ENGINEERING DESIGN STANDARD

EDS 02-0041

CABLE TUNNEL DESIGN STANDARD

Network(s): EPN, LPN, SPN

Summary: This standard sets out the use of the Cable Tunnel Design Manual to be used in the planning and design of new cable tunnels and shafts.

Originator: Mark Dunk Date: 18/03/2013

Approved By: Steve Mockford Approved Date: 03/05/2013

Review Date: 02/05/2016

This document forms part of the Company’s Integrated Business System and its requirements are mandatory throughout UKPN Branch. Departure from these requirements may only be taken with the written approval of the Director of Asset Management. If you have any queries about this document please contact the originator of the current issue.

Document History
(The document history notes below are intended as a guide only and may not cover all of the changes. If you wish to make use of this document it should be read in full.)

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<th>Version</th>
<th>Date</th>
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</tbody>
</table>
5.2.4 Flexible Horizontal Movement Cable System Cleat and Steelwork Maximum Spacings .................................................. 20
5.2.5 Flexible Horizontal Movement Cable System Cleat and Steelwork 3 Metre Spacing .................................................. 24
5.3 Cable Support in Shaft ........................................................................................................ 26
5.4 Design Fault Levels Assumptions .................................................................................. 26
6 Water Ingress Control and Removal .............................................................................. 27
7 General Access .................................................................................................................. 28
8 Shafts .................................................................................................................................... 28
  8.1 General ................................................................................................................................ 28
  8.2 Access.................................................................................................................................. 29
  8.3 Emergency Egress ............................................................................................................. 29
  8.3.1 Injured persons .............................................................................................................. 29
  8.4 Cable Receptor Eye ........................................................................................................... 29
  8.5 Shafts in Substation Sites .................................................................................................. 30
9 Ventilation ............................................................................................................................ 30
  9.1 General ................................................................................................................................ 30
  9.2 Ventilation Monitoring and Control ................................................................................ 31
    9.2.1 General ...................................................................................................................... 31
    9.2.2 DTS / TVCMS and SCADA ...................................................................................... 31
  9.3 Future Additional Cables ................................................................................................. 32
10 Smoke Detection ................................................................................................................ 32
11 Lighting and LV Electrics .................................................................................................. 32
  11.1 General LV Electrical ................................................................................................... 32
  11.2 Lighting.......................................................................................................................... 32
  11.3 Emergency Lighting ...................................................................................................... 33
  11.4 Siting of Luminaries ...................................................................................................... 33
  11.5 Small Power .................................................................................................................... 33
12 Communications ................................................................................................................ 34
13 Doors and Access Hatches ............................................................................................... 34
  13.1 Fire and Security Rating of Doors ................................................................................ 34
  13.2 Doors Generally ............................................................................................................. 34
  13.3 External Doors ................................................................................................................ 35
  13.4 Internal Doors.................................................................................................................. 35
14 Access Hatches .................................................................................................................. 36
15 Fire - Prevention and Protection ...................................................................................... 36
  15.1 Fire Plan ........................................................................................................................... 36
15.2 Fire Protection Equipment ......................................................................................... 37
15.3 General Structural Fire Resistance ............................................................................ 37
15.4 Fire Risks involving Cables and Joints ...................................................................... 37
15.5 Fires Involving Electrical Equipment ....................................................................... 38
15.6 Fire Detection ............................................................................................................ 38
15.7 Fire Suppression and Control ................................................................................... 38
16 External Works ......................................................................................................... 39
16.1 Vehicle and Pedestrian Access ................................................................................. 39
16.2 Drainage .................................................................................................................... 39
16.3 Water Supply ............................................................................................................. 39
17 Earthing ..................................................................................................................... 40
18 Health, Safety and Environment (CDM) ..................................................................... 40
18.1 CDM Regulations ...................................................................................................... 40
18.2 Design Risk Assessments (DRA) / Hazard Elimination and Management Lists (HEML): ............................................................................................................. 40
18.3 The Client .................................................................................................................. 40
18.4 Handover and As-built Records ................................................................................. 40
18.4.1 Tunnel route .............................................................................................................. 40
18.4.2 Cable records ............................................................................................................. 40
18.4.3 Location of shaft head houses and tunnel access points .......................................... 41
18.4.4 Operation and maintenance protocols ...................................................................... 41
18.4.5 As-built shaft and tunnel drawings ........................................................................ 41
18.4.6 DTS / TVCMS & SCADA systems ........................................................................ 41
18.4.7 Storage of records and data ...................................................................................... 41
18.4.8 Handover and Training ........................................................................................... 41
19 Reference Documents .................................................................................................... 42
1 Introduction

This document describes in outline the standard building and equipment requirements for cable tunnels, access shafts and ancillary equipment (ventilation, communications and fire suppression) for use in all three (SPN, LPN, EPN) UK Power Networks (UKPN) licence areas.

Whilst standardisation of tunnel design aspects is preferable, it is accepted that each project is specific. It is essential therefore that the tunnel design, whilst incorporating the requirements of this document, assesses each project design on its merits.

The designer must have due regard at all times to designing a tunnel that complies with all current UK Power Networks policy and European legislation and legal requirements.

Third party considerations, developers, local authorities etc., may influence the adopted design together with specific designers risk assessments, but it is essential that the requirements of this document are embedded within the final design.

UK Power Networks tunnel assets are strategically important to the continuity of supply. The risk of damaging more than one circuit must be kept very low, the consequences of damage to more than one circuit would be considerable.

All installations shall conform with the details within this document and those within UKPN engineering document EDS 02-0040 – Current Ratings Guide for Distribution Cables.

2 Design Considerations

In addition to detailed site and ground investigations the following requirements must be considered in the final design:

2.1 Legislation

The tunnel must be designed to the current UK Power Networks Codes of Practice, Design Guides, LPA legislation and British and European Standards.

Exemption from Building Regulations 2000 (amended 2010) may be claimed under Section 4 of the Building Act 1984 except where the structure is to be used as an office or dwelling. It is understood that Section 5 of the Sustainable & Secure Buildings Act 2004 removing this exemption for works carried out by Statutory Undertakers has yet to be implemented by the Secretary of State.

Where appropriate and/or applicable the design must comply with current Building Regulations (regardless of exemptions) and the Town & Country Planning Act.

2.2 Environment

The design must have due consideration for the local environment and comply with the Environment Agency and Local Authority requirements

2.3 Cable Spacing

Distances between cables and circuits are to be as set out in Section 5. Minimum cable spacing must be observed to reduce the risk of damage to other circuits in the event of fire or electrical fault and ensure efficient cooling.
2.4 Health & Safety

The shaft and tunnel structures are to be considered as confined spaces during construction and operation.

The design must comply with the Construction Design Management (CDM) and all Health, Safety & Environmental legislation; see Section 18.0.

2.5 Electrical Apparatus

The design must meet the technical and safety requirements for the plant and cables to be installed. Facilities must be provided for the delivery, offloading, handling and installation of plant and cables and for their possible future removal, additions or alterations.

Wherever practicable electrical connections are to be made where the risk from interruption or damage by flood water can be minimised.

All LV electrical installations shall comply with BS 7671 IEE Regulations and a compliance certificate must be obtained. The compliance certificate shall be retained on file, recorded on Ellipse and where possible a copy displayed on site.

2.6 Cable Entries and Routes

The design must provide for the co-ordination of cable entries from outside circuits and for power and control cable routes within the tunnel.

Design guidance for typical cable bending radii for copper cable is given below:

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Bending Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>132 kV Cables</td>
<td>3m</td>
</tr>
<tr>
<td>33kV Cables</td>
<td>1.6m</td>
</tr>
<tr>
<td>11kV Cables</td>
<td>1.2m</td>
</tr>
<tr>
<td>Control cables</td>
<td>0.6m</td>
</tr>
</tbody>
</table>

Actual cable bending radii are to be confirmed with the manufacturer by the Designer prior to the finalisation of the design.

The cable entries are to be sealed against water ingress into the shaft at the completion of construction. The sealing arrangement must be removable to enable the cables to be installed and the cables entries resealed.

Cable support steelworks and cleating systems are to be designed and specified to accommodate the weight of the cables and imposed short circuit loads of 20kN of which 10% (2kN) is transmitted into the support and structure.
2.7 Security


Project Managers must establish the security rating requirements for any installation before design commences, this must be reviewed on every occasion that new cables are installed.

For high risk areas where access to the tunnel and shafts is located the following measures may be required following a site specific security risk assessment:

- Dome cameras covering the approach to the substation;
- Motorised bollards or barrier access control with swipe in/out magnetic lock on main access door;
- Access to tunnel shafts with electronic Locken lock on main access door;
- Intruder alarm with PIR door contacts;
- Security lighting with infra red lamps for night vision;
- Appropriate signage.

Specifications of the above equipment can be advised by UK Power Networks Company Security, reference shall also be made to EDS 07-0101 Security Specification for UK Power Networks Operational Sites (internal document).

2.8 Flooding/Water Ingress

When considering the location of a new tunnel and shaft head house it is essential, as well as considering the ecological impact and design suitability, that the risk from future flooding is assessed. In the case of tunnels and shafts the primary sources of water ingress are considered to be from ground water and water from a water main failure. Water ingress from pluvial or tidal flood event shall be considered at all tunnel shafts.

2.8.1 Ground Water

The ground investigation works essential to the design of the tunnel and tunnel route will highlight the presence of ground water. If ground water is considered likely to be present, the design must make allowance for the sealing of all joints in both the shaft and the tunnel itself. In extreme cases the possibility of uplift may need to be considered.

2.8.2 Water Main

As all tunnels by their nature are located below street level then the risk of flooding by burst water main or, to a lesser extent sewer, must be considered. In these cases the local water service provider shall be contacted in order to confirm the size, location and, where possible, age of any mains water feed along the proposed tunnel route and at shaft locations in order to establish the risk and likelihood of water main failure. The design is to incorporate protection against or early warning of these flood events where appropriate. As with protecting against ground water ingress all shaft and tunnel joints shall be designed to be water tight.
2.8.3 Fluvial and Tidal

If it is found that the proposed route is affected by flooding from any of these potential causes then ideally an alternative site should be sourced. In real terms, however, this can not always be achieved and it therefore becomes essential that measures are put in place within the design in order to provide mitigation against the effects of flooding. Information regarding flood risk and levels can be obtained from the local Environment Agency office which can be contacted on 08708 506506 for all UK Power Networks licensed areas.

2.8.4 Mitigation

Possible mitigation solutions for the above flooding scenarios include specifying all above ground doors and access hatches as watertight or installing demountable flood protection barriers around shaft sites. Basic good construction and cable installation practices shall also be employed to ensure tunnel, shaft and cable entries are all watertight. Tunnel elevations shall be designed to fall towards the sump pump location (located at the lowest part of the tunnel section) and falls calculated to reduce puddling in the invert of the tunnel. Pump fail alarms will be taken back to UKPN control with an indication of the position of the failed pump.

2.8.5 Removal

Any water collecting in the tunnel will have to be removed, any discharge to a water course or public sewer will require a Discharge Licence from the appropriate body; this will be sourced through the appropriate UKPN Operational Property and Consents team. Any water likely to be considered contaminated will either have to be removed by tanker for treatment or passed through a Full Retention Oil Interceptor prior to discharge. The requirement and provision of this equipment must be considered at the design stage.

2.9 Fire Risk Assessment

It will be necessary for a fire risk assessment to be carried out by a competent person in compliance with the Regulatory Reform (Fire Safety) Order 2005.

It will also be necessary to carry out a Network risk assessment to establish the risk to the Network and need for mitigation/reconfiguration should circuits be affected by fire.

See also Section 14 Fire Prevention and Protection.

2.10 Functional Requirements

The principal function of the design is to provide structures to house and support the electrical cables and ancillary equipment and ensure a safe environment for operational and maintenance staff that work within the tunnel and general public safety.

2.11 Design Life

The life of the main fabric of the tunnel structure shall have a design life of not less than 120 years with internal and ancillary structures designed for a minimum 40 year life. In both cases careful consideration shall be given to minimum maintenance throughout.
2.12 Future Maintenance

The designer shall consider all future maintenance requirements together with possible addition and alterations to the installed cables and plant. The design shall provide for adequate access to and around cables and plant together with minimum future maintenance and risks to operational engineers.

In addition to maintenance, provision is to be made for the future removal and replacement of all cables and plant. This provision shall include consideration for maintaining wayleaves and access agreements throughout the life of the tunnel and shaft sites.

2.13 New Cables in Existing Tunnels

Before any plans to install cables in new or existing tunnels are finalised the Circuit Standards Manager within UKPN Asset Management shall be informed and consent for the scheme pre gate B obtained. Consent will be conditional upon a review of the risk to the existing assets from the installation and will consider, among other things, ventilation, cable sizing and spacing, cable type, loading, security and fire risk.

3 Tunnel Layout and Requirements

3.1 Tunnel Dimensions

Based on the information contained in the BEWAG Report – Special Report on Fire Resistant Cable Installation in Tunnels and the dimensions quoted in Section 5.1 of this guide, the minimum internal dimensions of the tunnel are to be 2.325m while maintaining the minimum clearances between each circuit and between each circuit and the tunnel or shaft walls. Note that the BEWAG report does not consider 33kV and 11kV cables so for design purposes the minimum spacing for these circuits shall be considered the same as for 132kV cables.

While this minimum dimension is desirable it may be preferable to adopt larger internal diameters, typically 2.59-2.8m, in order to utilise standard tunnel lining segments, a particular Tunnel Boring Machine (TBM) specification or specific ground conditions. If the tunnel is to accommodate multiple voltages then consideration of fire separation may inform the tunnel diameter.

Maximum emergency escape distance shall be no more than 1.2km. Consequently the tunnel length between access/egress points shall not exceed 2.4km to ensure this safe emergency evacuation distance is maintained; these figure are based on a maximum escape time of 30 minutes using breathing sets.

3.2 Design Structural Loads

Materials to be considered at ultimate strength with appropriate load and material safety factors.

External tunnel walls are to be designed to withstand:

- Earth and ground water pressures;
- Uplift from ground water level fluctuations;
- Loads from any buildings or structures constructed or planned over the tunnel route or where it forms part of the foundations of any structure. Advice is to be sought from the Structural Engineer regarding loads associated with this type of neighbouring project.
The tunnel is to be designed to contain or dissipate internal overpressure caused by cable or joint failure.

Typically the tunnel is expected to be constructed from pre-cast concrete sections of a diameter suitable for both the tunnel requirements and the Tunnel Boring Machine (TBM) constructing the tunnel although ground conditions may determine an alternative method (e.g. thrust bore).

It is recommended that the British Tunnelling Society (BTS) / Institution of Civil Engineers (ICE) Tunnel Lining Design Guide is referred to during the design, construction and maintenance of the tunnel.

4 Emergency Egress

4.1 Signage and Lighting

Photoluminescent signs, sizing and layout in accordance with BS 5499-1, are to be fixed to the walls of the tunnel at approximately 2 and 10 o’clock positions and to avoid being obscured by the cable installation. They are to be directional and show the distance to the nearest egress point where the exits are to be signposted.

Walkways and emergency escape routes shall be designed to be clear of trip hazards and obstructions.

5 Cable Layout and Configuration

5.1 General Arrangement Considerations

Based on the information contained in the BEWAG report – ‘Special report on Fire Resistant Cable Installation in Tunnels’ 132kV XLPE LSOH cables are to be arranged in a trefoil. In order to limit damage should a cable failure occur and to provide clear access the minimum separation distances below shall be observed:

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Vertical separation between circuits</td>
<td>200mm</td>
</tr>
<tr>
<td>Horizontal clearance for personnel access walkway</td>
<td>1000mm</td>
</tr>
<tr>
<td>Cable to tunnel wall</td>
<td>200mm</td>
</tr>
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</table>

The provision of blast shielding between phases or circuits is not recommended as it is considered that it will increase the overall effects of a cable failure by not allowing the blast pressure to dissipate and creating a pressure cell and increasing the likelihood of the blast being reflected back onto the fault area compounding the damage.

The installation of other voltages must also conform with the details above and the diagram overleaf otherwise some other mitigation to prevent damage must be provided.

It has been assumed that the circuits for all voltages shall be laid in trefoil configuration.
5.1.1 Cables

Cables in the tunnel, coupled with a high standard of installation, shall be protected against mechanical damage, fire and water both during installation and in operation.

Pre gate B the Cables and Circuits engineer in conjunction with planning shall provide a technical brief outlining the design parameters to include the following:

- Tunnel Diameter (mm);
- Tunnel Length (mm);
- Tunnel Depth to centre (mm);
- Air Velocity – current and future if forced ventilation is to be installed (m/s);
- Required ratings for cable circuits along the route (circuits to be installed and circuits that are existing);
- Voltage size and type of any existing cables;
Cables to be installed in tunnels and basements shall have the following design parameters:

- Cables shall be installed such that there is a clear walking space between the circuits on opposite sides of the tunnel. Taking into consideration the point raised above they shall be adequately supported for both installation and operation and secured in order to accommodate the dynamic operational forces and thermal expansion;
- Cable entries and unused ducts are to be sealed against ingress of water, dust and other materials;
- Cables shall be specified and supplied in accordance with the following UK Power Networks Design and Approval Standards:
  - EDS 02-4040 - 132kV Cables with Extruded Insulation Suitable for use in Cable Tunnels, Galleries and Cable Basements (internal document);
  - EDS 02-0940 - 11kV Single Core XLPE Insulated Cables in Triplex Format (internal document);
  - EDS 02-0945 - 20kV Single Core XLPE Insulated Cables in Triplex Format (internal document);
  - EDS 02-0905 - 33kV Single Core XLPE insulated Cables (internal document);
  - EDS 02-0995 - 66kV Cables with Extruded Insulation Suitable for use in Cable Tunnels, Galleries and Cable Basements (internal document);
  - EDS 02-0950 - Auxiliary Multicore and Multipair Cables (internal document);
  - EDS 02-0956 - LSOH Waveform Cables (internal document).
- No fluid filled or cables which increase the risk of fire may be installed in any tunnel

5.1.2 Joints

- Cable joint layout is directly related to the size and type of joints used. For the purposes of this design standard vulcanised inline splicer joints are to be used. They have the advantage of minimal affect on the flow of air in the tunnel.
- The distance between joints should be as large as practicable based on available cable lengths.
- The joints shall have similar fire resistance and low smoke and fume emission characteristics as the cables to which they are attached.
- Joints are generally staggered due to the spatial requirements of installing them; where possible joint bays are to be provided to avoid having joints encroaching into the tunnel access area.
- Joints are to be screened with a non-conductive shield to prevent unintentional contact.
- Attention is drawn to The Electricity at Work Regulations 1989 [44], which require joints and terminations to be both electrically and mechanically suitable.
- Joints are to be kept clean and dry and constructed in accordance with UK Power Networks policy and procedure.
5.2 Cable Cleating and Support

The design of cable cleating and support steel work shall be designed in accordance with the following tables in this standard. Cable support distances cannot be determined until a cable installation design has been undertaken and approved.

5.2.1 Rigid Cable System Cleat and Steelwork Spacings

For the installation of a rigid cable system in a cable tunnel, all steelwork and cleats shall be design so that it accommodates the largest cable which is likely to be installed. The following table has been calculated to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm².

5.2.1.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Cable Thrust (kN)</td>
<td>Cleat Spacing on Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>4.02</td>
<td>2.06</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>7.52</td>
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<td>1600mm² Copper</td>
<td>24.36</td>
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### 5.2.1.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath

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<th>Conductor Size (mm²) and material</th>
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<th>Short Circuit Operation</th>
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<td>Maximum Cable Thrust (kN)</td>
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<tr>
<td>300mm² Aluminium</td>
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<td>630mm² Aluminium</td>
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<tr>
<td>1200mm² Aluminium</td>
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<td>1600mm² Aluminium</td>
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<td>1200mm² Copper</td>
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<td>1600mm² Copper</td>
<td>24.36</td>
<td>1.71</td>
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### 5.2.1.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath

<table>
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<th>Conductor Size (mm²) and material</th>
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<th>Short Circuit Operation</th>
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<tr>
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<td>Maximum Cable Thrust (kN)</td>
<td>Cleat Spacing on Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>4.02</td>
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<tr>
<td>630mm² Aluminium</td>
<td>7.52</td>
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<tr>
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<td>11.43</td>
<td>3.96</td>
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<td>1200mm² Aluminium</td>
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</tr>
<tr>
<td>1600mm² Copper</td>
<td>24.36</td>
<td>1.71</td>
</tr>
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</table>

### 5.2.2 Flexible Vertical Movement Cable System Cleat and Steelwork Maximum Spacings

For the installation of a flexible vertical movement cable system in a cable tunnel, all steelwork and cleats shall be designed so that it accommodates the largest cable which is likely to be installed. The following table has been calculated to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:
- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm².
5.2.2.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate

<table>
<thead>
<tr>
<th>Conductor Size (mm$^2$) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
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<td>1600mm$^2$ Copper</td>
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### 5.2.2.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath

<table>
<thead>
<tr>
<th>Conductor Size (mm²) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
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<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
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### 5.2.2.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath

<table>
<thead>
<tr>
<th>Conductor Size (mm²) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m) l</td>
</tr>
<tr>
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5.2.3 Flexible Vertical Movement Cable System Cleat and Steelwork 3 Metre Spacing

For the installation of a flexible vertical movement cable system in a cable tunnel, all steelwork and cleats shall be design so that it accommodates the largest cable which is likely to be installed. The following table has been calculated to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm²;
- Steelwork cleat spacing = 3 metres;
- Number of short circuits straps = 1.

5.2.3.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate – 3 Metre Spacing

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Sag under Cable weight (mm)</td>
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## 5.2.3.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath – 3 Metre Spacing

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<th>Conductor Size and Material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
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</thead>
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<td>Sag under Cable weight (mm)</td>
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5.2.3.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath – 3 Metre Spacing

<table>
<thead>
<tr>
<th>Conductor Size (mm²) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Sag under Cable weight (mm)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
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</tr>
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<td>630mm² Aluminium</td>
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5.2.4 Flexible Horizontal Movement Cable System Cleat and Steelwork Maximum Spacings

For the installation of a flexible horizontal movement cable system in a cable tunnel, all steelwork and cleats shall be design so that it accommodates the largest cable which is likely to be installed. The following table has been calculated to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm²;
- Number of short circuits straps = 1.
### 5.2.4.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th></th>
<th></th>
<th></th>
<th>Side force on Cable (N/m)</th>
<th>Required Strength of Strap (N)</th>
<th>Sheath Strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m) I</td>
<td>Initial set sag (mm) f₀</td>
<td>Cyclic sheath strain (%)</td>
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<tr>
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5.2.4.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath

<table>
<thead>
<tr>
<th>Conductor Size (mm$^2$) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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### 5.2.4.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath

<table>
<thead>
<tr>
<th>Conductor Size (mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>1600mm² Copper</td>
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5.2.5 Flexible Horizontal Movement Cable System Cleat and Steelwork 3 Metre Spacing

For the installation of a flexible horizontal movement cable system in a cable tunnel, all steelwork and cleats shall be design so that it accommodates the largest cable which is likely to be installed. The following table has been calculated to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:
- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm²;
- Steelwork cleat spacing = 3 metres;
- Number of short circuits straps = 1.

5.2.5.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate – 3 Metre Spacing

<table>
<thead>
<tr>
<th>Conductor Size (mm²) and material</th>
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<th>Short Circuit Operation</th>
</tr>
</thead>
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<tr>
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<td>Initial set sag (mm) f₀</td>
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<tr>
<td>1600mm² Copper</td>
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<td>208</td>
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</table>
5.2.5.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath – 3 Metre Spacing

<table>
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<tr>
<th>Conductor Size (mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Initial set sag (mm)</td>
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<tr>
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5.2.5.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath – 3 Metre Spacing

<table>
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<th>Conductor Size (mm²) and material</th>
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<tbody>
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<tr>
<td>1600mm² Copper</td>
<td>0.96</td>
<td>202</td>
</tr>
</tbody>
</table>

5.3 Cable Support in Shaft

Cleats, fixings and frames are to be designed to support the vertical load of the cables as they rise up the shaft. Landing stages can be used as support points although the cables must be protected against mechanical damage where they pass through the flooring.

As a minimum the spacing between steelwork and cleats shall be half that for horizontal straight sections.

5.4 Design Fault Levels Assumptions

Unless accurate data is known the following will be used:

- 132kV 19.3 kA for 3 sec;
- 33kV 7.5kA for 3 sec;
- 11kV 13 kA for 3 sec.
6 Water Ingress Control and Removal

A risk assessment shall be carried out and a system designed to eliminate the flood risk as far as reasonably practicable. Reference to the STUVA Recommendations for Testing and Application of sealing Gaskets in Segmental Linings is recommended where appropriate.

The design process shall regard the prevention and exclusion of water ingress into the tunnel and shafts as a priority over its control and removal. It is possible for a large volume of water to build up within a tunnel and its removal to provide safe personnel access can be costly and take time. The mitigation methods mentioned in Section 2.11 or other available exclusion methods shall be considered as part of the design process.

Where water ingress cannot be controlled the provision of an adequate permanent pump and drainage system shall be considered at all low points along the tunnel network length. The pumps are to operate on an automatic float switch and be robust enough to deal with slurry and water. Consideration shall be given to duplicate pumps and pipe work, and to good accessibility to the pumps for regular servicing or changing over. Wherever possible pumps are to be located at the base of the shafts. The pumps installed are to be oil discriminating to a level of 5 parts/million (5mg/l) and be able to cope with silt and sediment.

Where flood water is discharged into a watercourse or sewer a Discharge Licence shall be obtained from the Environment Agency or local sewer utility. In order to record flow rates in enable accurate billing flow rate meters shall be installed at each pump location; remote readers are to be installed at the top of each shaft to enable recording of the total flow without inspectors having to enter the tunnel system. It is possible that the Environment Agency may consider the water to be polluted and that treatment in the form of oil or silt removal may be required prior to discharge.

Where the control of oil polluted water is considered a problem the pumped discharge from the tunnel should pass through a Full Retention Separator before discharging to a sewer or watercourse. The choice of oil separator shall be in line with Environment Agency policy document PPG 3. Of the two Classes of Oil Interceptor, Class 1 Interceptors are required when discharging into surface or controlled waters, Class 2 Interceptors are required when discharging into foul sewers. Where treatment requirements cannot be met through the utilisation of the oil discriminating pump and interceptor additional or alternative methods will have to be considered in the design and the overall costings.

The allowance for likely flow rates and the requirement for suitable oil and silt separation must be considered at the design stage.

See also Section 16.2 Drainage
7 General Access

Access to all shaft head houses is to be controlled by UK Power Networks standard electronic locks currently provided by Locken. Access hatches at other tunnel access points are to be secured with a dedicated physical locking system with the locks protected from corrosion by design and by an adequate maintenance regime.

Access to the tunnel is to be provided at the location of each shaft. Where possible the access door or hatch shall be located within a secure compound with parking provided for large vans (as largest Ford Transit) approx size 6.4m x 2.1m x 3m high with 3.7m wheel base. The delivery, offloading and handling of all plant and cable drums as normally packaged by the suppliers shall also be considered at the main tunnel access points.

Where intermediate shaft access points are located in trafficked areas then personnel access is to be provided from the footpath or other lower risk area where possible.

Prior to tunnel entry, UK Power Networks confined space entry procedures shall be adhered to. Access to UK Power Networks tunnels shall only be undertaken by trained and competent operatives.

Access is required 24 hours-a-day and is to be unrestricted.

See also Section 13 Doors and Access Hatches.

8 Shafts

8.1 General

In addition to providing personnel and plant access to the shaft and room for the ventilation inlet/extract plant, head houses are to provide space for a control room housing the LV distribution board, ventilation control/DTS interface system, and communications control systems.

If not located on a Grid or Primary substation site where facilities are already in place, toilet and hand washing facilities shall be provided within the shaft head-house where space permits.

The minimum shaft internal diameter (ID) is to suit construction methods, ground conditions, max no of cables, ventilation requirements and access equipment. For planning and initial design works this minimum ID is to be considered to be 7.5m. Where the physical environment (at and/or below ground level) calls for a limit to the shaft size to an ID less than 7.5m then the Designer must demonstrate that the reduction does not limit personnel or cable access and is not to the detriment of future cable installations within the shaft.

Main shaft head-houses are to provide room for occasional vehicle delivery of plant. Plant vehicle access into the head-house shall be via a secure sliding door, plant delivery to the shaft base shall be facilitated utilising a 5 tonne travelling crane located over the delivery point/area. Where space is of a premium it may be necessary to make provision for the temporary removal/dismantling of non-essential structures in order to fully utilise the access.

Copies of the as-built tunnel and shaft drawings and route details are to be kept at each head-house.

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8.2 Access

So far as reasonably practicable the use of permanent stairs is the preferred method of accessing the tunnel via the shaft and shall be considered where shaft diameter and cable configuration permit.

Where stair access cannot be accommodated ladder access shall conform to the following:

- Every ladder shall be securely fixed at its base, the shaft walls at suitable spacings and at the upper landing. It shall extend at least 1.1m above the upper landing unless other adequate alternative handhold is provided;
- Vertical ladders fixed are to be made of steel and shall be suitably earthed;
- Vertical ladders shall be designed in accordance with BS EN ISO 14122-4:2004;
- The foothold at every rung on all ladders shall be unobstructed. Landings shall be at intervals not exceeding 6m and shall be solidly constructed with hand rails / guard rails and toe boards and be protected against swinging loads being handled in the shaft;
- Openings for ladders shall be as small as is practicable and sited clear of the foot of the ladder above; trap doors in the landings above the lower ladder shall be considered. Every landing shall be adequately lit (see Section 11);
- Ladders and landing stages shall be designed to be clear of trip hazards and obstructions.

As with ladders landing stages and handrails are to be made of steel (rather than light alloy, timber or GRP) and shall be suitably earthed in accordance with UK Power Networks Earthing manual.

Working platforms and walkways are to be designed in accordance with BS EN ISO 14122-2:2001.

8.3 Emergency Egress

8.3.1 Injured persons

All shafts are to have provision for the emergency evacuation of personnel by either ambulance cages or by special emergency slings. To facilitate this clear access through the landing stages and clear of the ladder access is to be provided.

Installation of a permanent emergency egress system shall not be provided, rescue teams will provide their own tested equipment.

A Life Safety study shall be carried out to establish the best possible system for normal egress, emergency egress and removal of injured persons.

8.4 Cable Receptor Eye

Wherever ground conditions are suitable the cable receptor eye is to be constructed outside of the area of the shaft in order to prevent tunnel encroachment and allow room for utilising the maximum possible cable bending radii.
8.5 Shafts in Substation Sites

Where shaft heads are sited within a substation building they shall be segregated from the substation plant rooms and ventilated independently. This is to avoid the potentially high levels of moisture from the damp tunnel air entering the substation environment and affecting plant and equipment housed within the substation rooms.

Minimum 1 hour fire separation between the shaft head and substation is also required; this shall be extended to 4 hour fire separation where the shaft exits adjacent to oil filled plant.

9 Ventilation

9.1 General

The tunnel ventilation system shall be designed to provide an adequate throughput of air in order to control the temperature of the tunnel.

Using the CRATER analysis tool derived from the Cigre Electrical Technical Paper 143 tunnel ventilation outlet temperatures should not exceed 44°C based on a maximum design inlet ambient temperature of 28°C. Temperature within the tunnel and consequently the ventilation flow rate necessary to control the tunnel and cable temperature is directly related to cable rating and diameter, load, current density, number of circuits and tunnel diameter.

The important physical aspects of air quality are temperature, humidity and velocity.

Recommended minimum air velocity in the tunnel is 2.0m/s to prevent layering of methane or other noxious gases. The air as supplied shall be as cool and dry as is reasonably practicable, as during its passage into the tunnel its temperature will tend to become that of the tunnel walls and it will take up moisture.

Ventilation plant is to be located at suitable shaft locations. Longer lengths of tunnel may require additional intermediate ventilation and extraction plant installations to boost air flow and volume.

Where possible extraction/ventilation outlets should not discharge into public accessible areas. Where this is not possible vents are to be directed so as to cause minimum draft and noise nuisance. Fire stop dampers may be required and shall be designed to suit the ventilation scheme.

Ventilation plant and inlet and outlet vents shall be located so as not to cause unnecessary nuisance to local residents. A local baseline noise survey is required prior to the installation of ventilation plant at any location.

It is not considered necessary for ventilation fans and equipment to be gas IP rated.
9.2 Ventilation Monitoring and Control

9.2.1 General

In order to minimise future maintenance costs and resource requirements tunnel ventilation control systems shall be designed to operate in as simply as possible.

In order to maximise the efficiency of the tunnel operation and allow increased circuit loading it may be necessary to install more complicated automated systems using Distributed Temperature Sensors (DTS) and Tunnel Ventilation Control and Management Systems (TVCMS) to control air flow and temperature. The design of these systems will need to consider future operation and maintenance by UK Power Networks staff. Full operator manuals and training shall be provided at handover by the manufacturer.

9.2.2 DTS / TVCMS and SCADA

The tunnel and cable temperatures are to be remotely monitored by a proprietary Distributed Temperature Sensor (DTS) fibre optic system utilising a multimode (50-62.5 micron) fibre.

The DTS is to monitor cable and tunnel temperature by means of fibre optics located in the gap within the trefoil cable arrangement (normally 132kV only but also consider heavily loaded 33kV and 11kV circuits selected by the Circuit Standards Manager and along the soffit of the tunnel. This layout of fibre optics and sensors forms the basis of the Tunnel Ventilation Control and Management System (TVCMS). The DTS system is to be linked to the ventilation control system in order to control temperature by increasing or decreasing the ventilation rate and volume.

The cable DTS system will raise separate alarms should cable temperature exceed 65°C or if temperature rise exceeds 7°C/min; these alarms are to be communicated via the SCADA system to UK Power Networks Control located at Fore Hamlet, Ipswich.

The tunnel DTS system in the soffit of the tunnel will raise an alarm should tunnel temperature exceed 45°C or if temperature rise exceeds 7°C/min, this rate of rise is to be used to indicate fire; these alarms are to be communicated via the SCADA system to UK Power Networks Control located at Fore Hamlet, Ipswich. A local alarm audible / visual need to be triggered at each shaft.

The TVCMS is to be automated with a locally operated override. UK Power Networks Control will have no operational control. The TVCMS will alarm remotely to UK Power Networks control for failure only.

TVCMS maintenance information is to be available both locally and remotely.

UK Power Networks control requires ambient and cable hot spot readings for each tunnel section to be provided continuously.

The DTS/TVCMS system is to be developed and designed by a specialist consultant or designer in line with the information provided above.
9.3 Future Additional Cables

Where additional power cables are to be added to tunnels a survey must be carried out in order to assess their impact on the temperature gradient and fire risk throughout the tunnel section. A ventilation assessment and design must take into account the additional heat load before any cable installation takes place. Approval for additional cables in an existing tunnel asset must be obtained from the UKPN Asset Management Circuit Standards Manager.

10 Smoke Detection

Monitoring for the presence of smoke shall take place at the ventilation outlet points of the tunnel system. Access to this information shall also be available remotely with trigger alarms being sent to Control via the SCADA system.

Where appropriate an Aspirating Smoke Detection (ASD) system is to be used based on the Very Early Smoke Detection Apparatus (VESDA) system. The ASD system is to be designed and configured to be suitable for the ventilation outlet and to operate with minimal false alarms and be easy to maintain from floor access. Data on maintenance periods and procedures is to be provided by the manufacturer and/or Designer. User manuals and action to be taken upon an alarm must be clearly passed over at handover.

All ventilation shall be designed to avoid the need for intrinsically safe equipment.

11 Lighting and LV Electrics

11.1 General LV Electrical

Distribution boards are to be sited at each shaft head house and building services circuits are to be taken from the board in surface mounted conduits or trunking.

All electrical installations to comply with BS7671:2008 IEE Regulations 17th Edition.

11.2 Lighting

LV Lighting is to be provided in the shafts only. Inspections of the tunnel itself are to be carried out using portable or temporary lighting systems.

- Power for lighting is to be provided by an independent LV supply either from street level or dedicated distribution substations.
- Lighting switches to have neon indicators so they can be located in the dark.
- Main door entrance to have external light with PIR to operate as door is approached.
- Luminaires shall have a protective enclosure that conforms to a rating of IP 54 in accordance with BS EN 60529:1992 i.e. dust and water splash protected.
- Lighting shall be provided using Fluorescent lights for general access down the shaft and a combination of Fluorescent and Sodium lights at work areas e.g. at the base of the shaft.
- RCD lighting control is to be located within the head house of the shaft and is to be tested at 6 monthly intervals.
- In accordance with Section 5.0.2 wherever possible pumps and all other plant are to be located at the base of the shafts. Where this is not possible (e.g. a low point of a tunnel occurs between shafts) lighting in accordance with BS 6164:2001 and BS EN 60529:1992 shall be installed at the location of the plant only.
### 11.3 Emergency Lighting

Emergency lighting to be provided by 3hr self contained non-maintained battery conversion kits housed within general purpose luminaries and emergency exit signs.

Emergency lighting levels to be in accordance with BS 5266-7:1999 / BS EN 1838:1999.

### 11.4 Siting of Luminaries

With regards to the figures above all luminaires shall be fixed to provide maximum uniformity of lighting and minimum vulnerability to damage. They shall be easily accessible for installation, maintenance and repair.

- They shall be arranged so that their fields overlap and shall be sited to minimize shadows cast on walkways or working areas;
- Where higher intensity light sources are required glare shall be minimized by proper siting and the use of diffusers and screening.

### 11.5 Small Power

Power within the tunnel is to be supplied via 13A 1-phase IP65 rated sockets located every 100m along the length of the tunnel. Sockets are to be mounted such that they do not interfere with HV/EHV cable installation, operation or maintenance and are protected from potential flood levels within the tunnel.

An RCD controlling the small power sockets is be located within the head house of the shaft and is to be tested at prior to use.
12 Communications

The communications system is to be provided by a “leaky feeder” partially shielded coaxial cable running the full length of the tunnel. The cable is to be fed from each end of the tunnel section and a marshalling communications base station is to be located at each shaft head house.

It may be necessary to install repeaters, these should be designed to be fitted above flood level in a shaft and a level suitable for floor level access for maintenance.

The communications cable is to be located at the soffit of the tunnel min of 50mm from tunnel wall.

Dedicated radios tuned to the correct operational communications frequency are to be installed complete with charger units at each shaft head house.

It is expected that the local Fire Brigade will request a dedicated channel within the communications system in order to allow them to interface with all other Emergency Services. The exact details and requirements are to be discussed and agreed with the local fire brigade representative as part of the development of the Fire Risk Assessment and Fire Plan (see Sections 16.1 & 16.2).

The Communications system is to be fully developed and designed by a specialist designer in line with the information provided above.

UK Power Networks Control will only receive a communications alarm should the communications fail.

13 Doors and Access Hatches

13.1 Fire and Security Rating of Doors

Fire rating: doors and frames generally are to be steel galvanised and powder coated with fire ratings and specification:

- Generally 1 hour fire rated unless installed within a structural area or fire break requiring a greater rating (i.e. 4 hours);
- Security rating for external doors is to meet Government “Security Equipment Assessment Panel” SEAP class 3 or LPC Level 4; see Section 2.7.

13.2 Doors Generally

Doors/openings are to have a clear opening suitable to accommodate the largest section of plant expected to pass along that route.

Double doors to have one passive leaf secured with tower bolts top and bottom and kept normally closed. Active leaf to be hinged and fitted with ironmongery as scheduled. Minimum size clear opening of 1500mm wide x 2700mm high.

Single doors to be a minimum of 800mm wide x 2100mm high.
Doors to open outwards for escape purposes, be fitted with emergency escape devices to BS-EN 1125, i.e. full width panic bars and be self closing preferably with rising hinges or fitted with a closing device.

If a door is used solely for escape purposes then it should have no means of being opened from the outside. Ironmongery must be such as to allow single action escape in an emergency.

External doors to be self locking. Internal doors are not to be self locking.

Doors from rooms containing operational plant (e.g. ventilation plant) are to be fitted with internal panic bars. Doors from non-operational rooms (e.g. office, mess room stores) are to be provided with lever handles both sides and internal thumb-turns for lock release.

Threshold strips to be let into the screed or floor to ensure a smooth floor finish.

Heavy duty handles to be fitted to doors.

Dog/Hinge bolts to be fitted to all doors. Hinges to be stainless steel ball bearing type low maintenance heavy duty hinges. All doors to be fitted with self closers.

All doors opening onto a wall are to be fitted with doorstops.

Steel frames to be fixed in openings with chemical resin fixings.

The security level of the tunnels is to be at least that of the substations the tunnel head-houses are located at or those sites that the tunnel feeds.

13.3 External Doors

All external single, double leaf and, where required, sliding folding doors are to be certified to SEAP class 3. Doors to be complete with appropriate ironmongery to suit application and test certification.

The preference for securing the main access doors to each shaft is to have an electronic Locken locking system and/or the UK Power Networks proximity card system. Where a fail secure solenoid locking and UK Power Networks access control system using the proximity card with PIN verification reader is used a Key operated mechanical override shall be installed to ensure access in the event of a power failure. Where doors are to provide emergency egress only, they shall be operated by internal panic bar systems only with no external door furniture.

All doors are to be fitted with internal panic bar systems and door open alarm systems linked back to Control through SCADA.

13.4 Internal Doors

Internal door furniture on rooms containing electrical plant and in corridors:

- **Internal single doors**: Escape panic bar hardware internal to room and locking to suit local locking system on outside.
- **Internal double doors**: Dead leaf with tower bolts top and bottom, escape panic bar hardware internal to room
- **Live leaf**: As for single doors
14 Access Hatches

Access points to the tunnel other than those through the shaft(s) are to be secured with suitable access hatches.

Access hatches are to be located in pedestrianised areas or UK Power Networks owned property and are to have the following minimum requirements:

- Minimum EN124 loading class of B125;
- Flushing fitting with the surrounding pavement surface;
- Fully lockable with local area key suite;
- Easy maintenance;
- Equipped with accelerant catchment tray to prevent fluids entering the shaft;
- Shall be able to be lifted by a maximum of two persons;
- Provided with hold open stay;
- Provided with ‘hatch open’ alarms linked back to Control through the SCADA system.

15 Fire - Prevention and Protection

The introduction of any fuel to a shaft or tunnel shall be avoided. A Network Design Fire Risk Assessment shall determine and reduce ALARP the risk of cable failure affecting other circuits. The design must make sure that the tunnel will meet all of the requirements of the Fire Risk Assessment which is required to be undertaken and recorded upon completion of the construction of the tunnel.

It is considered unlikely that the Fire Brigade will enter a shaft or tunnel if smoke is present unless there is a risk to life. They will not enter at all without the presence of a competent and authorised UK Power Networks representative.

In accordance with Section 2.9, a Fire Risk Assessment is to be carried out on the tunnel, shafts and all other features of the tunnel design and construction. A competent and responsible person must make a suitable and sufficient assessment of the risks to which relevant persons are exposed for the purpose of identifying the general fire precautions he needs to take to comply with the requirements and prohibitions imposed on him by or under the Regulatory Reform (Fire Safety) Order 2005. It is essential that the Fire Risk Assessment and the Fire Plan mentioned below are developed in conjunction with the local Fire Brigade representative.

15.1 Fire Plan

This will be specific to the premises and will detail the pre-planned procedures in place for use in the event of a fire. A fire plan will be provided at each point of access. Again this is to be developed in conjunction with the local fire brigade representative.

The emergency plan must be recorded where:

- A license under an enactment is in force.
- An Alterations Notice under the Fire Safety Order requires it.
- You are an employer and have five or more employees.
This shall (where appropriate) include the following features:

- Action on discovering a fire;
- Warning if there is a fire;
- Calling the fire brigade;
- Evacuation of the premises including those particularly at risk;
- Power/process isolation;
- Firefighting equipment (see paragraph 12.3 below);
- Places of assembly and roll call;
- Liaison with emergency services;
- Identification of key escape routes;
- Specific responsibilities in the event of a fire;
- Training required;
- Provision of information to relevant persons.

15.2 Fire Protection Equipment

It is recommended that the HSE and the local fire service are consulted before the quantity, type and position of fire protection equipment is decided. Fire protection systems should be designed to save life and facilitate egress during a fire event.

15.3 General Structural Fire Resistance

Building elements are to be designed for the following fire resistance periods:

- Tunnel and shafts – 4 hours;
- Elsewhere 1 hour.

15.4 Fire Risks involving Cables and Joints

Circuit overloading or poor connection can cause heating with damage to insulation and subsequent breakdown which in turn can lead to arcing and ultimately the break out of fire.

In the event of a fire, cable insulation can ignite and spread the fire; itself producing fumes and smoke. Cables within the tunnel and shafts are to be LSOH XLPE cables supplied in accordance with UKPN document EDS 02-4040 - 132kV Cables with Extruded Insulation Suitable for use in Cable Tunnels, Galleries and Cable Basements (internal document), and designed to be low-smoke. All cables, including 33kV and 11kV, shall also be LSOH.

The special vulnerability of grouped cables in a vertical shaft should be noted and essential circuits, such as fire alarms and emergency lighting shall be segregated where possible from other circuits to reduce the risk and consequences of the spread of fire. In vertical shafts the cables shall meet the requirements of BS EN 50266-1 and BS EN 50266-2-1 to BS EN 50266-2-5 (see IEE Guidance Note 4 [49]).

Where communication and LV cables are vulnerable to attack by fire they shall have a fire resistance of 60 min when tested in accordance with BS EN 50200:2000 (which corresponds to a classification of PH 60 as detailed in BS EN 50200:2000, Annex D).

Joint failure can be explosive which may in turn lead to a fire breaking out. It is important that the tunnel is designed to contain the blast pressure or allow it to dissipate without damage to the tunnel structure.
15.5 Fires Involving Electrical Equipment

Electrical installations and equipment can cause fires by overheating and arcing. Failure can result from overloading or as a result of accidental damage or penetration by water. Because of the restricted space in tunnels it is particularly important that arrangements for isolating defective cables or equipment be carefully planned so that persons are not exposed to the hazards of electric shock and electrocution.

The network of cables shall be planned so that essential fire-fighting resources, lighting and ventilation control are not cut off in the process of isolating overheated equipment, and so that signals and communications are maintained.

15.6 Fire Detection

Fire detection will be via the DTS system. An alarm will be raised if the ambient tunnel temperature exceeds 65°C or there is a temperature rise greater than 7°C/min.

15.7 Fire Suppression and Control

The general fire mitigation measure is to minimise fire fuel material – e.g. by installing steel doors, preventing use of wood or other flammable materials and by good housekeeping. Equipment shall be located strategically in accordance with the route of the tunnel and location of shafts, and shall be regularly tested and properly maintained. The installation of oil filled plant and equipment in tunnels and tunnel shafts is not permitted.

- In the event of smoke or temperature rises being detected the main ventilation system is to be managed in accordance with the table below. UKPN Network Control will have agreed operating procedures to competently handle the next steps. It is unacceptable for the ventilation equipment to remain shut down for extended periods.
- Suitable portable fire extinguishers conforming to BS 7863 and to the appropriate part(s) of BS EN 3 shall be provided at each shaft head-house and are readily accessible by personnel. They shall be selected and installed in accordance with BS 5306-8 where guidance is given on the correct type of extinguisher to be used on specific fire types. For tunnels and shafts the two main types of fire are electrical and Class A (solid materials). CO₂, clean agent or powder extinguishers can be used on electrical fires whereas water or foam extinguishers are more suitable for Class A fires. Water and foam extinguishers that meet the requirements of the dielectric test of BS EN 3-2 can be used extinguisher fires in close proximity to live electrical equipment and may, in this case only, be preferable to CO₂ units. However these water or foam extinguishers shall not be used directly on live electrical equipment without specific consultation with the manufacturers and the local fire authority.
- All equipment shall be maintained in good working order and checked and maintained in accordance with the manufacturer's instructions.
A dry riser system is to be installed from the top of each shaft to the tunnel invert. The dry riser is to be accessible from outside of the shaft head-house but is to be made secure to prevent vandalism or misuse.

16 External Works

16.1 Vehicle and Pedestrian Access

With regards to the provision of access to shaft entrances the following shall be considered in the design:

- Access is to be provided for the delivery, offloading and handling of all plant and cable drums as normally packaged by the suppliers;
- Convenient access and parking for frequent visits by operational staff with van and equipment is required;
- Unrestricted 24 hour access is required for maintenance staff and vehicles.

16.2 Drainage

Parking, delivery and offloading areas, normally around shaft head houses, are to be drained into a dedicated soak-away or sewer. All surface water discharge is to pass through a Full Retention Oil Interceptor (in accordance with EA PPG 2) prior to entering the soak-away or sewer and is subject to the same controls and limitations as water pumped from the tunnel itself.

Foul water discharge from toilets housed within the shaft head house is to be connected to the nearest foul sewer. If a connection cannot be arranged then foul water will have to be discharged to a septic tank complete with level indicator and alarm.

16.3 Water Supply

Where applicable a fresh water supply to the shaft head house is to be installed to facilitate the operation of the toilet, hand washing and to provide a potable drinking water source.
17 Earthing

18 Health, Safety and Environment (CDM)

18.1 CDM Regulations
The design shall meet the requirements of the CDM Regulations 2007 and include:

- Informing clients of their duties;
- Design to minimise Health & Safety risks;
- Providing adequate information about the Health & Safety risks of the design;
- Provide details of residual and operational risks.

18.2 Design Risk Assessments (DRA) / Hazard Elimination and Management Lists (HEML):
Site specific DRA’s/HEML’s must be completed for all design elements by a person competent, with the foresight to identify all risks that may occur during the construction period, and by design, where possible minimise or remove all risks, encouraging a safe working environment. These documents shall be included in the CDM documentation for the tunnel system.

18.3 The Client
The client shall appoint a CDM Co-ordinator for all works at the commencement of the project.

18.4 Handover and As-built Records
Full as-built records are to be supplied by the Contractor to UK Power Networks upon completion and handover of the tunnel. Records are to include:

18.4.1 Tunnel route
The tunnel route is to be clearly marked on a map or plan showing accurately any incoming branches and all directional and level changes with cross-sections where appropriate.

18.4.2 Cable records
The cables and circuits within the tunnel are to be clearly recorded and marked on the Tunnel Route plan. Any feeds relevant but external to the tunnel are to be also recorded. All cable and joint information is to be forwarded to UK Power Networks Asset Records.

The fixing of labels identifying the circuits every 100m and at junctions shall be considered
18.4.3 Location of shaft head houses and tunnel access points

All tunnel access points and shaft head houses are to be recorded and marked on the Tunnel Route plan. Access procedures, particularly where they may differ from standard UK Power Networks entry procedures, are to be recorded.

18.4.4 Operation and maintenance protocols

Maintenance periods and procedures and equipment supplier information for all LV, ventilation and monitoring systems.

18.4.5 As-built shaft and tunnel drawings

Fully marked up as-built drawings detailing all structural and dimensional details of the shafts and tunnel and electrical schematic drawings of all LV power and lighting and sump pump systems.

18.4.6 DTS / TVCMS & SCADA systems

Monitoring and operating details including passwords and protocols. Operation and maintenance manuals, instruction guides for out of hours emergencies and information to be provided to UKPN Network Control shall be provided as part of the hand over of the tunnel system.

18.4.7 Storage of records and data

- Project and as-built drawings and structural details to be stored on Projectwise.
- Cable records to be stored with UKPN Network Records.
- Details of all plant, equipment and Civils assets to be stored on Ellipse.
- Periodic downloading of DTS information to be stored on Projectwise.

18.4.8 Handover and Training

The operation, inspection and maintenance procedures of all control and operational systems is to be clearly communicated and trained out by the Contractor and/or Delivery team to the Operations team taking control of the tunnel system.

User manuals and action to be taken in the event of emergency are to be summarised and documented on site in order to provide guidance in future years.
## 19 Reference Documents
In compiling this Design Manual the following documents have been taken into account:

<table>
<thead>
<tr>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEWAG Report – Special Report on Fire Resistant Cable Installation in Tunnels</td>
</tr>
<tr>
<td>Building Regulations 2000 (Amended 2010)</td>
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<tr>
<td>Buildings Act 1984</td>
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<tr>
<td>Sustainable and secure Buildings Act 2004</td>
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<tr>
<td>Town &amp; Country Planning Act</td>
</tr>
<tr>
<td>CDM 2007</td>
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<tr>
<td>BS 7671:2008 Requirements for Electrical Installations</td>
</tr>
<tr>
<td>Regulatory Reform (Fire Safety) Order 2005</td>
</tr>
<tr>
<td>BTS/ICE Tunnel Lining Design Guide</td>
</tr>
<tr>
<td>BS 5499 Fire Safety Signs</td>
</tr>
<tr>
<td>UK Power Networks Engineering Specification ES 02-4040 132kV Cables with Extruded Installation suitable for use in Cable Tunnels, Galleries and Cable Basements</td>
</tr>
<tr>
<td>Electricity at Work Regulations</td>
</tr>
<tr>
<td>STUVA Recommendations for Testing and Application of Sealing Gaskets in Segmental Linings</td>
</tr>
<tr>
<td>Environment Agency policy PPG 3</td>
</tr>
<tr>
<td>BS EN ISO 14122-4:2004 Fixed Access Ladders</td>
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<tr>
<td>Cigre Electrical Technical Paper 143</td>
</tr>
<tr>
<td>BS EN 60592:1992 (LV Lighting (Protection))</td>
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<tr>
<td>BS 6164:2001 (Lighting Levels)</td>
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<tr>
<td>BS EN 1125 (Emergency Escape Furniture)</td>
</tr>
<tr>
<td>BS EN 124:1994 Gully Tops / Manhole Tops for Vehicular &amp; Pedestrian Areas</td>
</tr>
<tr>
<td>BS EN 50266-1, 2-1, 2-5 Fire Resistance of Cables</td>
</tr>
<tr>
<td>BS EN 50200:2000 (Fire Resistance of Communications Cables)</td>
</tr>
<tr>
<td>BS 7863 / BS EN 3 Colour Coding of Fire Extinguishers</td>
</tr>
<tr>
<td>BS 5306-8 Selection and Installation of Portable Fire Extinguishers Code of Practice</td>
</tr>
<tr>
<td>Environment Agency policy PPG 2</td>
</tr>
</tbody>
</table>