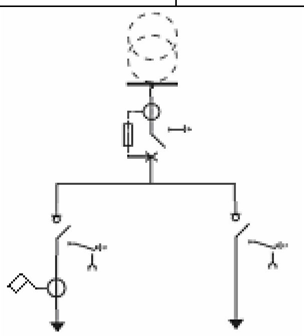
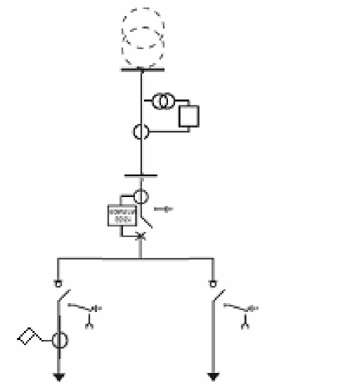
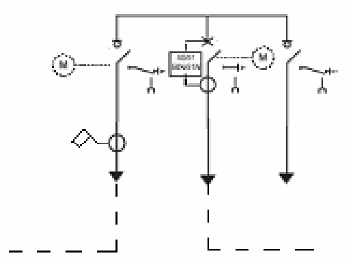
RMU2-TC/TLF
 	
Transformer mounted ring main equipment with 200A circuit breaker with cable box.
 	
TLF Protection
Non extensible
630 amp switch disconnectors
Fault flow indicator &
CTs on left ring switch
	Merlin Gerin Ringmaster
	
	RN2c-T1/21
	Lucy Sabre
	
	
		VRN2A - TC	• Compact Unit Substations
			• Transformer protection up to
			  • 1000 kVA@*11kV*
			  • *500 kVA 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using CT operated trip coils with provision for time limit fuses (TLF)
			
			Tee-off CB must not be used to feed circuits with a direct 11kV back-feed – earth switch is limited to 3.15kA fault level.

Table 3.3.4.1 3 of 7			

RMU6-DC/REL/EFCT
 	
Free standing ring main equipment with 630A circuit breaker complete with with directly mounted 11kV metering unit.
 	
Self Powered relay.
Non extensible
630 amp switch disconnectors
Fault flow indicator &
CTs on left ring switch
	Merlin Gerin Ringmaster
	
	RN6c-T1/21+ MU2-N1/16
	
	
		Lucy Sabre
		
		VRN6A +AIMU
			• Consumer Substations.
			• Transformer protection up to
			  • 3.8 *MVA@11kV*
			  • *2.3 MVA @ 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using Self Powered relay
			
			Tee-off CB may be used to feed circuits with a direct 11kV back-feed – earth switch is fully rated.
			
			Specify :
			VT Voltage – 11kV or 6.6kV
			CT Ration – 400/200/5

RMU6-CC/AUTO/REL/EFCT/2ACT Free standing ring main equipment with 630A circuit breaker with cable box. 2 actuators. For automation use (c/w RTU) Non-self powered relay Non extensible 630 amp switch disconnectors Fault flow indicator & CTs on left ring switch	Merlin Gerin Ringmaster **RN6c-T1/21 T200E-4MI-GPU** 	Lucy Sabre **VRN6A-FS**	• Network Automation • Installed with the 630 amp CB in the ring main as free standing equipment. • Switchgear repalcement. • Not used to protect local transformer Tee-off CB is used to feed circuits with a direct 11kV back-feed – earth switch is fully rated.

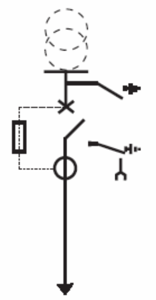
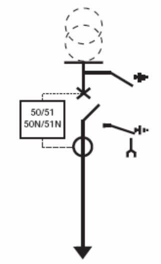
NOT ON CONTRACT
 	
Transformer mounted 200 amp circuit breaker with cable box.
 	
TLF Protection
Non extensible
Fully rated earth switch on incoming cable.
3.15kA rated earth switch towards transformer.
	Merlin Gerin Ringmaster
	
	CN2-T6
	
	
		N/A	• Radial connected transformers
			• CB is suitable for addition of remote control actuator.
			• Transformer protection up to
			  • 1000 kVA@*11kV*
			  • *500 kVA 6.6kV*
			• Overcurrent and Earth Fault Protection using CT operated trip coils with provision for time limit fuses (TLF)
			• CTs 100/50/5

Table 3.3.4.1 4 of 7			

NOT ON CONTRACT
 	
Transformer mounted 200 amp circuit breaker with cable box.
 	
Self powered relay
Non extensible
Fully rated earth switch on incoming cable.
3.15kA rated earth switch towards transformer.
	Merlin Gerin Ringmaster
	
	CN2-T1/21
	
		N/A	• Radial connected transformers
			• CB is suitable for addition of remote control actuator.
			• Transformer protection up to
			  • 3.8 *MVA@11kV*
			  • *2.3 MVA @ 6.6kV*
			• c/w Overcurrent and Earth Fault Protection using Self Powered relay
			• CTs 200/100/5

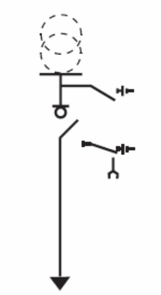
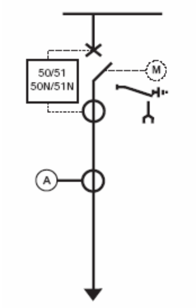
NOT ON CONTRACT Transformer mounted 630 Switch Disconnector with cable box. Non extensible Fully rated earth switch on incoming cable. 3.15kA rated earth switch towards transformer.	Merlin Gerin Ringmaster **SN6-S1/21** 	N/A	• Radial connected transformers sited remote from controlling CB or S/Fuse • Switch Disconnector is suitable for addition of remote control actuator • No Protection
ECB Extensible free standing circuit breaker 630A cable connected.	Merlin Gerin Ringmaster **CE6-T8/21** 	N/A	• Un-metered Feeder up to 12MVA • Consumer substations • CB is suitable for addition of remote control actuator. • c/w self powered IDMT Overcurrent and Earth Fault Protection using VIP 300 relay. • Protection CT's – 800/1A, Class X & Shunt Trip Coil 20v DC-250v AC • Ammeter 0 -600 amp CB may be used to feed circuits with a direct 11kV back-feed – earth switch is fully rated

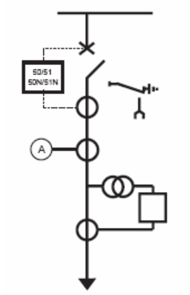
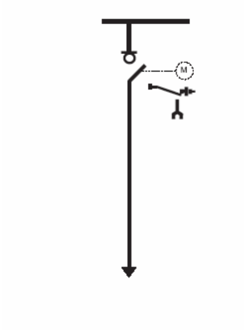
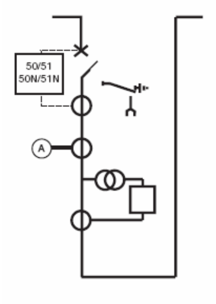
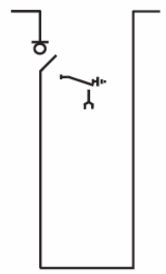
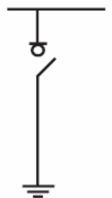
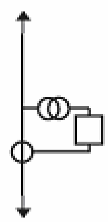
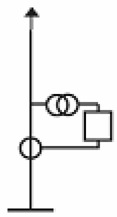
Table 3.3.4.1 5 of 7			
NOT ON CONTRACT Extensible free standing circuit breaker 630A cable connected. Metering CTs & VT	Merlin Gerin Ringmaster **CE6-T5 / 21** (CE6-T6/21 6.6kV)  	N/A	• Consumer substations • Metered consumer's feeders up to 12 MVA • CB is not suitable for addition of remote control actuator. • c/w self powered IDMT Overcurrent and Earth Fault Protection using VIP 300 relay. • Protection CT's – 800/1A, Class X & Shunt Trip Coil 20v DC-250v AC • Ammeter 0 -600 amp CB may be used to feed circuits with a direct 11kV back-feed – earth switch is fully rated
ESW Extensible free standing switch 630A cable connected.	Merlin Gerin Ringmaster **SE6-S2 / 21**  	N/A	• Ring feed substations with 3 or more feeder circuits (with Circuit Breaker CE2-T8/21 or CE6-T5/21) • Consumer substations • Switching stations • Switch disconnectors is suitable for addition of remote control actuator. • No Protection
NOT ON CONTRACT Bus Section Circuit Breaker Extensible free standing 630A Metering CTs & VT	Merlin Gerin Ringmaster **CE6-B3 / 21**  	N/A	• Consumer substations employing extensible switchgear with 630Amp SE6-S2/21 Switch Disconnectors • CB is not suitable for addition of remote control actuator. • Right hand Bus-bar Earth switch • c/w self powered IDMT Overcurrent and Earth Fault Protection using VIP 300 relay. • Protection CT's – 800/1A, Class X & Shunt Trip Coil 20v DC-250v AC • Metering 400/200/5 CTs

Table 3.3.4.1 6 of 7

NOT ON CONTRACT Bus Section Switch Extensible free standing 630A	Merlin Gerin Ringmaster **SE6-B1/21** 	N/A	• Consumer substations employing extensible switchgear with 630Amp SE6-S2/21 Switch Disconnectors. • Right hand Bus-bar Earth switch • No Protection • No Metering

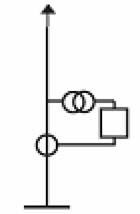
NOT ON CONTRACT
Bus-bar Earthing Switch
Extensible free standing
630A
	Merlin Gerin
	Ringmaster
	SE6-E1/21
	
		N/A	• Consumer substations employing extensible switchgear
			• Used to earth left hand bus-bars in conjunction with
			  • Bus section CB CE6-B3/21
			  • Bus section switch SE6-B1/21

FMU2 200A free standing metering unit with 11000/110 or 6600/110 VT Cable connected both sides	Merlin Gerin Ringmaster **MU2-M2/16 11kV** **MU2-M5/16 6.6kV** 	Lucy Sabre **AIMU**	Specify : VT Voltage – 11kV or 6.6kV CT Ratio 200/100/5 100 ?50/5
MU2 200A free standing metering unit with 11000/110 or 6600/110 VT Direct coupled to RMU Cable connected towards consumer	Merlin Gerin Ringmaster **MU2-M2/16 11kV** **MU2-M5/16 6.6kV** 	Lucy Sabre **AIMU**	Specify : VT Voltage – 11kV or 6.6kV CT Ratio 200/100/5 100 ?50/5

<table>
<tr><th colspan="4">Table 3.3.4.1 7 of 7</th></tr>
<tr><td rowspan="2">MU6
630A free standing metering unit with 11000/110

Direct couplet to RMU Cable connected towards consumer</td><td>Merlin Gerin Ringmaster

MU6-N1/16 11kV</td><td>Lucy Sabre

AIMU</td><td rowspan="2">Specify :
VT Voltage – 11kV or 6.6kV
CT Ration – 600/400/5</td></tr>
<tr><td colspan="2"></td></tr>
</table>

3.3.4.2 11kV Primary/Grid Substation Switchgear

11kV Distribution Switchgear shall generally be in accordance with ENATS 41-36, with more specific technical design information, as detailed in the Central Networks Plant Specification Manual.

This Primary switchgear includes indoor type multi panel switchboards etc, all available on a bulk purchase 'call-off' contract from the supplier.

The standard switchgear panel options available are all listed in the Central Networks drawings ref 02602.001 to 02602.008.

Size / Type	Use
1250Amp or 2000Amp Circuit Breaker Transformer Incomer Panel (T1/1 to T3)	• Transformer Incomer c/w protection relay functions :- LV IDMT Overcurrent, Directional Overcurrent, Restricted Earth Fault, Standby Earth Fault Stage 1 & 2, NVD, Transformer & Tapchanger Buchholz Trip & WTI Trip, Telecontrol, Auto-reclose
1250Amp or 2000Amp Circuit Breaker Bus-Section Panel (B1/1 to B4)	• Bus-section c/w protection relay functions:- IDMT Overcurrent, IDMT Earth Fault, Auto Trip Alarm, Trip Circuit Supervision, Telecontrol
630Amp Circuit Breaker Underground Feeder Panel (F1/1 to F7)	• Underground Feeder c/w protection relay functions:- IDMT Overcurrent, IDMT Earth Fault, Auto Trip Alarm, Trip Circuit Supervision, Telecontrol
630Amp Circuit Breaker Overhead Feeder Panel (F3 & F5)	• Overhead Feeder c/w protection relay functions:- IDMT Overcurrent, IDMT Earth Fault, Auto Trip Alarm, Trip Circuit Supervision, Auto-reclose, Telecontrol

3.3.4.3 Pole Mounted 11kV Switchgear

Section under preparation

3.4 Primary Network 33kV Rating and Data

3.4.1 33kV Cables

3.4.1.1 33 kV Network Cables

Single Core 33kV X.L.P.E. Insulated, Copper Wire Screened Solid Cables, Stranded Copper Conductors, Generally to BS 7870 4-10:1999, as detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.3

Size / Type	Use
150 mm^2 Cu	• Fault level must be below 21.4kA (706 MVA) for 1 second. • Earth fault level must be below 4.5kA for 1 second. • Circuit supplying 24 MVA 33/11kV transformer
400 mm^2 Cu	• Fault level must be below 57.2kA (1887 MVA) for 1 second. • Circuit supplying 40 MVA 33/11kV transformer • May be used for 24 MVA circuit where 150 mm^2 would result in excessive voltage drop.

3.4.1.2 Transformer 33kV Tails

Single Core 33kV X.L.P.E. Insulated, Copper Wire Screened Solid Cables, Stranded Copper Conductors, Generally to BS 7870 4-10:1999, as detailed in Central Networks Cables Cable Laying & Accessories Manual Section 2.3

Size / Type	Use
150 mm^2 Cu XLPE singles 1 per phase	• For use with 4/8MVA, 6/12MVA & 12/24MVA transformers. • HV tails of 33/11kV transformers • LV tails of 132/33kV transformers
400 mm^2 Cu XLPE singles 1 per phase	• For use with 20/40MVA transformers. • HV tails of 33/11kV transformers • LV tails of 132/33kV transformers
500 mm^2 Cu XLPE singles 2 per phase	• For use with 30/60/78 MVA transformers • LV tails of 132/33kV transformers
500 mm^2 Cu XLPE singles 3 per phase	• For use with 45/90/117 MVA transformers. • LV tails of 132/33kV transformers

3.4.1.3 33kV Cable Ratings

- Ambient ground temperature 10°C Winter, 15°C Summer.
- Soil thermal resistivity 0.9°C m/w Winter, 1.2°C m/w Summer.
- Loss Load Factor 0.5 - Load Curve G
- The Distribution 5 day limited time rating are not applicable to 33kV circuits as 33kV transformer repairs normally take more than 5 days to complete.
- Duct sections less than 15m long can be assumed to be laid direct.
- Cables in trefoil and solid bonded.

3.4.1.3 A Transformer Feeders - 50% utilisation – ungrouped NOTE 1									
CABLE		WINTER				SUMMER			
		Laid Direct		Ducted		Laid Direct		Ducted	
Size / Type		Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic
150mm^2	XLPE Cu singles	477	540	433	483	416	479	391	446
400mm^2	XLPE Cu singles	796	917	693	785	690	807	619	718
500mm^2	XLPE Cu singles	900	1041	776	883	778	916	691	806
NOTE 1 – Assumes that only one circuit is running at full load and the other is dead.									

3.4.1.3 B Interconnectors - 100% utilisation – group of 2 spaced 300mm apart NOTE 2									
CABLE		WINTER				SUMMER			
		Laid Direct		Ducted		Laid Direct		Ducted	
Size / Type		Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic	Sustained	Cyclic
150mm^2	XLPE Cu singles	426	482	387	432	368	424	344	392
400mm^2	XLPE Cu singles	675	805	610	691	602	704	537	623
500mm^2	XLPE Cu singles	681	910	681	775	676	796	597	697
NOTE 2 – Assumes that both cables are simultaneously running at full load e.g. to provide support during a 132kV outage. If the two cables are thermally independent – e.g. on separate routes then use Table 3.4.1.3A Ratings For cable separation other than 300mm consult the Assets Manager.									

3.4.1.4 33kV Transformer Tail Rating Tables

Transformer tails are based on Sustained ratings on the basis that:

- Transformer repairs will normally take more than 5 days top complete
- Load cycles may be less favourable than Engineering Recommendation P17 'Load Curve G'.

Assumptions

- Values for average environmental conditions
- Ambient ground temperature 10°C Winter 15°C Summer.
- Soil thermal resistivity 0.9°C m/w Winter, 1.2°C m/w Summer

- For other conditions including cables in air or clipped to wall use Engineering Recommendation P17 tables with all appropriate correction factors.
- Duct sections less than 15m long can be assumed to be laid direct.

Table 3.4.1.4. A

Transformer 33kV XLPE Tails Sustained Ratings

Formation	Size	Type	Winter amps		Summer amps	
A In trefoil – 1 core per phase	150mm^2	Cu Singles	482	477	421	416
R YB	400 mm^2	Cu Singles	816	796	707	690
	500mm^2	Cu Singles	926	900	802	778
B Laid singly – 1 core per phase – 2D spacing between cores	150mm^2	Cu Singles	511	489	445	425
	400 mm^2	Cu Singles	876	787	759	678
R Y B	500mm^2	Cu Singles	1003	879	867	755
C Laid singly – 1 core per phase - ducts touching	150mm^2	Cu Singles	473	442	429	399
R Y B	400 mm^2	Cu Singles	806	699	724	623
	500mm^2	Cu Singles	921	779	825	692
D In trefoil – 2 cores per phase - 300mm spacing	150mm^2	Cu Singles	418	414	362	359
R R YB YB	400 mm^2	Cu Singles	696	679	599	584
	500mm^2	Cu Singles	787	764	676	656
E Laid singly – 2 cores per phase - ducts touching	150mm^2	Cu Singles	390	368	346	326
R R YB YB	400 mm^2	Cu Singles	651	579	574	508
	500mm^2	Cu Singles	740	645	650	565
F In trefoil – 3 cores per phase - 300mm spacing	150mm^2	Cu Singles	374	371	323	320
	400 mm^2	Cu Singles	616	602	529	516
R R R YB YB YB	500mm^2	Cu Singles	695	675	596	578
G Laid singly – 3 cores per phase - ducts touching	150mm^2	Cu Singles	346	327	304	286
R R R YB YB YB	400 mm^2	Cu Singles	573	509	500	443
	500mm^2	Cu Singles	649	566	566	492

Cable screens bonded to earth at one end only – NORMAL ARRANGMENT

Cable screens bonded to earth at both ends – DO NOT USE

The current ratings are given for each core. For the total capacity of multiple cores per phase multiply the rating by the number of cores.

Transformer Nameplate Rating		CER Winter		CER Summer		Tails per phase	Current per core	
		MVA	Amps	MVA	Amps		Winter	Summer
6/12 MVA	33kV	12	210	9.5	166	1 x 150mm^2	210	166
12/24 MVA	33kV	24	420	19	332	1 x 150mm^2	420	332
20/40 MVA	33kV	40	700	32	560	1 x 400 mm^2	700	560
30/60/78 MVA	33kV	78	1365	60	1050	2 x 500 mm^2	683	525
45/90/117 MVA	33kV	117	2047	90	1575	3 x 500 mm^2	682	525

EATL 'CRATER' Spreadsheet settings used for Transformer Tail Ratings							
	Common settings						
Cable Characteristics							
Cable type	Copper wire screen BS 7870-4.10 (11kV)						
Conductor	Copper stranded						
Conductor size mm^2	150, 400 & 500						
Insulation type	XLPE						
Sheath type	Polyethylene						
Colour of Sheath	N/A						
Cu Wire Screen area mm^2	35 mm^2						
Bonding arrangement	Single point & Solid, No Transposition as required						
Operating Conditions							
Environment	In soil						
Drying out of soil	No Account taken						
Conductor temp	90 ^oC						
Soil Temp	10 ^oC Winter 15 ^oC Summer						
Soil Thermal Resistivity	0.9 m^{o}C/W Winter 1.2 m^{o}C/W Winter						
Soil depth	600 mm						
Loss Load Factor	1.0 (set to 1.0 so that Dist/Cyclic/Sust rating are equal)						
Utilisation %	100% (set to 100% so that Dist/Cyclic/Sust rating are equal)						
Limited Time days	N/A						
Cable Grouping	See below						
Soil Thermal diffusivity	5.0E-07x(0.9/g)^0.8						
Soil depth measured to	Top surface						
	Arrangement						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Cable grouping	No	No	No	Yes	Yes	Yes	Yes
Cable & Duct configuration							
Single core in trefoil	Y			Y		Y	
Single cores flat 2D Spacing between centres		Y					
Three ducts flat touching			Y				
Three ducts flat 2D spacing							
Three ducts in trefoil					Y		Y
One duct 3 singles in trefoil							
Duct Characteristics							
Duct type	Ridgiduct						
Duct size	125mm ID 148mm OD						
Grouping							
Grouping – trefoils flat	N/A	N/A	N/A	Y	Y	Y	
Grouping -trefoils tiered	N/A	N/A	N/A				Y
Spacing mm	N/A	N/A	N/A	300	225	300	225
No of Trefoils				2	2	3	3
				The Distribution rating as displayed on the 'Grouped' result screen is equal to the Sustained rating because Loss Load Factor is 1.0 & Utilisation is 100%			

3.4.1.5 33kV Cable Data Tables

Under preparation

CABLE		1 sec S/C rating		Resistance		Reactance		% Volt drop	Losses
Size	Type	Core kA	Screen kA	R W /km	%	jX W /km	%	per km per MVA	per km per MVA

3.4.2 33 kV Overhead Lines

3.4.2.1 33kV Conductors

Normal applications: 33kV unearthed bare wire construction shall generally be to ENATS 43-40 as detailed in Central Networks Overhead Manual Volume 1.

Special applications for wooded areas, protection of water-fowl, recreational areas: 33kV unearthed covered conductor construction shall generally be to ENATS 43-40 and ENATS 43-119,120,121. There is no standard Central Networks standard for covered conductor lines – refer to the Assets Manager for guidance.

Steelwork and fittings generally to ENATS 43-95 as detailed in Central Networks Overhead Manual Volume 2.

Size / Type	Use
150 mm^2 ACSR (Dingo) Central Networks East	• Fault level must be below 13.5kA (780 MVA). • Circuit supplying 24 MVA 33/11kV transformer
300 mm^2 HDA (Butterfly) Central Networks East	• Fault level must be below 23.4kA (450 MVA). • Circuit supplying 40 MVA 33/11kV transformer • May be used for 24 MVA circuit where 150 mm^2 would result in excessive voltage drop.
100 mm^2 AAAC (Oak) Central Networks West	• 22 MW Circuit
200 mm^2 AAAC (Poplar) Central Networks West	• 36 MW Circuit

3.4.3 33/11 kV Transformers

33/11kV & 33/11-6.6kV Dual Ratio Primary Transformers shall generally be in accordance with ENATS 35-2 with more specific technical design information, as detailed in the Central Networks' Plant Specification Manual.

Size / Type	Application
4/6/8MVA 13% Impedance @ 8MVA	• Primary Substations • HV Network supplying mixed loads up to 8 MVA • Industrial / commercial load up to maximum 6.2 MVA
6/9/12MVA 12% Impedance @ 12MVA	• Primary Substations • HV Network supplying mixed loads up to 12MVA • Industrial / commercial load up to maximum 9.6 MVA,
12/19/24MVA 24% Impedance @ 24MVA	• Primary Substations • HV Network supplying mixed loads up to 24 MVA • Industrial / commercial load up to maximum 19 MVA,
20/32/40MVA 28% Impedance @ 40MVA	• Primary Substations • HV Network supplying mixed loads up to 40 MVA • Industrial / commercial load up to maximum 32 MVA,

The above ratings relate to the cooling designations of ONAN/OFAF/OFAF CER where :-

i) ONAN (Oil Natural Air Natural) is the BS rating with natural oil circulation cooling only, i.e. without fans and pumps and at an ambient temperature of 20 deg C.

ii) OFAF (Oil Forced Air Forced)is the BS rating with forced (pumps) and air forced (fans) cooling, again at an ambient temperature of 20 deg C

iii) OFAF CER (Oil Forced Air Forced Certified Emergency rating) is the Continuous Emergency Rating, again with the fans and pumps in operation but at a lower ambient temperature of 5 deg C

Mixed loads - the OFAF rating at 5^{O}C is applicable

Industrial / Commercial loads - the OFAF CER rating at 20^{O}C is applicable

3.4.3.1 Standard Designs

The standard transformer designs are of the compact design incorporating the following features:-

Integral Coolers (Tank mounted radiators) including fans and pumps.

Integral 11kV Neutral Earthing Resistor (Tank mounted NER)

Integral Cooler & Voltage Control Cubicle.

Separable Elbow type cable terminations for both the 33 & 11kV.

Standard Central Networks equipment is intended for new-build applications with no exceptional conditions prevailing.

The designer must confirm that the standard plant will be suitable for the actual application. Where exceptional conditions are identified assistance must be obtained from the Central Networks Asset Standards Manager.

3.4.3.2 Identification of exceptional Conditions

Examples of the exceptional conditions that would need 'non standard' designs and special ordering include:-

Overhead type terminations, new shopping centre and underground/basement type applications, noise enclosures, installation in existing sites with separate cooler type plinths, non-standard impedance and/or NER ratings for local network peculiarities.

3.4.4 33 kV Switchgear

Under preparation

3.5 Grid Network 132kV Ratings and Data

3.5.1 132 kV Cables

Under preparation

3.5.2 132 kV Overhead Lines

Under preparation

3.5.3 132/33 kV & 132/11kV Transformers

Under preparation

3.5.4 132kV Switchgear

Under preparation

4. Network Voltage Policy

4.1 Voltage Limits

The network shall be designed to keep voltage levels within the statutory limits of:

- Customer connected at Low Voltage – 230 volts +10% - 6%
- Customers connected at High Voltage (6.6, 11 & 33kV) declared voltage +/– 6%
- Customers connected at Extra High Voltage (132kV) declared voltage +/– 6%

4.1.1 Use of the Voltage Limits

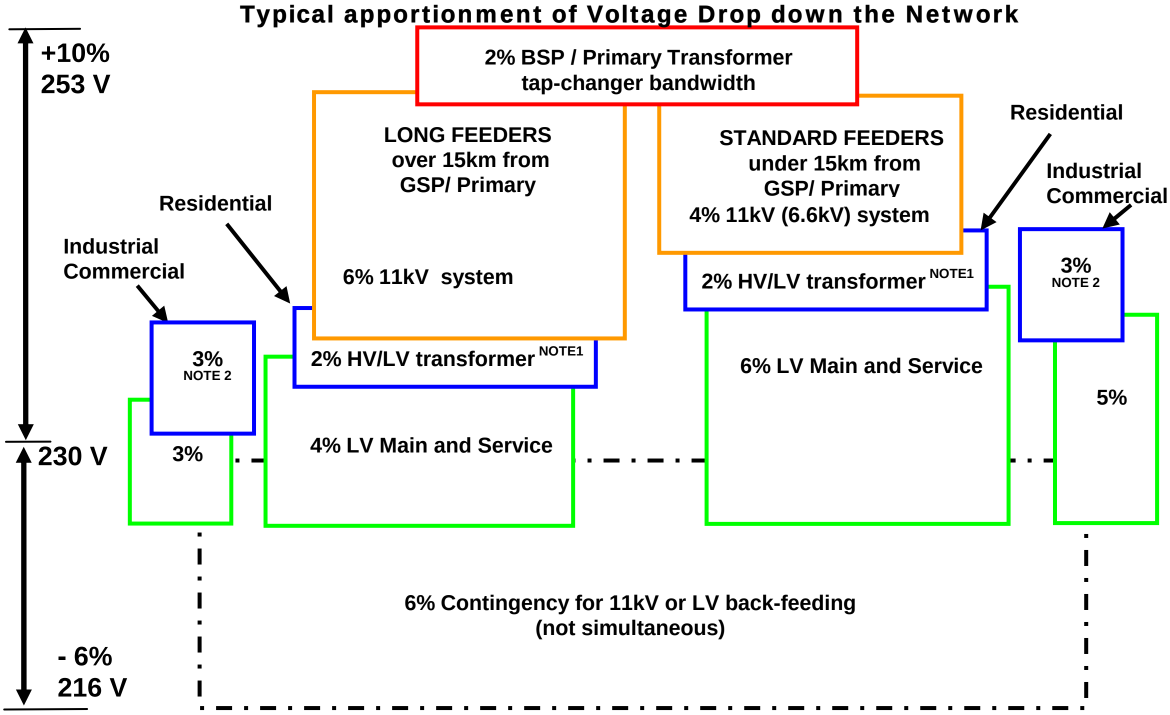
The 11kV and LV network shall be designed to make use of the full extent of the statutory limits taking into account normal and abnormal feeding arrangements.

To enable rational design of the network by independent parties the voltage limits are sub-divided and allocated to discrete elements of the network.

The allotment voltage drop to the HV/LV transformer and LV network will depend on the 11kV feeder length, loading and power factor. 11kV feeders extending further than 15km from the BSP/Primary substation should be classified as 'long' and the amount of voltage drop apportioned to the LV network may need to be reduced in line with the diagram below.

NOTE that the statistical likelihood of maximum voltage drop occurring simultaneously in each element of the network is remote. The overlap between network elements represents the performance of the overall network in reality.

Typical apportionment of Voltage Drop down the Network



NOTE 1 - 2 % in distribution transformer assumes power factor of unity and 100% loading.

NOTE 2 - 3 % in distribution transformer assumes power factor of 0.95 and 100% loading.

4.2 Voltage Control

The on-load tap changers on 132/11kV, 66/11kV, & 33/11kV transformers at Grid and Primary substations are the final stage of automatic voltage control on the network. The bus-bar voltage levels must not be allowed to exceed values that will cause customers to receive voltage above the statutory maximum. The worst case scenario is an LV customer connected adjacent to the first secondary substation on an 11kV (or 6.6kV) feeder at the time of minimum load.

The voltage on the LV bus-bars of secondary transformers depends on:

- The voltage of the input voltage at that part of the 11kV network.
- The nominal ratio of the secondary transformer
- The setting of the off-load tap changer of the secondary transformer.
- Voltage drop in the secondary transformer due to load

The nominal ratio of a standard secondary transformer is 11kV to 433v (250v). In effect this gives a 4% boost above 415v (240v) which used to be the nominal LV network voltage (pre 1998 the statutory limits were 240v +/- 6%).

Transformers at Secondary substations are fitted with off-load tap changers which have the following ranges:

Transformer type	Tap number				
	1	2	3	4	5
11kV/LV single ratio	+5%	+2.5%	0%	-2.5%	-5%
6.6kV/LV single ratio	+5%	+2.5%	0%	-2.5%	-5%
11/6.6kV/LV dual ratio					
set to 11kV	+5%	+2.5%	0%	-2.5%	-5%
set to 6.6kV	+8%	+4%	0%	-4%	-8%
Single phase pole transformers	+5%		0%		-5%

Note

The + & - % values refer to the number of turns on the HV winding. Therefore a +5% setting **reduces** the LV voltage by 5% and a -5% setting **increases** the LV voltage for a given 11kv input voltage.

The majority of off-load tap changers of secondary transformers are set to tap 3. However, there are variations throughout Central Networks for historical reasons or to meet local network needs. e.g.

- The 11kV network in Leicester City centre is run on tap 2 to allow a running level of 11.4kV to maximise load transfer capacity.
- May parts of Lincolnshire run on tap 4 to allow for voltage drop on long feeders.

4.3 Grid & Primary Substation 11kV Bus Bar Voltages

Designers of new Primary and Grid substations shall establish what the local running voltages and distribution taps settings are and ensure that the 11kV or 6.6kV bus-bar voltage remains within a 2% bandwidth peaking at the following voltages:

Tap setting of distribution transformers	Maximum Primary/Grid S/S bus bar voltage	
	11kV system	**6.6 kV system**
Tap 5	10.60 kV	6.15 kV * (-8.0% tap)
Tap 4	10.85 kV	6.4 kV * (-4.0% tap)
Tap 3	11.13 kV	6.68 kV
Tap 2	11.40 kV	6.85 kV * (+2.5% tap)
Tap 1	11.69 kV	7.01 kV * (+5.0% tap)

Note

*Most 6.6kV systems will have a mixture of dual ratio and single ratio transformers. The 6.6kV bus bar voltage has been selected to keep the transformers on the most unfavourable tap ratio inside the upper statutory limit.

4.4 11kV Network Voltage Regulation

4.4.1 Standard Feeders

- Designers of 11kV networks shall ensure that under normal feeding arrangements the 11kV voltage drop shall not exceed 4% at the normal open point.
- The 11kV network must be designed to ensure that during abnormal feeding the overall 11kV voltage drop at any part of the system does not exceed 10%. (i.e. back-feeding may use some or all of the 6% contingency element).

4.4.2 Long Feeders

- Long rural feeders may be designed to have a voltage drop that does not exceed 6% at the normal open point. The voltage drop allocated to the LV network must be reduced by 2%. This applies to the entire feeder as LV networks close to the source will be affected by large HV voltage drop during back feeding.
- The 11kV network must be designed to ensure that during abnormal feeding the overall 11kV voltage drop at any part of the system does not exceed 12%. This may be achieved by ensuring that appropriate load transfers can be made to reduce the load on associated parts of the network affected by or providing the back feed.
- A 'Long Feeder' is defined as extending beyond the 15km radius of a Bulk Supply Point or Primary Substation.

- Some feeders constructed of large cross-section conductors may be capable of maintaining the 11kV voltage to within "Standard Feeder" limits. Where calculations show this is feasible a feeder extending beyond the 15km radius may be defined as "Standard Feeder".

4.4.3 HV Customers

- High voltage metered customers must be maintained within nominal voltage +/- 6%.
- An 11kV feeder supplying only HV customers may be designed to 6% voltage drop.
- Where LV customers are supplied from the same 11kV circuit the apportionment of voltage drop to the LV networks must be reduced according to the 'Long Feeder' criteria.

4.5 Secondary Transformer Voltage Regulation

The voltage drop through a secondary transformer depends on the load and the power factor of the load.

	% voltage drop at Power Factor					
Size kVA	**Unity**	**0.99**	**0.98**	**0.95**	**0.9**	**0.8**
1000	1.4	2.7	3.3	4.3	5.4	5.7
800	1.3	2.5	3.0	3.9	4.9	6.1
500	1.5	2.5	2.9	3.7	4.5	5.5
315	1.7	2.6	2.9	3.6	4.3	5.1
200	1.6	2.4	2.7	3.3	3.9	4.7
100	1.8	2.6	2.8	3.4	3.9	4.6
200 padmount	0.9	1.4	1.6	2.0	2.4	3.0
100 padmount	1.6	1.9	2.1	2.4	2.6	2.9
Calculations based on the transformer data in section 3.3.3.4						

The values in the above table are at transformer name plate rating. Where the transformer is running into it's permissible overload rating the voltage drop values should be increased by the percentage overload.

A power factor of Unity may be assumed for domestic and light commercial loads and 1.5% allocated to the transformer voltage drop. Full use can me made of the 6% allocated to LV cable and service volt drop.

Industrial and heavy commercial loads will normally have a less favourable power factor often around 0.9 to 0.95. Allocate 4% to the transformer and reduce the allocation to mains and services to 5%.

Note 1 Cable loading is often the limiting factor on LV feeder length rather than voltage drop on industrial / commercial networks.

Note 2 Poor power factor may be encountered where electricity retail company's prices do not charge for maximum demand. This can be the cause voltage complaints on some industrial / commercial networks. It may be possible to redress the problem by raising the off-load tap on the secondary transformer but *care should be taken to ensure that volts do not exceed the statutory maximum at light load periods. It may be necessary to apply Line Drop Compensation at the Primary substation to buck the voltage at light loads.*

4.6 LV Network Voltage Regulation

Designers of LV networks shall ensure that under normal feeding arrangements the combined LV main and service voltage drop shall not exceed:

- Domestic housing / light commercial (up to 140kVA)
  - 6% Standard 11kV Feeders
  - 4% Long 11kV Feeders
- Industrial / heavy commercial
  - 5% Standard 11kV Feeders
  - 3% Long 11kV Feeder
  - Networks with poor power factor or transformer running on overload, the values for Standard or Long 11kV Feeders less the increase in transformer regulation over 4%.

Abnormal feeding (i.e. back-feeding) may use some or all of the 6% contingency bandwidth given that planned work should normally be time for periods of light load.

See Section 6 of this Manual for the method to be used for voltage drop calculation.

4.7 Line Drop Compensation

Line drop compensation is applied to some Primary and Grid Substations within East Midlands Electricity, but the use of this is dependent on the geographical location of the particular substation and the nature of the circuits it feeds.

During the design of line drop compensations voltage control schemes, system volt drop calculations for the 11kV outgoing feeders have to be conducted and the line drop compensation settings applied accordingly. Distribution substations supplied from the Primary or Grid Substation will then have their taps set according to their distance (circuit length) from the source, which is usually done in a ″zoned″ manner.

CAUTION. The presence of embedded generation will effect the operation of Line Drop Compensation rendering it inappropriate for some 11kV networks.

4.8 Voltage Regulators

4.8.1 LV Regulators

Historically, some voltage complaints due to long LV feeders have been resolved by installing shaded pole voltage regulators controlled by Astatic relays. Invariably the loop impedance of such networks is well outside the limits specified in the current Loop Impedance Policy. No new LV voltage regulators shall be installed on the Central Networks network.

4.8.2 Static Balancers

Interconnected Star Balancing Transformers, commonly known as Static Balancers improve voltage regulation by redistributing some of the neutral current across the phases. They have proved to be particularly useful on long LV feeders serving small numbers of customers by improving the load balance. Again, the loop impedance of such networks is often well outside the limits specified in the current Loop Impedance Policy. No new LV static balancers shall be installed as a permanent voltage complaint remedy. However, refurbished units may be used as an interim measure whilst permanent network reinforcement is organised.

4.8.3 11kV Voltage Regulators

11kV voltage regulators are not yet a standard plant item on the Central Networks network. However, their use may be developed in future to resolve issues causes by embedded generation or to deal with voltage drop on long feeder where Line Drop Compensation is not appropriate.

The voltage regulators presently available are single phase units designed for pole mounting. Only two single phase units, connected in open delta, are required to regulate a three phase line.

No 11kV voltage regulators are to be installed on the network without the involvement of Technology & Standard section of Central Networks Asset Development.

5. LV Earth Loop Impedance Policy

5.1 Introduction

Low voltage networks must be designed to provide acceptable quality of supply and safe fault clearance times. These requirements are fundamentally influenced by the loop impedance of the low voltage network comprising of the combined impedance of the transformer, LV main and service cable.

5.2 Provision of Protective Multiple Earthing

There is no maximum limit of loop impedance for a PME supply defined in either the current edition of BS7671 "Requirements for Electrical Installations" or Electricity Association Engineering Recommendation P23/1.

PME terminals may be provided at any value of loop impedance.

5.3 Specific Requirements

5.3.1 New LV networks

New LV networks shall be designed to a maximum loop impedance of 0.24 ohms at the most remote cut-out. *(Limiting factor – quality of supply - step voltage change)*

Where the LV feeder fuse is 400 amp or 630 amps, the maximum loop impedance shall be further limited to 0.19 or 0.12 ohms respectively. See Table 1. *(Limiting factor – fault clearance time)*

5.3.2 Service alterations

Where the loop impedance at the cut-out will exceed the values in Table 1, the service position shall not be permitted to be inside the building.

Where the loop impedance at the cut-out does not exceed 0.38 ohms, a 100 amp cut-out fuse may be used. See Table 3

The allowable loop impedance may be increased to 0.52 ohms provided that a 80 amp cut-out fuse is used. See Table 3

Where the loop impedance exceeds 0.52 ohms, the LV network must be reinforced to reduce it to this value.

Where the loop impedance exceeds 0.35 ohms, the customer must be advised that the loop impedance exceeds the typical maximum value shown in Engineering Recommendation P23/1 as it may affect the design of the building's electrical installation.

5.3.3 In-fill developments supplied from existing LV mains

In-fill developments supplied from existing LV mains shall be designed to a maximum loop resistance of 0.24 ohms at the service breech joints.

Where the loop resistance above exceeds 0.24 ohms, the LV network must be reinforced to reduce it to this value.

Where the loop impedance at the cut-out will exceed the values in Table 1, the service position shall not be permitted to be inside the building.

Where the loop impedance exceeds the criteria for substation fuse operation then consideration should be given to changing the fuse to a smaller size before resorting to system reinforcement subject to network loading.

5.3.4 Street lighting services

On new developments, runs over 20m of $25mm^2$ hybrid must have a loop impedance calculation carried out to confirm that the substation fuse will clear correctly and is within the limits shown in Table 1. In some circumstances it may be necessary to extend the mains cable towards the street lamp to reduce the service cable length.

Where street lamp cables over 5 metres are connected to existing mains the loop impedance calculation must be carried out to confirm that the substation fuse will clear correctly and is within the limits shown in Table 1. Again, a mains cable extension may be required.

Long runs of service cable supplying a number of lamps must be sub-fused in the first lamp on the run to protect the remainder of the service cable. The size of the sub-fuse should correlate to the loop impedance at the last lamp on the run. See Table 2.

Where the loop impedance exceeds 0.35 ohms the street lighting authority must be advised that the loop impedance exceeds the typical maximum value shown on Engineering Recommendation P23/1. The maximum cut-out fuse size should be selected from Table 4 to protect the internal wiring of each lamp.

Table 1		
LV Fuse (to BS 88 Part 5)	**Max Loop Impedance**	
	(100 sec) note1 S/S Feeder	**(5 sec)** note4 Cut out
630 Amps	0.12 ohms	0.054 ohms
400 Amps	0.19 ohms	0.096 ohms
315 Amps	0.27 ohms	0.13 ohms
200 Amps	0.45 ohms	0.20 ohms

Table 2	
Street Lamp Fuses to BS 88 part1&2	**Max Loop Impedance (100 sec)** note2
25 Amps	3.27
20 Amps	3.86
16 Amps	6.07
10 Amps	9.66
6 Amps	19.32

Table 3	
House Cut-out Fuses to BS 1361	**Max Loop Impedance (5 sec)** note3
100 Amps	0.38 ohms
80 Amps	0.52 ohms
60 Amps	0.73 ohms
45 Amps	1.00 ohms

Table 4	
Street Lamp Fuses to BS 88 part1&2	**Max Loop Impedance (5 sec)** note3
25 Amps	2.40 ohms
20 Amps	3.04 ohms
16 Amps	4.36 ohms
10 Amps	7.74 ohms
6 Amps	14.1 ohms

[note1] based on Central Networks Protection & Control Manual
[note2] based on maximum curves in BS 7654
[note3] based on table 41D in the current edition of BS7671
[note4] based on Cooper Bussmann BS Fuse Links Catalogue Jan 2003

- The 100 sec values relate to the maximum allowable fuse clearance times for Distribution Network Operator owned underground cables.
- The 5 sec values relate to the maximum allowable fuse clearance times for wiring inside buildings according to the current edition of BS7671 "Requirements for Electrical Installations (IEE Wiring Regulations 16th Edition.)"

5.3.5 Replacement or alterations to existing mains

Any work to replace or alter existing mains shall not result in an increase in the loop impedance values at the remote ends of the network.

5.3.6 Temporary Back-feeding

The loop impedance limits may be exceeded during LV back-feeding or temporary generation.

5.4 Notes of Guidance to Loop Impedance Policy

East Midlands Electricity's Loop Impedance Policy has been formulated from the following considerations:

5.4.1 Quality of supply:

The connected loads will act upon the network impedance to produce cumulative voltage drop along the cables. The magnitude of the loads, the balance across the phases and the impedance of the network all affect the voltage drop.

Disturbing loads will cause sudden changes in voltage, which may be noticed by customers even though the voltage level does not go outside statutory limits. The effects of disturbing loads are primarily influenced by loop impedance. Electricity Association Engineering Recommendation P28 recommends that the maximum step voltage change caused by a switched single phase load of 7.2kW (i.e. an electric shower) should not exceed 3%. This equates to a maximum loop resistance of 0.24 ohms. P28 requires that the 3% limit applies at the point of common coupling with other customers (i.e. the service breech joint or at the first cut-out of a looped service).

New housing developments should normally be designed with the 7.2kW/3% step voltage limit applied at every cut-out in order to pre-empt complaints from large numbers of customers affected by their own shower installations. Exceptionally, the limit may be applied at the service joint where longer mains are unavoidable such as small in-fill housing developments.

Some parts of existing networks may exhibit higher step voltage changes as they were installed according to the engineering standards applicable at the time.

5.4.2 Protection of mains & services

5.4.2.1 New developments

Feeder Protection
Central Networks policy is to fuse new LV mains such that phase to neutral faults on mains and services are cleared within 100 seconds after allowing a 15% voltage reduction for arc resistance.

House service cut-outs
Non-electric heating – 80 amps
Electric Heating 100 amp
Industrial / Commercial 100, 200, 315, 400, 630 amp as appropriate to the load.

For Central Network's standard fuse range, the corresponding loop impedances are:

Table 1	
LV Feeder Fuse (to BS 88 Part 5)	**Max Loop Impedance (100 sec)** [note1]
630 amps	0.12 ohms
400 amps	0.19 ohms
315 amps	0.27 ohms
200 amps	0.45 ohms

Table 2	
Street Lamp Fuses to BS 88 part1&2	**Max Loop Impedance (100 sec)** [note2]
25 amps	3.27
20 amps	3.86
16 amps	6.07
10 amps	9.66
6 amps	19.32

[note1] based on Central Networks CoP17 Protection & Control
[note2] based on maximum curves in BS 7654

5.4.2.2 Existing networks

Many existing LV networks have loop impedances in excess of these values in Table 1 as they were installed according to the engineering standards applicable at the time.

Where cables or overhead lines are replaced or altered it is not necessary to bring the feeder into compliance with the loop impedance value for a new network. However, the loop impedance must not be made worse as this may result in a deterioration on quality of supply (flicker and/or volt-drop) or increased operation time of protective devices. Particular care should be taken when replacing the larger sizes of copper O/H line with 95 ABC.

Where service alterations are carried out or small in-fill developments have to be supplied it may not be reasonably practicable to achieve these values of loop impedance at the cut-out. In these situations the hazard from an un-cleared service cable or cut-out fault is controlled by ensuring that the service cable does not enter the building (i.e. outdoor meter box and cable fixed externally to the wall.)

The design of hybrid service cable results in most faults self-clearing by burning back the aluminium phase core down inside the XLPE insulation. Furthermore, XLPE does not burn as easily as PVC and any fumes produced are external to the dwelling. The local neutral/earth potential rise is controlled in a safe manner by the equipotential bonding of the building's wiring according to the current edition of BS7671 "Requirements for Electrical Installations".

5.4.2.3 Long Street Lighting cables

Short lengths of street lighting cable have similar loop impedances to house services.
On new developments, runs over 20m of 25mm^2 hybrid require a loop impedance calculation to ensure that the substation fuse will clear correctly.

Where street lamp connections are made to existing mains the loop impedance must be ascertained for runs in excess of 5m of 25mm^2 hybrid.

Long runs of cable supplying a number of lamps may introduce loop impedances higher than can be protected by the substation fuse.
This can result in:

Open circuit faults presenting a danger to staff at lamp columns

Short circuits burning out entire cable runs
The lamp columns becoming and remaining alive in the street presenting a danger to passers-by and staff.

In these cases a sub-fuse must be introduced into the first lamp on the run to protect the remainder of the circuit. Then size of the sub-fuse should correlate to the loop impedance at the last lamp on the run according to Table 2 above.

5.4.3 Protection of consumer's equipment

The current edition of BS7671 "Requirements for Electrical Installations" requires that circuits be protected such that earth faults are cleared within:

5 seconds on stationary equipment
0.4 seconds on circuit supplying socket outlets.

With knowledge of the loop impedance at the supply terminals the installation designer can select appropriate fuse/MCB ratings to protect the sub-circuits.
The designer may also rely upon the Distribution Network Operator's cut-out fuse to protect the bus-bars of the installation's consumer unit.
The maximum loop impedance that will ensure a 5 second fault clearance at the consumer unit is determined by the house service cut-out fuse size as shown in Table 3.
Similarly street lamp cut-out fuses provide protection to the street lighting authority's protective devices. Maximum loop impedances at street lamps are shown in Table 4.

Table 3

House Cut-out Fuses to BS 1361	Max Loop Impedance (5 sec) [note3]
100 amps	0.38 ohms
80 amps	0.52 ohms
60 amps	0.73 ohms
45 amps	1.00 ohms

Table 4

Street Lamp Fuses to BS 88 part1&2	Max Loop Impedance (5 sec) [note3]
25 amps	2.40 ohms
20 amps	3.04 ohms
16 amps	4.36 ohms
10 amps	7.74 ohms
6 amps	14.1 ohms

[note3] based on table 41D in the current edition of BS7671

Newly designed networks should not normally produce loop impedances in excess of the above values except on long street lighting runs. In this case the street lighting designer must co-ordinate the cut-out fuse rating with the prevailing loop impedance.
This requirement is applicable to new connections whether or not a PME earth is made available.

Installations with services installed prior to the 15th Edition of the IEE Wiring Regulation 1981 need not comply with these cut-out fuse clearance times.

5.4.4 Provision of PME terminal

There is no maximum limit of loop impedance for a PME supply defined in either the current edition of BS7671 "Requirements for Electrical Installations" or Electricity Association Engineering Recommendation P23/1.

The values of loop impedance in Electricity Association Engineering Recommendation P23/1 are indicative values for the majority of installations whether they use PME or other forms of earthing. **They are not maximum values permitted for provision of PME.**

Engineering Recommendation P23/1 'Customer's Earth Fault Protection for Compliance with the IEE Wiring Regulations for Electrical Installations

This document provides guidance to electrical installation designers who need to use the loop impedance to ensure that sub circuit fuses clear within the times specified in the current edition of BS7671 "Requirements for Electrical Installations". (i.e. 0.4 seconds for portable equipment or 5 seconds for stationary equipment). This requirement first appeared in the 15th Edition of the IEE Wiring Regulation issued in 1981.

To meet this requirement, the installation designer needs to know the loop impedance at the cut-out of the property resulting from the length and size of Distribution Network Operator's LV network.

For a building with an existing service this value can be readily obtained by carrying out a loop impedance test. The value obtained must then be added to loop impedance of the internal wiring to determine whether the proposed fuse clearance times are satisfactory.

However, at the design stage of a new building there is no existing cut-out to test but the installation designer still needs to establish a loop impedance figure to base his design on. As he cannot carry out a loop impedance measurement at this stage he should normally ask the Supply Authority to provide the loop impedance of the proposed LV network at each property to be connected.

In order to prevent Distribution Network Operators being inundated with this type of enquiry, the Electricity Association produced Engineering Recommendation P23/1.

P23/1 provides a typical maximum value of LV network loop impedance (e.g. 0.35 ohm for supplies up to 100amp) with the caveat:
"Higher values could apply to consumers supplied from small capacity pole transformers and/or long lengths of low voltage overhead lines."

These values and the caveats on their use are reproduced in East Midlands Electricity's 'Notes of Guidance to Electrical Contractors on Earthing and the Characteristics of Supply'.

Table 5	
Type of supply	**Typical Max Loop Impedance**
Single or three phase supply up to 100 amps Cable sheath earth terminal	0.8 ohms
Single phase supply up to 100 amps PME or PNB earth	0.35 ohms
Three phase supply up to 200 amps PME or PNB earth	0.35 ohms
Three phase supply 200 to 300 amps PME or PNB earth	0.2 ohms
Three phase supply 300 to 400 amps PME or PNB earth	0.15 ohms

Building installation designers will normally use the above figures to design circuit protection.

Central Networks' standard LV network design procedure will not normally result in the values being exceeded on Greenfield sites.
However, in-fill developments and service alterations may result in higher values. In these cases the building installation designer must be advised of the actual values.

6. Low Voltage Network Design Calculations

6.1.1 Voltage Drop Calculation Methodology

i) Central Networks LV network design is based on the principles of ACE Report No 13:1966.

ii) LV networks for adoption may be designed to other standards (e.g. ACE Report No 49:1981 using Debut). However Central Networks will judge the design results against ACE 13 criteria.

Central Networks' application of the ACE 13 design principals is explained below.

6.1.2 Mains LV volt drop calculation:

i) First the voltage drop is calculated assuming that the customers are uniformly distributed along each section and equally distributed across the three phases. This is the Balanced Voltage Drop. In order to account for variations in customer's utilisation patterns the Balanced Voltage Drop is multiplied by Correction Factors F1 (Unbalance Factor) and F2 (Diversity Factor).

ii) The Correction Factors produce high multipliers for low customer numbers and/or low ADMDs. As the number of customers and/or ADMDs increases the Correction Factors decrease to represent the aggregation of individual utilisation patterns.

iii) The voltage drop on each section is calculated by considering the voltage drop due to customers connected to the section (distributed customers) separately from the voltage drop due to customers supplied through the section (terminal customers). The two volt drops are then summated. Note that the Diversity Factor F2 differs between the distributed and terminal calculations. The distributed calculation considers the sum of the distributed and terminal customers affecting the section whilst the terminal calculation considers only the number of terminal customers.

Volt drop due to distributed customers in section:

$$Vd = Rp*L/2 * F1*F2d*Nd*(a/3)*4.166$$

Volt drop due to terminal customers supplied through section

$$Vt = Rp*L* F1*F2t*Nt*(a/3)*4.166$$

Section voltage drop is then Vs = Vd + Vt
The cumulative voltage drop along the feeder is the sum of each section voltage drop.

Key to formulae

N = Number of customers supplied by service (e.g. 2 = loop service)
Nd = Number of customers distributed along the section of main
Nt = Number of customers terminally supplied through the section of main
Rp = phase resistance

Rn = neutral resistance
a = ADMD in kW
U = Unbalance = 1/sqrN
Unbalance Correction Factor F1 = 1+4.14U
Diversity Correction Factor F2d = 1+12/a.(Nd+Nt)
Diversity Correction Factor F2t = 1+12/a.Nt
Combined Correction Factor = F1 * F2d or F1 * F2t
4.166 = amps per kW based on 240v nominal running voltage

6.1.3 Service Voltage Drop Calculation

i) This is calculated from the single phase voltage drop due to the maximum load expected on the service. This load is estimated to be 2aN+8 kW.

ii) Service Voltdrop = (2aN+8)*4.166 * (Rp + Rn)

6.1.4 Loop impedance

Maximum earth loop resistance to the most electrically remote service cut-out shall not exceed the values detailed in the Loop Impedance Policy Section of this Manual.

7. Disturbing Loads & Distributed Generation

Under preparation

8. Environmental Requirements

8.1 Development at Sites that have Legal Environmental Protection

Certain areas of land and natural features have legal protection due to their environmental character or sensitivity. Such designations include Sites of Special Scientific Interest (SSSI), National Nature Reserves, Special Areas of Conservation and Scheduled Ancient Monuments.

It is an offence to access or carry out work on these sites without the express consent of the appropriate regulatory body. Any development proposed by the company must therefore be carried out so as to avoid any potential impact on these sites or their immediate vicinity, wherever practicable. If work cannot be planned so as to avoid these sites, consultation must be carried out with the relevant regulatory body and an appropriate consent obtained to allow agreed actions to be carried out at the site. When carrying out work that has a potential impact on SSSIs, any additional actions that could enhance the site should also be agreed with the regulatory body.

In Central Networks East the information relating to these sites is held on the company's Geographic Information System (GIS). All sites display a warning of their protection and an "environmental sensitivity" layer contains additional information that provides details about the site and appropriate contact details.

Further information regarding the legal protection of these sites and the required process of consultation, is contained in the company's Wayleaves and Property Policy and Procedures Manual."

8.2 Escape of insulating oil

The main environmental risk posed by the release of oil from equipment is the pollution of water resources such as rivers, lakes and underground aquifers. The Water Resources Act 1991 prohibits causing or knowingly permitting the discharge or entry of polluting matters, such as oil, into controlled waters.

The sections of this Manual dealing with the siting of Secondary, Primary and 1232kV substations specify the requirements for each type of installation.

8.3 Transformer loss evaluation criteria employed

i) The transformer data tables in section 3.3.3.4 of this manual shows the maximum losses of transformers purchased by Central Networks together with the maximum loading permissible on a domestic load cycle.

ii) When establishing the permissible maxim cyclic loading for each size and type of transformer Central Networks considers the environmental impact of losses. As a result the maximum cyclic loading of low loss transformers may be higher than for standard loss transformers whilst still incurring similar daily kWh losses.

iii) Accordingly, should the Applicant wish to offer a higher loss transformer than Central Networks' standard unit then the Applicant must demonstrate that the loading applied to the transformer does not result in excessive losses. In practice this means that a high loss transformer must be run to a lower loading than a standard loss unit.

iv) Generally, daily transformer losses should not exceed 1.5% of the total daily energy supplied during periods of maximum demand.

Based on a model domestic load cycle of:

7hrs @ 0.3 pu
7hrs @ 0.4 pu
2hrs @ 0.5 pu
3hrs @ 0.6 pu
3hrs @ 0.8 pu
2hrs @ 1.0 pu

9. New Network Acceptance Requirements

9.1.1.1 Scope

All new network extensions and modifications must be tested in accordance with the requirements of this Manual. This includes:

- Network installed by Central Networks direct labour and Contractors directly employed by Central Networks and their sub contractors

- Networks to be adopted by Central Networks under Ofgem's Competition in Connections process.

9.1.1.2 LV Networks and associated Substations

Test Requirements:

Tests must be carried out either before or immediately after energising the network as required by the Testing Schedule. Documented results for all tests shall be submitted to Central Networks within two working days of energisation except for those tests indicated below as being required before energising the network .

Central Networks will not energise any network extension unless the Applicant's contractor is available on site ready to commence the electrical testing required immediately after energising. This is to ensure that any unsafe electrical conditions are expediently identified and made safe. Central Networks inspectors may witness a sample of these tests.

Testing Schedule			
Equipment	**Test required**	**Action**	**When**
Each service	Insulation resistance PME & Phase identification Cut-out sealing	Over 50MΩ Mark phase colour as connected in service joint and fit PME label Insert the fuse and carrier into the cut-out and seal with plastic tick seals	*Prior to jointing* *Immediately after jointing* *Immediately after jointing the service.*
Each service	Polarity check Phase rotation (3ph) Earth loop impedance Cut-out sealing	Check according to Electricity Association Engineering Recommendation G14 Check rotation and mark ABC or ACB at cut-out. Less than 0.19 or 0.24 ohms depending on S/S fuse size Insert the fuse and carrier into the cut-out and seal with plastic tick seals	*Immediately after energising the network* *Immediately after energising the network* *Immediately after energising the network* *Immediately after testing the service.*
Each new section of main	Insulation resistance between phases and phase to neutral/earth. Continuity	Over 50 MΩ Continuity of the mains will be proved by carrying out earth loop impedance tests on each service. (see above)	*Prior to jointing* *Immediately after energising the network*
Each P.M.E. electrode	Earth resistance	Tests not required.	N/A
Substation earthing	Soil resistivity Hot Site: Cold Site:	Use to establish earthing design HV electrode resistance LV electrode resistance HV/LV separation distance Combined HV/LV electrode resistance	*All these results will be required two working days BEFORE Central Networkswill energise the substation*
LV fuse cabinet	Insulation resistance	Over 50 MΩ	*Prior to energising to network*
HV/LV transformer *Off site*	Insulation resistances HV-LV winding/earth oil moisture content oil electric breakdown strength measured losses statement of pcb content	Manufactures test sheets acceptable	*These results will be required two working days BEFORE Central Networks will energise the substation*
HV/LV transformer *On site*	Pressure test Phasing checks Tap commissioned on No load output voltage at commissioning	See HV Cable Tests Check phase rotation correct Central Networks to advise on required setting for each locality	*Prior to energising to network* *Immediately after energising the network* *Immediately after energising the network* *Immediately after energising the network*

Testing Schedule *continued*			
Equipment	**Test required**	**Action**	**When**
HV Switchgear *On site*	Pressure test Protection test, secondary injection of CB relay Dummy HV fuse trip tester for switch/fuses Functional test of interlocks and operation Busbar resistance if work includes connection or extension of busbars. Gas pressure if gas filled	See HV Cable Tests Manufactures test acceptable Test on site Check all operations 'Ducter' tests Check gauge fitted to switchgear	*All these results will be required two working days BEFORE Central Networks will energise the substation*
HV Cables *on site including compact unit substation / padmount jointed into circuit*	Pressure test Cables & switchgear only *transformer switch open* Cables, switchgear & transformer *transformer switch closed* Continuity	30 kV dc centre point earthed AB-C, A-BC 15 minutes each 18 kV dc ABC – Earth 15 minutes Check all phases have equal resistance	*All these results will be required two working days BEFORE Central Networks will energise the substation*
Completed Substation	Network phasing LV phasing HV Ring	Confirm that HV & LV busbars are National Standard (i.e. A=Red, B=Yellow, C=Blue) Where the local LV network is not national standard it may be necessary to cross or roll LV cable connections onto the LV board. Liaise with Central Networks if non National Standard phasing has to be used. Check phasing with LV interconnection (if provided) Check HV ring phasing is correct before making system parallel. (in conjunction with Central Networks System Control)	*Immediately after energising the network* *Immediately after energising the network* *Immediately after energising the network*

Insulation tests of LV equipment may be carried out using 500 or 1000 volt instruments

10. Applicable Engineering Standards

Under preparation

11. Glossary

Under preparation