ENGINEERING DESIGN STANDARD

EDS 08-0150

LONDON 33KV DISTRIBUTION NETWORK DESIGN AND CUSTOMER SUPPLIES

Network(s): LPN

Summary: This standard provides guidelines for the development of the 33kV distribution network in London and the provision of the associated customer supplies.

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Approver: Steve Mockford Date: 23/11/2015

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Reason for update: Minor version update

What has changed:

- Reference to EDS 08-0149 changed to EDS 05-0002
- Reference to ECS 06-0030 updated to EDS 06-0019
- The extent and provisions of supplies from the London 33kV network has been clarified in all relevant sections.
- London 33kV distribution network map added as Appendix A
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1 Introduction

This standard provides guidelines for the development of the 33kV distribution network in London and the provision of the associated customer supplies.

In response to customer requirements, the London 33kV network has been developed to provide high resilience connection for point loads with a maximum demand between 8MW and 15MW and building services being adapted to support 33kV rather than 11kV connections.

2 Scope

This standard covers distribution networks supplying large point loads at 33kV in London including:

- Load characteristics.
- Grid substations.
- Feeder groups.
- Switchgear.
- Protection.
- Earthing.
- Civils.
- Customer substations.
- Customer LV supplies.
- Network implementation.
- Auto switching.

3 Abbreviations and Definitions

3.1 Abbreviations

<table>
<thead>
<tr>
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<tr>
<td>CBF</td>
<td>Circuit Breaker Fail</td>
</tr>
<tr>
<td>DEF</td>
<td>Directional Earth Fault</td>
</tr>
<tr>
<td>DOC</td>
<td>Directional Over-Current</td>
</tr>
<tr>
<td>DUoS</td>
<td>Distribution Use of System</td>
</tr>
<tr>
<td>IDNO</td>
<td>Independent Distribution Network Owner</td>
</tr>
<tr>
<td>MPAN</td>
<td>Meter Point Administration Number</td>
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<tr>
<td>OD</td>
<td>Outside Diameter</td>
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<tr>
<td>POC</td>
<td>Point of Connection</td>
</tr>
<tr>
<td>REF</td>
<td>Restricted Earth Fault</td>
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<tr>
<td>XLPE</td>
<td>Cross-linked Polyethylene</td>
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3.2 Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Bussing</td>
<td>A section of busbar at a grid substation that is fed by a different grid substation</td>
</tr>
<tr>
<td>Grid Substation</td>
<td>Transformation and switching point from an upstream voltage of 132kV</td>
</tr>
<tr>
<td>HV</td>
<td>The ESQCR Regulations 2002 (3) defines HV as ‘any voltage exceeding LV’. It should be noted that HV is a term used in the UK and many legacy documents (including those referenced in this standard) define this to be 11kV and 6.6kV. This should be taken into account when cross referencing with other documents</td>
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<tr>
<td>LV</td>
<td>Voltages of 1000V or less</td>
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<tr>
<td>n-1</td>
<td>First system outage</td>
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<tr>
<td>Primary Substation</td>
<td>Transformation and switching point from voltages below 132kV to supply 11/6.6kV distribution network or customers</td>
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4 Network Configuration

4.1 Load Characteristics

A 33kV distribution network has been established to supply point loads above 5MVA in London. The extent of the network is shown in Appendix B.

Service congestion in the public highway and increasing load densities, as a result of large office developments and data centres, has necessitated a move to a higher distribution voltage than 11kV.

The majority of buildings requesting new connections in the City of London are large in area and the plots are very densely populated. Many tenants and owners are from the financial or insurance sectors where electricity supply resilience is critical and developers can offer good supply resilience as a strong selling point. As such, the developers are typically requesting and paying for supply resilience, in excess of that required by ENA ER P2/6, from two grid substations.
4.2 Grid Substations

In the first instance 132/33kV substation assets in the vicinity of the 33kV network in London shall be utilised to provide the required 33kV connections.

The need for future increases in capacity is to be catered for by upgrading existing substations or constructing new substations in accordance with the 'ideal' single line diagram shown in Figure 4.1. The bussing bar concept is explained in Appendix A.

![Figure 4.1 – ‘Ideal’ 132/33kV Grid Substation Configuration](image)

Figure 4.1 is provided for guidance only, and is not intended to be overly restrictive to planners and designers. For example:

- Additional switch positions may be justified to cater for radial/ring feeds to nearby customers.
- Due to space constraints within existing transformer chambers, 60MVA cyclic rated transformers may offer a more economical solution. **Note:** A new generic transformer may need to be specified and sourced to support this scenario.

4.3 Feeder Groups

Feeder groups typically consist of four circuits rated at 30MVA each to give an n-1 firm rating of 90MVA\(^1\). The feeder group spines shall be run between two grid substations (each with a summer firm rating of 120MVA) as shown in Figure 4.2. Customers shall be connected into a main spine via a loop in/out arrangement (switchboard to have 2 x incomer and 1 x metered circuit-breakers as a minimum), with up to 22.5MVA ideally being connected to a single feeder via one or more customer substations. Refer to Appendix B for a typical 33kV network.

Refer to EDS 02-0034 for the standard sizes of 33kV single core XLPE cables and the associated technical information.

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\(^1\) The developments currently use feeder groups with circuits rated at 20MVA to give an overall n-1 firm rating of 60MVA. **Note:** The protection settings will need to be reviewed when they are reclassified at 30MVA in the future.
Feeder and transformer CBs are distributed between all busbar sections as required for the local network configuration. This will also determine which bus-section/coupler CBs are normally open and if auto-switching is required.

Figure 4.2 – Feeder Group Arrangements with Bussing Busbar Concept
5 Network Design

5.1 Cables and Ducts

Cables shall be rated to 30MVA which can usually be provided by a 630mm² copper conductor, XLPE insulated, 50mm² copper wire screen cable.

The standard duct block configuration for a 33kV feeder group main spine is shown in Figure 5.1 and should be used wherever possible.

(i) 200mm OD Emtelle duct, with 3 x 33kV XLPE cables in trefoil.
(ii) 88.9mm OD Emtelle duct, with 1 x 7-core pilot cable.
(iii) 88.9mm OD Emtelle duct, with 2 x sub-ducts, each containing 1 x fibre optic cable.
(iv) 88.9mm OD Emtelle duct, with 3 x sub-ducts, each containing 1 x fibre optic cable.
(v) Earth cable may be required to be run out for some distance (depending on earthing design) from primary and customer substations.

Figure 5.1 – Standard Duct Block Configuration for 33kV Main Spine

5.2 Switchgear

The switchgear shall be suitable for a system voltage rated for 33kV nominal.

The 33kV three-phase fault level at the customer’s point of connection (assuming an infinite infeed at 132kV with three transformers) is approximately 21kA therefore the switchgear short-time withstand current should be 25kA. However, to allow for the connection of generation\(^2\) in the network switchgear rated at 31.5kA should be considered. Refer to EAS 00-0003 for the approved switchgear.

The equipment shall be suitable for networks having the neutral point of source transformers solidly or impedance earthed.

\(^2\) Generation of 10MVA at the customer’s 11kV busbars will contribute approximately 1kA to the three-phase fault level at 33kV.
5.3 Protection

This section provides an overview of the protection and auto-switching philosophy. Refer to EDS 05-0030 for specific details.

5.3.1 Protection Block Diagram

A simplified single line diagram depicting the proposed operation of a typical 33kV distribution feeder group network is shown in Figure 5.2. The 33kV distribution network feeder groups shall be run closed, with each section of cabling being unit protected to prevent disturbances to customers for n-1 circuit faults. The design is largely based on an HV ring connection.

![Diagram showing protection and auto-switching philosophy]

Figure 5.2 – Protection Overview

5.3.2 Customer Protection Scheme Requirements

1. All customer switchboards shall be protected by circulating current busbar protection which will trip all incoming circuits into the switchboard and services out of the switchboard.

2. All customer services shall be unit protected with backup provided by directional overcurrent (DOC) and directional earth fault (DEF). This back-up will have circuit breaker fail (CBF) enabled which will trip the incoming circuits if a service circuit-breaker is deemed to have failed.

3. Interconnectors at customer substations adjacent to other customer 33kV substations on parallel 33kV circuits shall also have unit protection. Should the unit protection pilot wires fail at these points an overcurrent and earth fault facility should be then enabled within the unit protection relay. There shall be no provision for DOC and DEF on these
interconnections but CBF shall be installed on a separate relay to the unit protection relay which will trip the grid circuit-breakers if the interconnected customer circuit-breakers are deemed to have failed.

4. In the event of a two section customer switchboard, two zones of busbar protection shall be utilised. If current transformers can only be fitted to one side of a circuit-breaker, two protection elements on one unit protection relay will be used.

5. DEF relays shall be used at customer substation incomers as fault passage indicators.

6. Customer services on the customer side shall have overcurrent and earth fault protection and any suitable protection that is required by the customer’s design which is acceptable to UK Power Networks.

5.3.3 Grid Substation Protection Scheme Requirements

1. Grid substation incoming circuit-breakers shall have bias differential transformer protection as a main protection with a two stage standby earth fault and LV and HV restrictive earth fault (REF). As a back-up, the incoming circuit-breakers will have overcurrent and earth fault with circuit-breaker fail (CBF) enabled.

2. All busbar zones will have circulating current protection and overcurrent and earth fault graded protection as back-up.

3. Grid substation feeders will be unit protected and have overcurrent and earth fault graded protection as back-up protection.

4. Grid substation interconnectors shall be unit protected and fitted with overcurrent and earth fault back-up protection.

5. The following rules shall also apply to grid substation interconnectors:

- Bussing busbar (load-end, as designated by Network Control) is graded to operate first.
- In the event of a fault on the interconnector, the incoming circuit-breaker on the bussing busbar circuit-breaker only opens for fault current running in a direction away from the bussing bar.
- At the main busbar (feed-end, as designated by Network Control), the overcurrent and earth fault protection is graded to operate second to switch out the faulted feeder.
5.3.4 Auto-switching and Feeder Group Setting

This section provides an overview of the auto-switching philosophy. Refer to EOS 05-0031 for further details.

Flexible auto-switching shall be provided by a programmable microprocessor auto switching relay as follows:

- The signalling is to be provided via a fibre optic cable between the grid substations.
- For the loss of a transformer, the relay will initiate a pre-programmed switching sequence to transfer the group feeder load to the other substation.
- If a change of supply end is required, then the main busbar is isolated by opening the bus-section (bus-coupler for double busbar equipment), and the remote auto-switching is signalled to close the bussing bus-section to energise the feeder group from the remote end.

5.4 Substation Earthing

It is important that the earthing for the UK Power Networks and customer substations are considered at an early stage to ensure that a suitable substation earthing system can be installed during the construction of the building foundations. Refer to EDS 06-0019 which includes further guidance for developers.

5.5 Substation Accommodation and Civil Requirements

The arrangements for accommodating the UK Power Networks switchgear and the customer’s switchgear shall be in accordance with EDS 07-0020.

In order of preference the following shall be provided:

1. Separate buildings for UK Power Networks and the customer with a cabled connection between UK Power Networks and the customer’s equipment. The UK Power Networks substation building shall normally be provided by the customer and shall contain all of UK Power Networks’ connection assets. Access to this substation shall be restricted to UK Power Networks operational/authorised personnel only.

2. Separate but adjacent switch rooms within the same building owned by the customer. As above, a cabled connection shall be provided between UK Power Networks and the customer’s equipment, and access to the UK Power Networks switch room shall be restricted to UK Power Networks operational/authorised personnel.

In all cases the UK Power Networks switch room shall be accessible from an external door which has direct vehicular access suitable for plant delivery. Provision of other access and emergency egress doors shall comply with the door requirements detailed in EDS 07-0105 and EDS 07-0020.

Where required, the customer shall also carry out the civil works to provide an access roadway, site fencing and a building to house plant and equipment. These shall all be constructed in accordance with EDS 07-0020, EDS 07-0105 and EDS 07-0021.

The physical dimensions of the required spatial accommodation at each voltage and for each arrangement are provided in EDS 07-0020.
6 Customer Supplies

6.1 Customer Substations

Where a customer is in the vicinity of the London 33kV distribution network in London large point loads (typically \geq 5MVA) will usually be supplied at 33kV. Due to the protection requirements of this network, the customer substation shall contain a three-panel single busbar switchboard (two incomer circuit-breakers and one metered service circuit-breaker) as a minimum requirement. However, in most cases it is envisaged that customers of this type shall require multiple metered infeeds, with five and seven-panel switchboards being common where the customer chooses to step down to 11kV, or have one or more firm 33kV internal building ring networks. Five and seven-panel switchboards also add extra resilience compared to a three-panel switchboard, as the customer will remain on supply for a fault on one of the busbars. Typical 33kV switchboard single line configurations are shown in Figure 6.1, Figure 6.2 and Figure 6.3.

Contractually, parallel services shall not be allowed within a customer network that is supplied from more than one UK Power Networks substation as there are safety issues in terms of protection for both the customer and UK Power Networks. A mechanical and/or electrical interlocking system shall be provided depending on the type of switchgear in accordance with EDS 05-0002.

Note: Although loads below 5MVA are not desirable due to load balancing issues, smaller loads may be considered at the discretion of Asset Management.

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**Figure 6.1** – Customer Substation Three-panel Switchboard (Minimum Requirement for 33kV POC)

**Figure 6.2** – Customer Substation Five-panel Switchboard
6.2 Separation of UK Power Networks and Customer HV equipment

The preference is for physical separation of the UK Power Networks HV equipment from the customer's HV equipment for reasons of safety and authorisation. Both the customer and UK Power Networks need to retain full rights of access and operation over all the equipment they own. In order to realise this design the UK Power Networks substation shall include only the UK Power Networks equipment required to supply the customer substation.

An HV substation shall be used to provide the customer with full control over their equipment. It is anticipated that end users shall be supplied by transformers on an n-1 contingency basis. It is assumed that the transformer shall be owned and operated by the customer, in practice this shall be negotiated between the customer and UK Power Networks during the connections process. In cases where UK Power Networks own and operate the transformers, they shall be housed within the UK Power Networks' substation with suitable changes to the metering points.

6.3 LV Supplies

The 33kV network shall supply large commercial or domestic customers. It is the customers' responsibility to distribute the 33kV throughout their development and transform it directly to lower voltages for their end users (for example 11kV or 400/230V). The installation and maintenance of all equipment (transformer, switchgear etc) associated with these supplies is the responsibility of the customer. These supplies shall be independent of the UK Power Networks local network.

6.4 Generation

Where the customer also has on-site generation either a generator inhibit shall be provided in accordance with EDS 05-0002 or paralleling arrangements agreed with UK Power Networks' Network Control.

6.5 Emergency Trip

A customer emergency trip shall be provided in accordance with EDS 05-0030 and EDS 05-0002.
6.6 Metering Options

The following sub-sections outline the metering options available to customers:

- Where all end connections within a building network are equipped with full settlements metering issued from UK Power Networks MPANs, a CT chamber shall not be installed nor any integral CTs connected.

- Where some but not all end connections within a building network are equipped with full settlements metering issued from UK Power Networks MPANs, a CT chamber shall be installed or integral CTs connected as appropriate.

- Where the development is of a speculative nature or the final arrangements for a building network are not finalised then a CT chamber shall be installed or integral CTs shall be connected as appropriate at the intake by UK Power Networks. It is acceptable for a CT Chamber or integral CTs to remain connected when all end points of a building network have received metering and the boundary metering function is no longer required.

Metering CTs, CT chambers or provisions for whole current meters within a building network shall not be installed or owned by UK Power Networks (refer to EDS 08-0118).

In relation to a connection to a licensed distribution system, i.e. IDNO Inset Network, the intake connection shall not be metered and therefore no metering CT connection or metering CT chamber is required (refer to EDS 08-0113).

Where metering of the intake is required the customer shall provide:

- Accommodation for a metering termination box to be located no further than 20m from the CT position.
- The metering accommodation shall be weather protected and be provided with lighting.
- The accommodation shall allow the metering termination box to be mounted at a height of between 1m and 1.8m, with a free working space of not less than 1m.
- A duct for the multicore cable from the CT position to the meter box.
- An external meter cabinet of a type approved by UK Power Networks.

Duplicate metering CT ratio name plates are provided by the supplier of the CT chamber/integral CTs. These CT ratio name plates shall be fitted inside the metering termination box when this is installed.
7 References

7.1 UK Power Networks Standards

Regional Development Plan – City of London 33kV Network

EAS 00-0003       MV Switchgear
EDS 02-0034       33kV Single Core XLPE Cables
EDS 05-0002       Protection and Control Schemes for Customer Demand and Generation Connections
EDS 05-0030       London 33kV Distribution Network Protection Requirements (internal only)
EOS 05-0031       London 33kV Automatic Load Transfer Scheme (internal only)
EDS 06-0019       Customer EHV and HV Connections (including Generation) Earthing Design and Construction Guidelines
EDS 07-0105       Grid & Primary Civil Design Standards
EDS 07-0020       Civil Requirements for New Customer Supplies and Generator Connections between 6.6 and 33kV
EDS 07-0021       Substation Temporary Access Road
EDS 08-0113       Guidance for the Application of ENA Engineering Recommendation G88 and G81 Inset Networks (IDNOs and other Licensed DNOs)
EDS 08-0118       Supplies to Multi-occupied Buildings
EDS 08-0141       HV Customer Supplies

7.2 National and International Standards

ENA ER P2/6       Security of Supply
Appendix A – Bussing Bar Concept

The ‘bussing bar’ arrangement is illustrated in Figure 7.1 and Figure 7.2. Both feeder groups A and B, shown in red and green respectively consist of four circuits rated at 30MVA, evenly loaded at 90MW and supplied from three 60MVA transformers.

Group A is intact and supplied by Substation A with all four feeders connected to a separate bussing bar at Substation B.

Group B has an onerous (n-1) condition close to Substation A. Under these conditions, the power flow on the remaining three circuits would increase to its rated value of 30MVA. All customers connected to the faulted feeder would experience no interruption with unit protection isolating the faulted cable section and supply continuity maintained via the bussing bar at Substation B as shown in Figure 7.1.

For the loss of all three transformers at either Substation A or Substation B, as shown in Figure 7.2, the auto switching scheme would be configured to prevent customers at both feeder groups from experiencing an interruption, although a transient interruption during auto-closure of the bus-section circuit-breakers at both substations would be noticed.
Appendix B – 33kV Network Example

Feeder and transformer CBs are distributed between all busbar sections as required for the local network configuration. This will also determine which bus-section/coupler CBs are normally open and if auto-switching is required.

Figure 7.3 – 33kV Network Example
Appendix C – London 33kV Distribution Network Map

The current extent of the London 33kV network is shown below and new connections are generally available in and around it depending on the proximity of the 33kV network to the point of connection.