NSP/002/001 - Guidance Document for the Installation of Fibre Optic Underground Cables

1. Purpose

The purpose of this document is to provide guidance on the installation requirements for fibre optic cables installed in cable duct systems located on the Northern Powergrid (the Company) distribution network.

This document supersedes the following documents, all copies of which should be destroyed;

Document Reference	Document Title	Version	Published Date
NSP/002/001	Guidance Document for the Installation of Fibre Optic Underground Cables	3.0	Nov 2020

2. Scope

This guidance document applies to fibre optic cable systems installed into cable duct systems for use on the distribution networks of Northern Powergrid and shall be read in conjunction with NPS/002/024 – Technical Specification for Fibre Optic Cables, Wrap, OPGW and ADSS

(Further information on the range of assessed products for use with fibre optic underground cables can be found on the Northern Powergrid website https://www.northernpowergrid.com/document-library/ when searching for the latest version of the "Assessed Products Database").

This document is complementary to the standard installation practice for underground cable laying as detailed in NSP/002 – Policy for the Installation of Distribution Power Cables and as such shall be read in conjunction with these documents. Special care must be taken while handling fibre optic cable, in any situation, as they are more susceptible to damage than conventional cables.

The following appendices form part of this Code of Practice:

- Appendix A - Calculating Pulling Tension for Underground Cables, and,
- Appendix B - Optical Power Budget – example of losses created in the route.

2.1. Table of Contents

3. Technical Requirements

3.1. Underground Fibre Optic Cable Installation Requirements

Fibre optic cables manufactured and supplied in accordance with NPS/002/024 – Technical Specification for Fibre Optic Cables, Wrap, OPGW and ADSS must be installed within sub ducts located within a continuous protective duct system. The fibre optic cable shall normally be installed in minimum lengths of 2km but may extend to 4km depending upon the optimum location of joint chambers and the type of installation equipment employed. Where practicable the duct system shall be designed before the fibre optic cable is ordered in conjunction with the installation contractors. Once the duct system has been established then the fibre optic cable can be ordered in the optimum lengths to match the duct system. Where detailed information on a scheme is not available at the early planning stages, the project shall be planned on a requirement for pull chambers to be installed every 480m and jointing chambers every 1920m.

Note: - The number of fibre splice joints in a fibre optic cable route has an effect on the overall level of attenuation introduced into a fibre route thus affecting the planned fibre budget for the job. For more information on the fibre budget please see Appendix B.

Fibre optic cables shall be tested whilst still on the delivery drum before any installation work commences in accordance with clause 3.6.1 of this document.

All cable ends shall then be re-sealed in readiness for installation. Testing shall be repeated in accordance with clause 3.6.2 of this documentation following installation of each length of fibre cable and before any splicing takes place to ensure no adverse changes in the attenuation of the fibre have occurred during the installation process.

The 8kN draw cord inside the sub-ducts shall be used for pulling in the fibre optic cable The Contractor shall ensure a swivel is located between the cable hauling rope and the hauling eye attached onto the fibre optic cable to ensure that the fibre optic cable is not subjected to undue twisting during the cable installation works.

Care must be taken at all times to avoid damaging the fibre optic cable. The cable should not be sharply bent or crushed. The quality and performance of the optical fibres circuit may be damaged if the cable is subjected to excessive pulling tensions or excessively small bend radii. At all times, the maximum pulling tension and minimum cable bend radius must be observed

Cables shall be installed using a capstan winch clutched at 2,000kg maximum and running at 30m/s maximum speed. The installers shall ensure that all cables are lubricated during installation using a water based biodegradable lubricant.

Where intermediate pits exist in the cable route the cable shall be installed through each chamber in one operation. Cable guides shall be used to support the cables in all intermediate pits.

Cables shall not be bent to an internal radius of less than 25 times the external diameter of the optical fibre cable, or less than the radius recommended by the manufacturer, whichever is greater.

All cable runs shall be provided with 10m re-termination loops at all joint chambers. These loops shall be neatly coiled in the jointing chambers. All cables entering a control room or building shall also be provided with 10 m re-termination loops to be installed under the floor in the Communications Room or, where this is not possible in the nearest joint chamber.

In addition all cable runs shall be provided with a 10m cable service loop nominally located every 500m, at the nearest cable pulling chamber.

Cable installation shall be carried out in a similar manner to sub-duct installation. Each section of sub-duct must be checked for blockages, cleaned and free of stones, soil or debris. A continuous draw rope shall be in place and its movement shall be unhindered through each installed duct.

Particular care must be taken when installing the cable, as optical fibres are delicate and easily damaged.

The cable reel, tensioning equipment, pay-off reel and pulling winch shall be aligned with either ends of the pulling chamber, and appropriate equipment such as snatch blocks, cable guides and swivel attachments used for the process.

Cables emerging from sub-ducts shall be sealed to the sub-duct end using a heat shrink sleeve. All cables shall be labelled with the pulling/jointing chamber number and the fibre start/end site names. Sufficient cable must be left at the first pulling chamber to allow the anaconda conduit to be fitted and the cable to travel up the tower or pole to be spliced onto the overhead fibre system or subsequently pull back into the substation terminating equipment.

3.2. Cable Ducts

Fibre optic cables ducts shall be installed in accordance with NSP/002 – Policy for the Installation of Distribution Power Cables with minimum installation depths as specified in clause 3.2.6 using the depths applicable to “LV & Services”. The ducts shall maintain the minimum cable spacing from other cables as specified in NSP/002; clause 3.2.9 using the “Mains cable and a cable containing telephone pairs” option.

The fibre optic cable ducts are specified to include for the following legend; “Northern Powergrid Fibre Cable”, to be marked on the ducts. The lettering shall be 8mm high in Black and repeated three times with a 120° spacing around the circumference, every 150mm along the length of the duct.

Ducts shall be orientated when being installed to ensure that this marking is prominently displayed.

Where ducts are installed in open cut trenches the cable ducts shall be identified and protected through the use of tile tape as detailed in NSP/002; clause 3.2.10 using the option applicable to “Service cables” with tile tape as specified in NPS/002/003 – Technical Specification for Protection Tile, Protection Tape, Cable Ducting and Route Markers.

The fibre optic cable ducts shall be 96.5mm outside diameter (90mm internal diameter) green cable ducts provided manufactured and supplied in accordance with NPS/002/003.

Two sub-ducts shall be installed inside each main fibre optic duct. The sub-ducts shall be black 32mm outside diameter (27mm internal diameter) ducts manufactured and supplied in 500m lengths in accordance with NPS/002/003.

Sub-ducts are designed to withstand a maximum pulling in tension of 110kg or 1.1Kn and a minimum bend radius of 0.45m (temperatures >5°C) or 0.55m (temperatures <5°C).

The sub-ducts shall be sealed to the outer ducts at all joint and pulling chambers to prevent debris entering the outer duct. All sub-ducts shall incorporate pre-installed polypropylene or equivalent rot-proof draw ropes of 8.0kN breaking capacity and be sealed with plugs to prevent water ingress. The pulling ropes shall be attached to the sealing plugs or secured to the fixed hardware in the underground chamber.

The duct system shall be checked for any blockages or obstructions before the sub-duct is installed. If necessary, the duct shall be ‘rodded’, brushed and prepared with a suitable draw rope.

The end of the sub-duct shall be appropriately terminated to allow it to be pulled through the duct.

A sub-duct shall be given a minimum of 24 hours after being installed to settle before being cut to the appropriate length. In warm conditions this may be extended to 48 hours. Specially designed cutting tools shall be used on the sub-duct, with great care taken not to damage the draw rope within. The draw rope shall at all times be secured to plugs at both ends of the sub-duct.

The external surface of the sub-duct may be lubricated if the length of duct requires this. The appropriate applicator for the type of sub-duct shall be used.

The drum carrying the sub-duct and the pulling winch shall be aligned with the duct and sufficiently secured. Sub-duct pulling shall be carried out at a steady pace. The tensions used for installation are based on the rated breaking strength of the cable. Typically 20% of this value is used. However, this tension is the total allowable tension that the cable can be subjected to during installation. Due to frictional forces, the tension on the cable is often greater than the pulling tension and this must be factored in to the installation practice. Appendix A describes this in more detail.

Sufficient continuous direct communication shall be implemented between the operators of both the winch and drum to ensure speed control and emergency stopping is possible.

Snatch blocks and installation wheels shall be attached to anchor points in the pulling chambers to aid the pulling operation.

The sub-duct shall be continuous through all pulling chambers, unless the cable is to be jointed or a cable loop is to be left. This cable loop shall be loosely secured, to the trench walls with cable ties. Jointing sleeves or sub-duct connectors may be used to join two lengths of sub-duct within a pulling chamber, but may not be used between two pulling chambers. The two sections of draw rope shall be connected using appropriate rope splicing methods.

Where two sections of sub-duct have been joined, they should only be secured to the pulling chamber or splice enclosure walls once the cable pulling operation has been completed.

Where the sub-duct is to be left for a period of time before the cable is installed, all ends must be sealed to prevent moisture ingress.

Where the underground fibre install is related to an overhead line project, then an anaconda conduit, or similar, shall be attached to the tower or pole leg beside the first pulling chamber, and joined to the first pulling chamber following cable installation. This tubing shall travel up the structure to meet the splice enclosure and shall be secured at 2m intervals. Further details can be found in NSP/004/123 – Guidance document on the installation of Fibre Optic Wrap onto Overhead Line Conductors.

3.3. Underground Chambers

Underground jointing and pull chambers shall be installed along the continuous duct route to provide access for installation of the fibre cable and for jointing/splicing of the fibre cable. The joint and pull chambers shall be 450mm x 600mm (for jointing/splicing chambers) or 450mm x 450mm (for pull chambers).

(Further information on the range of assessed products for use with fibre optic underground cables can be found on the Northern Powergrid website https://www.northernpowergrid.com/document-library/ when searching for the latest version of the “Assessed Products Database”).

Chambers shall be specified as BS EN 124 class B125 footway or class D400 Carriageway depending upon their installation locations, further guidance on the correct format for manhole covers can be found in BS 7903 ’Guide to selection and use of gully tops and manhole covers for installation within the highway’. Chambers may be supplied as prefabricated composite stacking type designs or as non-reinforced concrete cast in situ designs.

The chambers shall be designed for installation 600mm below the finished ground level onto a supporting base. The base shall typically consist of a wet or dry mix concrete base, reinforced if specified. For D400 carriageway loadings the base shall be 200mm thick reinforced concrete or for B125 non-carriageway applications, it shall typically be a minimum layer of 100mm of MOT type 1 fully compacted material. The base shall normally overlap the size of the chamber by 100mm on all sides. When the base material is being prepared, provision shall be made for installation of a sump drain in each chamber. This shall typically consisting of a 150mm x 150mm x 75mm diameter sump drain located in the base of the chamber connected to a plastic drainage pipe routed through and away from the supporting slab.

Note: - Where chambers are installed in unmade ground locations the chambers base may be provided from a 100mm layer of pea gravel which will be deemed to provide natural drainage.

All chambers shall be provided with lockable covers and frames to prevent unauthorised access that match the mechanical requirements of the chamber at its specific installation location. The chamber covers shall be embossed with an identification marking of "Northern Powergrid Optical Fibre".

The intermediate pull chambers will normally be located approximately 500m along the duct route or with a frequency as necessary to cope with changes in direct encountered along the duct route.

Note: - Where the opportunity has been taken to establish a possible future fibre optic cable route through the installation of a duct system during the cable excavation works, the duct system may omit the requirement for the installation of sub-ducts or underground chambers. Instead these can be retrofitted at a future point in time when the fibre cable is required.

Care shall be taken in the selection of pulling and jointing chambers positions to allow for sufficient space adjacent to the chambers to allow the set-up cable and sub-duct pulling locations and for the parking of vehicles in safe positions for fibre optic jointing activities. This shall include a risk assessment of the location taking into account blind bends, potential traffic hazards or pedestrian obstruction for instance and future work.

Note: - The splicing of fibre optic cables is normally carried out in the rear of the installers van using the spare fibre cable coiled in the jointing cambers to allow the work to be carried out in a clean and dry location.

3.3.1. Location of Jointing/Pull Chambers with respect to EHV Cable Routes

As discussed previously the fibre optic cable jointing or pull chambers can be installed at the time of installation of the cable duct or at a future date. In both cases the installation of the fibre optic duct will often be installed in associated with the installation of HV or EHV cable duct routes. As a result we need to consider the optimum location of the jointing or pull chambers to reduce the risk of inadvertent damage to the adjacent HV or EHV cables or the potential ground sterilisation adjacent to any existing HV or EHV joints that might create issues should we find the need to carry out repairs on those joints. Since any such repairs are likely to involve the installation of two new joints and a length of replacement cable, the fibre optic jointing or pull chambers shall be located a minimum of 20m up or down circuit from the centre line of existing or planned joint positions.

Additionally since HV or EHV cable routes are likely to be installed in the highway in future due to restricted routes in the footpaths we need to consider the optimum location of chamber locations to the left and right of the HV or EHV cable route.

Where we have a double circuit adjacent cable route it shall be assumed that the fibre optic cable ducts will be installed at the same depth and are located between the associated cable routes. As such both fibre optic duct routes will normally be routed into a common fibre optic chamber.

Where practicable the fibre optic chambers shall be located in any adjacent footpath to the left or right of the cable route or where this is not possible the centreline of the chamber shall be located at least 1.5m away from the nearest adjacent HV or EHV cable. All chamber positions will be agreed with the project manager before the start of the installation works.

3.4. Fibre Optic Cable Splices.

Fibre optic jointing shall be carried out using fusion type fibre splices, All splicing shall be carried out in strict accordance with the cable manufacturer's and splicer manufacturer's instructions. The Contractor shall be suitably trained in such jointing techniques. The colour code for identifying each fibre is detailed in NPS/002/024. – Technical Specification for Fibre Optic Cables, Wrap, OPGW and ADSS.

(Further information on the range of assessed products for use with fibre optic underground cables can be found on the Northern Powergrid website https://www.northernpowergrid.com/document-library/ when searching for the latest version of the "Assessed Products Database").

The contractor shall identify each fibre optic cable with a waterproof type of cable marker system before it enters the splice.

Wherever practicable the cable preparation and splicing work shall be carried out either in the back of the splicing vehicle or a suitably covered work area, and not in the chamber itself. The loose tubes containing the optical fibres shall be cut back to the required length using the appropriate tools. The fibres must have all traces of gel removed from their external surface.

The splice cassette shall, on completion of all splicing, contain nominally 2m but not less than 1.5m of excess fibre. The excess fibre should be securely stored observing the minimum bending radius requirements of the fibre.

The cable central strength member shall be either clamped or directed away from the fibres, and be free to move without obstruction or stressing the fibres.

All fibres shall be fusion spliced (as opposed to mechanical splicing) using a suitable splicing machine. Completed splices shall be protected by a mechanical splice protector. The protected splices shall be placed in the splice organiser (splice trays) within the splice enclosure, which should be sealed upon completion of the work to the manufactures recommended procedures.

Splice Losses – the mean splice loss must be equal to or less than 0.15dB the maximum individual splice loss shall be equal to or less than 0.2dB.

Non-conforming splice losses shall be reworked, the splice will be cut out, the fibres re-cleaved and re-spliced. If the splice still does not conform to the specification, the process must be repeated, up to a maximum of three times. Evidence of these attempts shall be recorded as Optical Time-domain Reflectometer (OTDR) traces and presented back to Northern Powergrid with the final test results in the "As built records".

If the attenuation measurement, after the third splice attempt, still does not conform, then the following concessions will apply:

- Mean splice loss <= 0.15dB
- Maximum splice loss must not be greater than 0.3dB

If after splicing the fibre the third time, the concession criteria are not met, an alternative splicing machine must be used. If non-conformance still applies, then this effectively eliminates the splicing techniques as a source of the fault, thus implying the fault lies within the fibre optic cable. This shall then be discussed with the project manager.

3.4.1. Fibre Identification

Fibres in buffer tubes shall be coloured for identification purposes using the following sequence taken from NPS/002/024 - Technical Specification for Fibre Optic Cables, Wrap, OPGW and ADSS.

Fibre No	Colour	Fibre No	Colour
1	Blue	7	Red
2	Orange	8	Violet
3	Green	9	Pink
4	Brown	10	White
5	Grey	11	Black
6	Yellow	12	Turquoise

A single tube shall not contain more than 12 fibres, the colour sequence will repeat in the next tube, but the tube will also be a different colour.

3.5. Fibre Optic Cable Terminations

At the remote ends of the fibre optic circuit the fibre optic cables shall be spliced onto fusion type pigtails that have been factory fitted with Lucent (LC/UPC) type connectors before being terminated into cubicle or wall mounted patch panels. All terminations shall provide minimum insertion loss values of <0.5dB per connector.

All single mode fibre optic patch leads shall be yellow in colour and supplied with factory fitted duplex 'LC/UPC' connectors on both ends unless required otherwise e.g. connections onto Relays or Multiplexers that have been supplied with 'ST' connectors. All 'LC/UPC' connectors shall be supplied complete with attached dust covers to protect the fibre ends when not being used. All fibre shall be terminated into the patch panels irrespective of the current need requirements.

Where fibre optic cables enter into the control or communications room, they shall be protected throughout their route from the duct to the communications cabinet. This shall normally be achieved through the use of a flexible conduit system secured to the wall of the trench or cable onto cable trays. The flexible conduit shall normally be secured into the base of the communications cabinet with cable glands and then continue to the top of the cabinet and then back down to the level of the appropriate patch panel. Care shall be taken with the routing of the flexible conduit to maintain the minimum bending radius of the fibres. Trench covers (checker plate) shall be modified / cut to accommodate the conduit and the conduit route shall not present a tripping hazard.

3.6. Testing Requirements

3.6.1. Testing Prior to Installation

Once the cable drum has been delivered to the Contractor, tests at 1550nm on each fibre from the cable end on the outside of the drum shall be taken to ensure that there is no damage prior to installation. Testing at the 1550nm wavelength will show up any microbends from the manufacture process. Northern Powergrid reserves the right to witness these tests. The contractor shall provide test results in the form of a test certificate that contains all relevant details and inform Northern Powergrid of any cable damage discovered.

3.6.2. Testing After Cabling

After the cable is installed but before any route splicing occurs, 'OTDR' tests shall be carried out on each fibre length in one direction to ensure that there is no damage post-installation. These tests shall be carried out at 1550nm to check for microbends or breaks caused by cabling damage and the results in the form of a test certificate that contains all relevant details shall be presented to Northern Powergrid.

3.6.3. End to End Testing Following Completion of Terminations

Northern Powergrid Telecoms or their approved contractors shall carry out termination works of all fibre cables within the Northern Powergrid building. This shall include the internal cabling, mounting of fibre wall boxes, installation of cabinet and Optical Distribution Frames (ODF's) etc. On completion of the installation works the fibre route shall be subjected to bi-directional end to end 'OTDR' and insertion loss measurement (ILM) test at both 1310nm and 1550nm. The results shall be recorded and presented to Northern Powergrid for evaluation and comparison with those provided by the installation contractor.

3.7. Commissioning Direct Fibre Links Between Hardware Interfaces

A link from site A to site B is presented at the 'ODF' or patch panel at each end and fibre patch cords are run to the hardware interfaces at each end.

I. At site A; inspect and clean the fibre patch cord; preferably with a 'Cletop' Cassette Cleaner or similar product. Also, clean the 'ODF' and equipment fibre ports using a 'one click' connector cleaner (such as that provided by AFL). Then connect the patch cord to the transmit port of the local device. Connect the other end of the same patch cord to an optical power meter, then measure and record the received level.

II. Remove the patch cord end from the optical power meter and connect it to the 'ODF' on the assigned port.

III. At site B; inspect and clean the fibre patch cord (as previously described) and connect it to the 'ODF' on the corresponding fibre port. Connect the other end to an optical power meter and measure and record the received level. This is the level that the local device at B will receive from the transmitter at site A. Then connect the patch cord to the receiver of the unit at site B.

IV. Carry out the same procedure for the link transmitting from B to A.

3.8. As Built Records

In addition to the 'OTDR' trace files and insertion loss measurements, the contractor shall provide photographs of each splice enclosure with close ups of the splice trays using a macro camera setting so that the quality of fibre preparation and splicing work is clearly visible. Further photographs of the splice enclosure fitted in a splice chamber, or on a tower or pole (with the tower/pole reference number) shall also be submitted to verify that the close up is of the correct enclosure.

The contractor shall also provide a report including showing the following information as part of the final project record:-

- Details of the optical route
- Date of the tests
- A end identity and B end identity
- Section length in km
- Total number of splices
- The location of each slice and its location in the route i.e. overhead or underground
- Type and location of chambers including grid ref and OHL tower or pole number.
- Wavelength used for testing
- 'OTDR' – make, model calibration date
- Calculated route attenuation from A end connector to B end connector

Copies of the 'OTDR' traces are to be supplied to Northern Powergrid by the contractor in a digital form.

Optical Power Loss Test

ILM tests are to be carried out on each fibre in the route, in both direction, at 1310nm and 1550nm. All results are to be recorded on the test report.

The test report must contain the following:-

- Details of the optical route
- Optical budget for the route as provided by Northern Powergrid
- 'A' end and 'B' end identification
- Date of test
- Total number of splices
- Equipment details
- Fibre identification number
- Operating wavelength
- Launch Power (dB)
- Attenuation of A-B and B-A (dB)
- Average attenuation (dB)
- Pass / Fail

In addition the contractor shall provide Northern Powergrid with a complete set of map sheets at 1:500, 1:2500 or 1:10,000 scale marked up to show the as built duct route with all chambers and splice positions marked up accordingly that are suitable to incorporate in to the Mains Record system and for issue to third parties in accordance with 'Safe Dig Utility Pack' requests.

4. References

The products described within this document shall comply with the relevant International Standards, British Standard Specifications and all relevant Energy Networks Association Technical Specifications (ENATS) current at the time of tendering, except where varied by this standard. In respect the following documents are particularly relevant.

4.1. External Documentation

Reference	Version / Date	Title
BS EN 124-1	2015	Gully tops and manhole tops for vehicular and pedestrian areas. Definitions, classification, general principles of design, performance requirements and test methods.
BS EN 124-4	2015	Gully tops and manhole tops for vehicular and pedestrian areas. Gully tops and manhole tops made of steel reinforced concrete.
BS EN 124-5	2015	Gully tops and manhole tops for vehicular and pedestrian areas. Gully tops and manhole tops made of composite materials.
BS EN 7903	1997	Guide to selection and use of gully tops and manhole covers for installation within the highway.

The supplier shall provide with the tender full technical details of the equipment offered and shall indicate any divergence from these standards or specifications.

4.2. Internal Documentation

Reference	Title
NPS/002/003	Technical Specification for Protection Tile, Protection Tape, Cable Ducting and Route Markers
NPS/002/024	Technical Specification for Fibre Optic Cables, Wrap, OPGW and ADSS
NSP/002	Policy for the Installation of Distribution Power Cables
NSP/004/123	Guidance document on the installation of Fibre Optic Wrap onto Overhead Line Conductors

4.3. Amendments from Previous Version

Reference	Description
Clause 2 Scope	The scope has been amended to remove incorrect references to clause NPS/002/029 and replace it with available guide from our Approved Products Database.
Clause 3.3 Underground Chambers	This clause has been amended to remove incorrect references to clause NPS/002/029 and replace it with available guide from our Approved Products Database.
Clause 3.4 Fibre Optic Cable Splices	This clause has been amended to remove incorrect references to clause NPS/002/029 and replace it with available guide from our Approved Products Database.
Clause 4.2 Internal Documentation	This clause has been amended to remove incorrect references to clause NPS/002/029

5. Definitions

Term	Definition
Attenuation	The reduction in optical power as a signal passes along a fibre due to dispersion, absorption and scattering. Usually expressed in decibels (dB).
Cable Gland	Device used for the entry of cables to provide strain relief at the points where they enter electrical equipment. Also provides sealing.
Duct	An underground buried tube or pipe installed to house and protect an underground cable.
EHV	Extra high voltage.
Fusion Splice	A permanent joint accomplished by heating the ends of two optical fibres and joining them together.
HV	High voltage.
ILM	Insertion Loss Measurement - Insertion loss is the loss of signal power resulting from the insertion of a device in an optical fibre and is usually expressed in decibels (dB).
LC/UPC	(Lucent Connector) A miniaturized version of the fibre-optic SC connector.
Mains records	Ordnance Survey map grid reference records of the companies mains apparatus installed on third party or public land for the purpose of distributing electricity.
MOT Type 1 fully compacted	MOT Type 1 fully compacted granular sub-base material, often referred to as MOT Type 1 - Crushed Concrete. Crushed Concrete is literally crushed concrete, meeting the requirement of the Department of Transport Specification for Highway Works, Clause 803. The “SHW”. Type 1 can also be constructed of other hard inert materials, slag or rocks, such as Limestone, Granite or Gritstone.
ODF	Optical distribution frames are passive devices which terminate optical cables allowing arbitrary interconnections to be made.
Optical Budget	The optical power budget in a fibre-optic communication link is the allocation of available optical power (launched into a given fibre by a given source) among various loss-producing mechanisms such as launch coupling loss, fibre attenuation, splice losses, and connector losses, in order to ensure that adequate signal strength (optical power) is available at the receiver. In optical power budget attenuation is specified in decibels (dB).
Optical Fibre	A strand of very thin, optically pure glass that can carry digital information over long distances.
OTDR	Optical Time-domain Reflectometer.
Patch Lead	Short length of fibre optic cable, with a connector at each end, used to join items of equipment such as optical distribution frame and relay panel.
Pulling Chamber	A box shaped area, at intermittent points along an underground trench, which forms part of an underground ducting system. This box allows the sub-duct or cable to be pulled part way along a trench. Also known as a draw box.
Ripcord	A cord placed directly under the jacket of a cable in order to facilitate stripping (removal) of the jacket.
Single-mode Fibre	An optical fibre designed to carry only a single ray (mode) of light.
Splice	Where two lengths of fibre are joined together.
The Company	Northern Powergrid.

6. Authority for Issue

6.1. CDS Assurance

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

		Date
Liz Beat	Governance Administrator	17/02/2022

6.2. Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

Review Period - This document should be reviewed within the following time period;

Standard CDS review of 3 years?	Non Standard Review Period & Reason	
No	**Period: 1 Year**	**Reason: As instructed by Paul Black on EXT1 Auth Form - Document Review 1 year to allow review of alternative installation methods**
Should this document be displayed on the Northern Powergrid external website?		Yes
		Date
Ged Hammel	Senior Policy & Standards Engineer	01/03/2022

6.3. Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

		Date
Michael Crowe	Protection Manager	09/03/2022
Steve Salkeld	Policy & Standards Engineer	28/02/2022
Joe Helm	Policy & Standards Engineer	28/02/2022

6.4. Authorisation

Authorisation is granted for publication of this document.		
		Date
Paul Black	System Engineering Manager	24/03/2022

Appendix A - Calculating Pulling Tension for Underground Cables

The installation of an underground cable is slightly different from the installation of overhead cables. This is mainly due to the addition of frictional forces caused by pulling the cable through a sub-duct.

The maximum allowable pulling tension is calculated in the same way as an overhead cable, that is, 20% of the rated breaking strength.

The tension used to pull the cable into the duct must be great enough to overcome the frictional forces acting on it. The tension needed for installation can be calculated using the following calculations. However, this tension must be found to be less than the maximum allowable pulling tension.

A 1.1 Straight Pull

When pulling a cable along a horizontal stretch of duct, the following calculation shall be used:

$T = T0 + \mu \times W \times L$

Where:

T = Total Tension on the cable (Pulling Tension)

T0 = Tension needed to pull the cable of its reel (=0 if assisted)

μ = Coefficient of Friction (0.5 for standard ducting, 0.25 if lubricated)

W = Weight of Cable per unit length (Mass in kg multiplied by 9.8)

L = Length of Cable being Pulled

A 1.2 Pulling Up or Down a Slope

When pulling a cable up or down a slope, Figure A1 and equation (A2) shall be used.

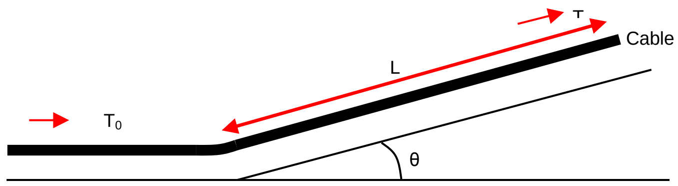


Fig A1: Pulling an Underground Cable up a Slope

$T = T1 + W \times L (\sin\theta + \mu \cos\theta)$

Where:

T = Total Tension on the Cable

T1 = Pulling Tension

μ = Coefficient of Friction (0.5 for standard ducting, 0.25 if lubricated)

W = Weight of Cable per unit length (Mass in kg multiplied by 9.8)

L = Length of Cable being Pulled

θ = Gradient of Pull (Upward is positive, Downward is negative)

Appendix B - Optical Power Budget – Example of Losses Created in the Route

The difference between transmitter power and receiver sensitivity is defined as the optical power budget (or margin). Power loss in the fibre optic link must not exceed this value.

Transmitter power is defined as the minimum peak optical power injected into the fibre by the optical transmitter.

Receiver sensitivity is defined as the minimum received peak optical power that will produce a recovered electrical signal with timing distortion of less than + 4 nanoseconds.

B 1 - Allocating the Optical Power Budget

The optical power budget available for each fibre optic link must be allocated into three categories:

- Aging Margin
- Fibre Attenuation
- Connector Loss
- Splice Loss

B2 - Aging Margin

- To protect against deterioration of fibre or component performance, 3 dB of the power budget for each link is reserved as an aging margin.

B3 - Fibre Attenuation

- Single mode fibre typically has an attenuation of 0.36 dB/km or less. (at 1310 nm).

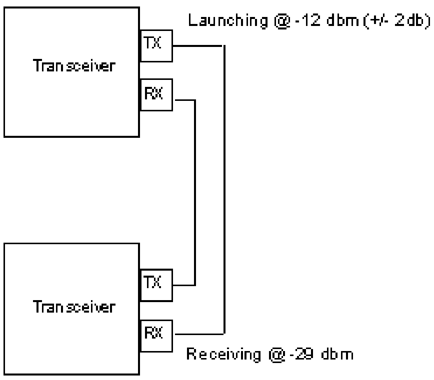
B4 - Connector Loss

- LC connectors have a maximum allowable loss of 0.5 dB for each fibre-to-fibre connection. This connector loss must be allowed for when calculating your optical power budget.

B5 – Splice Loss

- Maximum allowable splice losses assumed as 0.3dB per splice.

Example



When calculating your optical power budget, the goal is to create a configuration where the launch calculation minus the receive calculation is the maximum db loss possible. This will create a network with strong signal integrity.

The picture above can be calculated as follows:

Launch:	-12 dB (+/- 2 dB)
Receive: minus	-29 dB
	= 17 dB

Because of the +/- 2 dB factor on Launch power a worst case scenario will be to make the power budget 15 dB instead of 17 dB.

The calculation of connector loss, aging timer and attenuation must be less than 15 dB.

Example of a typical 8km route using 2km standard lengths

Connector loss: (typical value 0.5 dB per connector) i.e. 2 x 0.5 dB = 1 dB.

Splice loss: (typical value 0.3 dB per splice) i.e. with 1 splice/2km this becomes 4 x 0.3 = 1.2 dB.

Aging Timer loss: (safety margin) 3 dB.

Fibre cable attenuation loss: (0.36 dB/km) therefor assuming 8km of cable = 2.88 dB

Total Losses 8.08 dB

As can be seen the loss budget in this example works fine but assuming the start and finish equipment values remained the same and we increased the circuit length to 20km then the losses in the cable and connectors would sum to 14.8 dB which would be suggesting that 20km would be the maximum circuit length allowed to guarantee signal integrity without the use of repeaters.

To increase the allowable fibre route length beyond the distance discussed in this example we would need to either reduce the number of splices though longer installed sections or we would need to improve the optical budget associated with the sending and receiving equipment.

The purpose of this example is to demonstrate the effect that changing the construction plan from the original design plan can have on the final performance of a fibre optic link.

Note: - This example does not include any additional potential losses created by patch leads or other potential connections created within the end to end route.