IMP/001/013 - Code of Practice for Underground Cable Ratings and Parameters

1. Purpose

The purpose of this document is to state Northern Powergrid's policy for the derivation of ratings and the parameters to be applied when designing underground cable systems. The document applies to the distribution systems of both Northern Powergrid (Northeast) Ltd and Northern Powergrid (Yorkshire) plc, the licensed distributors of Northern Powergrid.

This Code of Practice also helps to ensure the company achieves its requirements with respect to the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004), The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002 (as Amended)[1], the Health and Safety at Work Act 1974, the Electricity Distribution Licences, The Distribution Code and The Grid Code.

This document supersedes the following documents, all copies of which should be withdrawn from circulation;

Document Reference	Document Title	Version	Published Date
IMP/001/013	Code of Practice for Guidance on the Selection of Underground Cable Ratings	4.1	Jun 2021

2. Scope

The parameters stated in this document apply to:

- existing underground distribution cables at all voltage levels; and
- new underground distribution cables at all voltage levels installed as part of distribution system developments including new connections, system reinforcement and asset replacement.

[1] This includes The ESQC (Amendment) Regulations 2006 (No. 1521, 1st October 2006) and The ESQC (Amendment) Regulations 2009 (No. 639, 6th April 2009).

2.1. Table of Contents

3. Code of Practice

3.1. Assessment of Relevant Drivers

The key internal business drivers relating to the derivation of ratings and parameters to be applied when designing underground cable systems are:

- Employee commitment - achieved by providing our employees with the information necessary to develop a safe distribution system that is fit for purpose and to help ensure that employees are not exposed to risks to their health as far as reasonably practicable;
- Financial strength - achieved by developing a distribution system that has a minimum overall lifetime cost;
- Customer service - achieved by providing information on equipment ratings and other parameters to third parties who are interested in a connection to Northern Powergrid's distribution system;
- Regulatory integrity - achieved by designing a robust distribution system that meets mandatory and recommended standards;
- Environmental respect - achieved through due consideration being given to the environmental impact of new developments including the impact on system losses and carbon footprint; and
- Operational excellence - achieved through improving the quality, availability and reliability of supply.

The external business drivers relating to the selection and application of underground cable ratings are detailed in the following sections.

3.1.1. Requirements of the Electricity Act 1989 (as amended)2

Section 9 (1) of the Electricity Act 1989 (as amended) places an obligation on Distribution Network Operators (DNOs) to develop and maintain an efficient, co-ordinated and economical system of electricity distribution and to facilitate competition in the supply and generation of electricity.

Discharge of this obligation is supported by this document in providing guidance on the application of appropriate cable ratings.

3.1.2. The Health and Safety at Work Act 1974

Section 2(1) of The Health and Safety at work Act 1974, states that 'It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees.' Section 3(1) also states that 'It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety.'

This is addressed in this Code of Practice by:

- Stating the continuous, cyclic and where applicable emergency rating appropriate to underground cables forming the distribution system;
- Stating the assumptions associated with these ratings; and
- Providing impedance data so that short circuit levels can be accurately calculated.

[2] The Utilities Act 2000 and The Energy Act 2004 and The Energy Act 2004 (Amendment) Regulations 2012 (No. 2723, 2012)

3.1.3. Requirements of The Electricity Safety, Quality and Continuity (ESQC) Regulations

The ESQC Regulations 2002 (No.2665, 31st January 2003) and its amendments[3] impose a number of obligations on the business, mainly relating to safety and quality of supply. All the requirements of the ESQC Regulations that are applicable to the design and development of the distribution system shall be complied with.

Reg. No	Text	Application to this Code of Practice
3(1)(a)	…distributors…shall ensure that their equipment is sufficient for the purposes for and the circumstances in which it is used.	This Code of Practice will contribute to compliance with the ESQC Regulations by providing cable parameters for any analysis which is required to be carried out to ensure that the continuous, cyclic, emergency and short circuit duties to which equipment is exposed is within its capability.
23	A distributor shall ensure that his network shall be- (a) so arranged… as to restrict, so far as is reasonably practicable, the number of consumers affected by any fault in his network.	Guidance is given on the application of appropriate underground cable ratings such that an appropriate level of demand can be secured during outage conditions.

3.1.4. Requirements of the Electricity at Work Regulations 1989

Regulation 5 of The Electricity at Work Regulations 1989 states: 'No electrical equipment shall be put into use where its strength and capability may be exceeded in such a way as may give rise to danger' and places obligations on the business relating to the safety of plant and equipment used on the distribution system. It requires that plant and equipment is designed and operated within the limits of its capability.

Discharge of this obligation is supported by this document in providing guidance on the application of appropriate cable ratings.

3.2. Key Policy Requirements

The general objective in operating and developing the distribution system is to obtain a simple and robust system having minimum overall cost, taking into account the initial capital investment, system losses and the maintainability and operability over the life of the asset.

This Code of Practice is written to help ensure that the distribution system is operated and developed in such a way as to:

- prevent danger to members of the public and Northern Powergrid staff and our sub-contractors;
- discharge the obligation under section 9 of the Act, and specifically to have due regard to future requirements and network performance;
- ensure the underground cable network has an appropriate capacity to supply our customers under normal and outage conditions; and
- satisfy all other relevant obligations.

3.3. Underground Cable Ratings and Impedance Data

This Code of Practice is split into two parts; cable ratings (section 3.4) and cable impedance data (section 3.5). The cable ratings section is split into two main sections; generic static ratings and bespoke static ratings.

[3] This includes The ESQC (Amendment) Regulations 2006 (No. 1521, 1st October 2006) and The ESQC (Amendment) Regulations 2009 (No. 639, 6th April 2009).

3.4. Cable Ratings

3.4.1. General

A generic static rating (GSR) is the current carrying capacity of a cable quoted by a manufacturer or engineering standard using standard assumptions about installation conditions and environmental factors. The GSRs can be used for existing cables on the distribution system where installation conditions are unknown.[4] GSRs can also be used for initial planning purposes for proposed cables, where the installation conditions are not yet known or where the assessed[5] loading of the cable is significantly lower than the generic static rating value.

If the rating of a particular cable is critical, then a bespoke static rating (BSR) may be required. This involves a more accurate assessment of the on-site conditions combined with manufacturer specific ratings. This will involve calculations that may require the use of analytical software which thermally models the cable in accordance with IEC 60287. Northern Powergrid presently approve the use of the EA Technology software called CRATER for this purpose, as it has been developed in conjunction with DNOs via our innovation programme.

Where a BSR of an existing cable is insufficient for the assessed[6] loading, the application of a bespoke dynamic rating (BDR) may be considered. Application of a BDR requires real time monitoring[7] and an associated control system[8] to regulate the current flowing in the cable.

Application of a BDR should only be considered for an existing cable where it is more economic than developing the distribution system such that the application of a GSR or BSR is sufficient. For all new cable installations the planned loading should be less than its GSR or BSR. It is envisaged that application of a BDR for cables will only be used in a minority of cases, at EHV and 132kV, where traditional cable replacement or other system development is uneconomic taking into account the BDR equipment costs, the cost of electrical losses and the risks associated with application of a BDR.

When considering applying BDR an assessment of the electrical losses shall be made in accordance with the Code of Practice for the Assessment of Asset Specific Losses, IMP/001/103.

As the application of a BDR for underground cables is in its infancy, before considering a potential application, further guidance should be sought from the System Planning Manager.

[4] It is worth noting that a significant number of the existing cables used on the distribution system were designed, manufactured and installed many years ago; the specifications, material used and design tolerances have changed during this period and it can be difficult to establish a definitive rating (and the assumptions used to derive it) for every cable deployed in the distribution system, hence the use of generic static ratings.

[5] i.e. existing loading or future calculated loading.

[6] i.e. existing loading or future calculated loading.

[7] Report CLNR-L164 suggested a Distribution Temperature Sensing (DTS) system would be impractical for existing cables, however real time environmental information can be used to estimate the cable operational temperature at hot spots along the cable.

[8] Such as an Active Network Management scheme to regulate loadings.

A summary of the different types of cable ratings are shown in Table 1.

Feature	Generic Static Rating (GSR)	Bespoke Static Rating (BSR)	Bespoke Dynamic Rating (BDR)
Application	New and existing cables	New and existing cables	Existing cables only
Typical application voltage	LV, HV, EHV* & 132kV* (*initial planning stages)	HV, EHV, 132kV	EHV, 132kV
Measurements	None	Initial measurements and/or site specific assessment	Periodic measurements through monitoring
Monitoring	None	None	Required
Control system	None	None	Required to regulate current flow
Risk	Low	Low - Medium	High
Technology readiness level	High	High	Low

Table 1 - A summary of the features of different cable ratings

3.4.2. Continuous, Emergency and Cyclic ratings

Three ratings for each cable have been provided in Appendix 1 for continuous, cyclic and emergency conditions, both for laid direct and ducted installations. As a general rule, the continuous as laid rating should be used in the first instance when assessing the suitability of a particular cable and this should accommodate the expected initial and future loading on the cable under all credible running arrangements. The cyclic rating of a cable may be used in line with guidance provided in the following Codes of Practice which also provide further information on the appropriate choice of cable and additional considerations:

- Economic Development of the LV System, IMP/001/911;
- Economic Development of the HV System, IMP/001/912;
- Economic Development of the EHV System, IMP/001/913; and
- Economic Development of the 132kV System, IMP/001/914.

Emergency cable ratings are provided for operational purposes only. A summary of the continuous, emergency and cyclic ratings are shown in Table 2.

	Continuous	Cyclic	Emergency
Rating Multiplier	1	1.14	1.21
Permitted daily load profile[9]	Continuous	8hrs at 1.14 followed by 16hrs at <=0.6[10]	3hrs at 1.21 followed by 21hrs at <=0.8
Typical application	Planning Stage Operational Scenarios	Planning Stage Operational Scenarios	Operational Scenarios Only

Table 2 - A summary of the application of continuous, emergency and cyclic ratings

The cyclic rating above is likely to cover the majority of installation conditions as LLF's are generally lower than 0.5 on Northern Powergrid's network. Where the load profile is more onerous than that above, then a bespoke assessment of cyclic rating shall be made.

[9] When the permitted daily load profile is repeated for more than one week per year the effect of the drying out of the soil must be considered. See section 3.4.4.2.

[10] These factors broadly reflect the conditions presented in ER P17 i.e. LLF of 0.5 and load curve G.

3.4.3. Generic Static Ratings

The ratings quoted in Appendix 1 of this document are GSRs for different cable types. These values are derived from a variety of sources including:

- Ratings for imperial three and four core cables manufactured to BS 480 are given in BEBS-C2 (copper conductors), BEBS-C6 (aluminium conductors) and ERA report F/T 183;
- Ratings for imperial split-concentric cables are given in BEBS specification C7 schedule D;
- Ratings for cables manufactured to BS 6480 are given in ERA report 69-30 Part 1;
- Ratings for cables manufactured to BS 6346 are given in ERA report 69-30 Part 3;
- Ratings for concentric service cables are given in EATS 09-7 Table 1;
- Ratings for split-concentric service cables manufactured to BS 4553 are given in the schedules of Engineering Recommendation C67; and
- Ratings for three phase polymeric insulated CNE service and distribution cables shall be the same as the equivalent size 4 core armoured LV cable manufactured to BS 6480.

The standard conditions used for Northern Powergrid's GSRs in Appendix 1 are shown in Table 3.

Ratings for 6kV cable data has not been provided as this is a non-preferred voltage for which cable ratings shall be based upon the 11kV current rating. Any new cable connected to an existing 6kV system shall be capable of being operated at 11kV.

25kV traction supply cable data has not been provided and shall be determined on a bespoke basis.

	Low Voltage Cables	High Voltage Cables	EHV Cables & 132kV Cables
Ambient air temperature	25°C		
Ambient soil temperature	15°C		
Thermal resistivity of soil	1.2°C.m/W[11]		
Depth of laying (to centre of cable or trefoil group)	0.5m	0.8m	
Maximum conductor temperature[12]	Concentric and Split-concentric service cable 70°C PILC 65°C Waveform 80°C Consac 90°C	PILC/PICAS, belted, solid 65°C PILC/PICAS, screened, solid 70°C XLPE 90°C	XLPE cables 90°C PPL 90°C Pressure cables 85°C Paper cables 65°C
Bonding	Solid		
Arrangement	Multicore	Multicore or Trefoil/Triplex	Multicore or Trefoil

Table 3 - Table showing the installation and environmental parameters used for Generic Static Ratings

[11] Work undertaken as part of the Customer Led Network Revolution (CLNR) project suggests that the standard installation values of soil resistivity used to determine cable ratings in Engineering Recommendation P17, parts 1-3 are considerably lower at 0.9°C.m/W than measured values taken at Northern Powergrid substation sites. From the sites measured, soil resistivity values varied between 1.5°C.m/W and 2.0°C.m/W. However, the historical standard for soil resistivity in the UK is 1.2°C.m/W and shall be used for generic static ratings. See section 3.4.3.4 for further considerations for on soil thermal resistivity.

[12] When selecting the appropriate maximum conductor operating temperature of the cable, care should be taken to ensure that the operating temperature of the new cable co-ordinates with that of any existing cable that is to be connected to it. New cables may have to be de-rated to a lower operating temperature to ensure maximum operating temperatures are not exceeded on existing cables and in such cases assessment of the reduced rating is required to ensure the capacity of the new cable is sufficient for the circumstances in which it is to be used. This is particularly relevant where an XLPE cable with an operating temperature of 90°C is connected to a paper insulated cable with an operating temperature of 65°C. Further co-ordination may be required to take into account the expansion rate differences between stranded conductor cable and solid conductor cable and the thermal resistivities of the respective cable insulations. Further guidance is available from the Policy and Standards manager.

3.4.3.2. Bespoke Static Ratings

Where the GSRs are insufficient for the assessed loading or the installation conditions differ from those stated in Table 3, a BSR can be applied. A BSR assessment can be undertaken either applying the de-rating factors in Appendix 2 or using an enhanced ratings assessment tool that is based on IEC 60287 (such as CRATER).

The following sections detail the various factors which should be considered for a BSR assessment.

When a BSR have been applied to a circuit it should be noted on the asset records.

3.4.3.3. Depth of Laying

The de-rating factors stated in Appendix 2a shall be applied to all cables up to and including 33kV whose depth differs from the standard installation depth stated in Table 3. Reference should be made to the Policy for the Installation of Distribution Power Cables, NSP/002 for information on appropriate depths of cables in different situations.

When studying the rating of a cable circuit with a varying horizontal profile (such as a trenchless installation) the deepest point shall be taken as the depth of laying to be used for the calculation.

When cables are installed at shallow depths or when they are strapped to the sides of structures, the effect of solar gain shall be taken into consideration, in accordance with ENA EREC C98 'Physical Protection of Cables Crossing Bridges'.

3.4.3.4. Thermal Resistivity of Soil

The de-rating factors stated in Appendix 2b can be applied to all cables up to and including 33kV laid in soil where the average thermal resistivity is at a value other than 1.2°C.m/W. The suggested soil resistivity for different materials in different conditions is shown in Table 4.

Material	Normal Winter	Normal Summer	Dried Out
Soil	1.05 °C.m/W	1.20 °C.m/W	2.70 °C.m/W
Selected Sand	1.05 °C.m/W	1.20 °C.m/W	2.70 °C.m/W
Cement Bound Sand	1.05 °C.m/W	1.20 °C.m/W	1.20 °C.m/W
Unknown Material	1.20 °C.m/W	1.20 °C.m/W	3.00 °C.m/W

Table 4 - A table showing soil thermal resistivity for bespoke static ratings

'Normal Winter' and 'Normal Summer' shall be applied to material outside the 50°C isotherm, 'Dried Out' shall be applied to material within the 50°C isotherm, in conjunction with the following:

- Where a cable is specified to operate with a cyclic current pattern during normal operation but may operate at maximum current rating continuously for not more than one week of the year (i.e. a typical distribution cable circuit), drying out of the soil does not need to be considered, and the Thermal Resistivity of the surround is considered normal.
- Where a cable is specified to operate with a continuous current pattern during normal operation drying out of the surround must be considered[13].

[13] Although the continuous rating shown in section 3.4.2 infers a cable has a continuous rating, this rating assumes the installation conditions remain constant. However in a minority of cases where the profile is continuous and repeated for more than one week per year (such as a biomass generator) the soil may dry out and the cable will become derated. Where non-cyclic loads of this nature are being considered a BSR should be used to derate the cable.

The engineering analysis will allow on-site conditions[14] and specific cable characteristics to be modelled in order to produce a BSR. It is worth noting that the choice of a cable backfill with a lower thermal resistivity can release additional capacity in new installations[15]. Appendix 2b details typical gains that can be possible with different backfill thermal resistivity

3.4.3.5. Ambient Temperature

The de-rating factors stated in Appendix 2c shall be applied to cables up to and including 33kV laid direct where the ambient ground temperature is at temperatures other than 15°C. The suggested ground temperatures to use are show in Table 5.

	Normal Winter	Normal Summer
Laid direct (<5m deep)	10°C	15°C
Laid direct (≥5m deep)	10°C	10°C

Table 5 – A table to show ambient temperature assumptions for bespoke static ratings

3.4.3.6. Proximity

All de-rating factors quoted are based on the centre to centre spacing of each cable in the case of multi-core cables or the centre to centre spacing of each group of cables in the case of single core cables laid in either flat or trefoil formation. As per section 2.1(b) of Engineering Recommendation P17, Current Rating Guide for Distribution Power Cables, for cables laid in close proximity to other loaded circuits where runs are short (say less than 15m) and the congestion is not excessive, the effects of proximity de-rating can be ignored.

Single Core Cables Laid Direct

The de-rating factors in Appendix 2d shall be applied to single core cables up to and including 33kV that are in close proximity to other underground cables and laid direct.

Single Core Cables Laid in Ducts

The de-rating factors in Appendix 2e shall be applied to single core cables up to and including 33kV that are in close proximity to other underground cables and laid in ducts.

Multi-Core Cables Laid Direct

The de-rating factors in Appendix 2f shall be applied to multi-core cables up to and including 33kV that are in close proximity to other underground cables and laid direct.

Multi-Core Cables Laid in Ducts

The de-rating factors in Appendix 2g shall be applied to multi-core cables up to and including 33kV that are in close proximity to other underground cables and laid in ducts.

3.4.3.7. Ducts

As per section 2.1(a) of Engineering Recommendation P17, Current Rating Guide for Distribution Power Cables, for cables laid direct that contain a continuous ducted section of less than 15m in length, the effects of duct de-rating can be ignored. Cables laid in ducts that are filled with an appropriate bentonite filling that is appropriately sealed into the duct shall be rated as if it was laid direct.

[14] E.g. the presence of other cable, cables installed in ducts or at non-standard depths.

[15] The use of special stabilised backfill is only typically viable for EHV and 132kV cables where the costs of installing a larger size cable may be prohibitive and where the installation conditions are such that the backfill is likely to be undisturbed during the life of the cable installation.

3.4.3.8. Sheath Earthing

Where cables are not solidly bonded at both ends (i.e. cross bonded[16] or bonded at one end) the uplift in current carrying capacity can be determined using software such as CRATER.

3.4.3.9. Single Core Cables Laid Flat

Where single core cables are not laid in trefoil but laid flat spaced, the ratings uplift can be determined in CRATER. Care should be taken that the increased reactance values are also taken into account.

3.5. Nominal Impedance Data

Appendix 3 shows typical impedance data for commonly used cables on the Northern Powergrid network. This data can used for most applications where manufacturers' data is not available.

The impedance data stated in Appendix 3 is derived from a variety of sources including:

- Manufacturer's datasheets;
- ENA TS 09-12 (Impregnated Paper Insulated Corrugated Aluminium Sheathed 6350/11000 Voltage Cable);
- ENA TS 09-17 (Single Core Cables for Use in Substations Having Extruded Insulations and Rated Voltage of 6350/11000 Volts, and 19000/33000 Volts);
- ENA TS 09-21 (Cross-linked polymeric insulated triplex cables for a rated voltage of 6350/11000 V (Um = 12000V);
- BICC Cables Handbook (3rd edition) tables, formulae and empirical data;
- ABB/Westinghouse Transmission and Distribution Reference Book (5th edition); and
- DSS/007/031 (Overhead Line and Cable Impedance Data) – Legacy draft document.

It is intended the data will be amended from time to time to include new cable designs. The data shown in Appendix 3 includes the positive, negative and zero sequence components for resistance, inductive reactance, capacitance, susceptance and charging current for HV, EHV and 132kV cables. The phase, neutral and earth resistance and inductive reactance are shown for LV cables.

3.5.1. Resistance

For cables the positive sequence resistance (R1) and negative sequence resistances values (R2) are equal. The AC resistance values are shown in Table 3 for maximum operating temperature. The DC resistance at 20°C value is also shown.

The AC resistance at operating temperature should be used for calculation of the worst case for voltage regulation calculations. For fault level studies the AC resistance at 20°C should be used to give a worst case fault level.[17]

[16] As per NSP/002 Section 3.6.1 all new 33kV, 66kV and 132kV cables systems shall be solidly bonded. Cross bonding uprating shall only be used on existing cable systems.

[17] For cable sizes less than 400mm^2 the DC resistance can normally be used as a proxy for AC resistance in most applications.

The positive and negative sequence resistances are usually available from manufacturer's datasheets; however the zero sequence resistance values are not as readily available. Where the zero sequence resistance values are not available they can be calculated as follows:

Cable Type	Zero Sequence Resistance (R_0)
Single core cable	$R_{1(20°C)} + R_{metallic\ covering}$
Three core cable	$R_{1(20°C)} + 3x\ R_{metallic\ covering}$
Three core cable (with individual sheath)	$R_{1(20°C)} + R_{metallic\ sheath}$ in parallel with $3x\ R_{armour}$

Table 6 – A table to show the calculation method for zero sequence resistance (R_0)[18]

3.5.2. Reactance

For cables the positive sequence reactance (X_1) and negative sequence reactance values (X_2) are equal. These values are shown in Appendix 3.

The positive and negative sequence reactance values are usually available from manufacturer's datasheets; however the zero sequence reactance values are not as readily available. Where the zero sequence reactance values are not available they can be calculated as follows:

Cable Type	Zero Sequence Reactance (X_0)
Single Core cable	$X_0 = 0.314[0.46 \log_{10}(D/d) + K]$ (Ω/km) D = mean diameter of metallic covering (mm) d = conductor diameter (mm) K = 0.050 for solid conductors K ≈ 0.055 for stranded conductors
Three core cable	$X_0 = 0.434\log_{10}(D/GMD)$ (Ω/km) D = mean diameter of metallic covering (mm) GMD = Geometric Mean Diameter 0.75x diameter of a circle which circumscribes conductors

Table 7 – A table to show the calculation method for zero sequence reactance (X_0)[19]

3.5.3. Capacitance, Susceptance and Charging Current

The capacitance of a cable is a calculation of the stored charge between a conductor and an earthed screen and/or another conductor. For single core and individually screened conductors the positive (C_1), negative (C_2) and zero sequence capacitance (C_0) are equal.

Where zero sequence capacitance data is not available for belted cable it can be assumed the zero sequence capacitance (C_0) is 0.83x the positive sequence capacitance (C_1).[20]

The susceptance (B) is the imaginary part of admittance. It is calculated as the reciprocal of the capacitive reactance. $B = 1/X_c = 2\pi fC$

From the susceptance, the charging current can therefore be calculated as:

$I_c = BV_{P\text{-}E} = 2\pi fC\ V_{P\text{-}E}$

[18] Based on BICC Cable Handbook – 3rd edition (P176).

[19] Based on BICC Cable Handbook – 3rd edition (P12 & P177).

[20] Based on BICC Cable Handbook – 3rd edition (P16).

4. References

4.1. External Documentation

Reference	Title	Version and Date
	ABB/Westinghouse Transmission and Distribution Reference Book	5th edition
	BICC Cables Handbook tables, formulae and empirical data	3rd edition
BEBS-C2	Specification for impregnated paper insulated solid type lead or lead alloy sheath power cables for voltages up to and including 22kV (incorporating amendments 1 to 6 inclusive)	
BEBS-C6	Specification for impregnated paper insulated solid type lead or lead alloy sheath power cables having aluminium conductors for voltages up to and including 22kV (incorporating amendments 1 to 3 inclusive)	
BEBS-C7	Specification for polyvinylchloride insulated power cables for voltages up to and including 3,300 volts (incorporating amendments 1 to 9 inclusive)	
BS 4553	PVC insulated split concentric cables with copper conductors	1998
BS 480-1	Impregnated paper-insulated cables for electricity supply lead or lead alloy sheathed cables for working voltages up to and including 33kV	July 1954
BS 480-2	Impregnated paper-insulated cables for electricity supply. aluminium cables for working voltages up to and including 22kV	July 1954
BS 6480	Impregnated paper insulated cables for electricity supply – lead or lead alloy sheathed cables for working voltage up to and including 33kV (metric units)	1988
EATS 09-7	PVC insulated concentric service cables with stranded copper or solid aluminium phase conductors and copper concentric conductors	
ENA TS 09-12	Impregnated Paper Insulated Corrugated Aluminium Sheathed 6350/11000 Voltage Cable	
ENA TS 09-17	Single Core Cables for Use in Substations Having Extruded Insulations and Rated Voltage of 6350/11000 Volts, and 19000/33000 Volts	
ENA TS 09-21	(Cross-linked polymeric insulated triplex cables for a rated voltage of 6350/11000 V (Um = 12000V)	
Engineering Recommendation C55/4	Insulated Sheath Power System Cables	1989
Engineering Recommendation C67	Specification for impregnated paper insulated solid type cables for voltages up to and including 33,000 volts and PVC insulated cables for voltages up to and including 3,300 volts	
Engineering Recommendation C98	Physical protection of Cables Crossing Bridges	
Engineering Recommendation P17, Part 1	Current Rating Guide for Distribution Cables	1976
Engineering Recommendation P17, Part 2	Solid Type Cables for 33kV	1976
Engineering Recommendation P17, Part 3	Ratings for 11kV and 33kV Cables having extruded insulation	Issue 1, 2004
ERA Report 69-30 (Part 1)	Sustained ratings for paper insulated lead covered cables to BS 6480	1969

Reference	Title	Version and Date
ERA Report 69-30 (Part 3)	Sustained ratings for PVC insulated cables to BS 6346	1969
ERA Report F/T183	Current ratings for paper insulated cables to BS 480 (1954) and varnished – cambric – insulated cables to BS 608 (1955)	
HSAWA	The Health and Safety at Work Act	1974
IEC 60287	Electric cables - Calculation of the current rating	2020
SI 2002 No. 2665	The Electricity Safety, Quality and Continuity Regulations	31 January 2003
SI 2006 No. 1521	The ESQC (Amendment) Regulations 2006	1 October 2006
SI 2009 No. 639	The ESQC (Amendment) Regulations 2009	6 April 2009
The Act	The Electricity Act 1989 (as amended by The Utilities Act 2000 and The Energy Act 2004 and The Energy Act 2004 (Amendment) Regulations 2012 (No. 2723, 2012)	2012
The Distribution Code	The Distribution Code covers all material technical aspects relating to connections to the operation and use of the Distribution Network Operators (DNO's).	Issue31, May 2018
The Electricity Distribution Licence	Standard conditions of the Electricity Distribution Licence.	April 2015
The Grid Code	The Grid Code sets out the operating procedures and principles governing the relationship between NGET and all Users of the National Electricity Transmission System be they Generators, DC Converter owners, Suppliers or Non-Embedded Customers.	Issue 6 Revision 1 September 2021

4.2. Internal Documentation

Reference	Title
* DSS/005/040	Standard Current Ratings for 11kV and LV Cables
* DSS/005/039	Standard Current Ratings for 33kV and 66kV Cables
* DSS/007/031	Overhead Line and Cable Impedance Data
~ Legacy Northern Electric document	
* Legacy Yorkshire Electricity document	
~O.257	Low Voltage Underground Mains and Services
~O.259 (DRAFT)	High Voltage Underground Cable Systems
IMP/001/103	Code of Practice for the Methodology of Assessing Losses
IMP/001/911	Code of Practice for the Economic Development of the LV System
IMP/001/912	Code of Practice for the Economic Development of the HV System
IMP/001/913	Code of Practice for the Economic Development of the EHV System
IMP/001/914	Code of Practice for the Economic Development of the 132kV System
NPS/002/019	Technical Specification for LV Distribution and Service Cables
NPS/002/020	Technical Specification for 11 & 20kV Power Cables
NPS/002/021	Technical Specification for 33kV Power Cables
NPS/002/022	Technical Specification for 66kV Power Cables
NSP/002	Policy for the Installation of Distribution Power Cables

4.3. Amendments from Previous Version

Section	Amendments
Appendix 1a – LV underground cable generic static ratings	Amended the KVA ratings for two phase "Service Cable - Imperial".
Table 9, Table 10, Table 11, Table 12, Table 13 and Table 14	Included the ducted rating for the LV underground cable.
Table 32	The existing 132kV XLPE Metric Conductor (Single Core - Trefoil) ratings for 300mm^2, 400mm^2, 500mm^2, 630mm^2, 800mm^2, 1000mm^2 and 1200mm^2 have been amended with the data from TELE-FONIKA Kable SA (TF Kable) based on the cable installation with the metallic screens solidly bonded to earth at both the ends. Previous ratings were based on the cable installation where the metallic screen was cross bonded which does not comply with the NSP/002 – Policy for the Installation of Distribution Power Cables.

5. Definitions

Term	Definition
Al	Aluminium
B_0	Zero Sequence Susceptance
B_1	Positive Sequence Susceptance
B_2	Negative Sequence Susceptance
BDR	Bespoke Dynamic Rating
BSR	Bespoke Static Rating
C_0	Zero Sequence Capacitance
C_1	Positive Sequence Capacitance
C_2	Negative Sequence Capacitance
CAS	Corrugated aluminium sheath
Continuous rating	The maximum continuous current that can be carried without the maximum conductor temperature being exceeded.
CRATER	Cable RATER (Cable ratings tool)
Cu	Copper
Cyclic rating	Rating for a load cycle equivalent to 8 hours at enhanced rating, preceded by 16 hours at 0.6 continuous rating (1.14 x continuous rating)
d	conductor diameter
D	mean diameter of metallic covering
DNO	Distribution Network Operator. The person or legal entity named in Part 1 of the Distribution Licence and any permitted legal assigns or successors in title of the named party.
EHV	EHV refers to voltages equal to or greater than 33kV and less than 132kV.
Emergency rating	Rating for a load cycle equivalent to 3 hours enhanced rating preceded by 21 hours at 0.8 continuous rating (1.21 x continuous rating)
GMD	Geometric Mean Diameter
GSR	Generic Static Rating
HV	HV refers to voltages greater than 1000V and less than 33kV.
I_C	Charging Current
k	Conductor Stranding constant
LLF	Load loss factor
LSF	Low smoke and fume
LV	LV refers to voltages less than 1000V.
MDPE	Medium density polyethylene
Northern Powergrid	Northern Powergrid (Northeast) Ltd and Northern Powergrid (Yorkshire) plc.
PE	Polyethylene
PICAS	Paper insulated corrugated aluminium sheath
PILC	Paper insulated lead covered
PPL	Paper polythene layer
PVC	Polyvinyl chloride
R_0	Zero Sequence Resistance
R_1	Positive Sequence Resistance
R_2	Negative Sequence Resistance
STA	Steel tape armour
SWA	Steel wire armoured
U	System Voltage
X_0	Zero Sequence Reactance
X_1	Positive Sequence Reactance
X_2	Negative Sequence Reactance
XLPE	Cross-linked polyethylene

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	05/09/2022

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	
Yes	**Period:** n/a	**Reason: n**/a
Should this document be displayed on the Northern Powergrid external website?		Yes
		Date
Anuj Chhettri	Smartgrid Development Engineer	Date 08/09/2022

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
Paul Hanrahan	Engineer - Asset Management	Date 08/09/2022

6.4. Authorisation

Authorisation is granted for publication of this document.

		Date
Mark Callum	Smart Grid Development Manager	Date 08/09/2022

Appendix 1a – LV Underground Cable Generic Static Ratings

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
0.23	0.007	Cu	1	Paper	Split Conc	-	56	13	64	15	68	16	46	11	53	12	56	13
0.23	0.0225	Cu	1	Paper	Split Conc	-	110	25	125	29	133	31	91	21	104	24	110	25
0.23	0.04	Cu	1	Paper	Split Conc	-	155	36	177	41	188	43	129	30	147	34	156	36
0.23	0.007	Cu	2	Paper	Lead	STA	62	29	71	33	75	35	51	24	59	27	62	29
0.23	0.0225	Cu	2	Paper	Lead	STA	120	55	137	63	145	67	100	46	114	52	121	55
0.23	0.04	Cu	2	Paper	Lead	STA	165	76	188	87	200	92	137	63	156	72	166	76

Table 8 - Cable Ratings – LV Services Imperial

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
0.23	4	Cu	1	PVC	Split Conc	PVC	53	12	60	14	64	15	44	10	50	12	53	12
0.23	16	Al	1	PVC	Split Conc	PVC	84	19	96	22	102	23	70	16	79	18	84	19
0.23	4	Cu	1	PVC	Concentric	PVC	53	12	60	14	64	15	44	10	50	12	53	12
0.23	25	Al	1	PVC	Concentric	PVC	115	26	131	30	139	32	95	22	109	25	115	27
0.23	35	Al	1	PVC	Concentric	PVC	140	32	160	37	169	39	116	27	132	30	141	32

Table 9 - Cable Ratings - LV Services Metric

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
0.4	0.06	Al	4	Paper	Pb	STA	135	94	154	107	163	113	112	78	128	88	136	94
0.4	0.1	Al	4	Paper	Pb	STA	185	128	211	146	224	155	154	106	175	121	186	129
0.4	0.15	Al	4	Paper	Pb	STA	225	156	257	178	272	189	187	129	213	147	226	157
0.4	0.2	Al	4	Paper	Pb	STA	270	187	308	213	327	226	224	155	255	177	271	188
0.4	0.25	Al	4	Paper	Pb	STA	310	215	353	245	375	260	257	178	293	203	311	216
0.4	0.3	Al	4	Paper	Pb	STA	350	242	399	276	424	293	291	201	331	229	352	244
0.4	0.0225	Cu	4	Paper	Pb	STA	100	69	114	79	121	84	83	58	95	66	100	70
0.4	0.04	Cu	4	Paper	Pb	STA	140	97	160	111	169	117	116	81	132	92	141	97
0.4	0.05	Cu	4	Paper	Pb	STA	160	111	182	126	194	134	133	92	151	105	161	111
0.4	0.06	Cu	4	Paper	Pb	STA	175	121	200	138	212	147	145	101	166	115	176	122
0.4	0.075	Cu	4	Paper	Pb	STA	205	142	234	162	248	172	170	118	194	134	206	143
0.4	0.1	Cu	4	Paper	Pb	STA	240	166	274	190	290	201	199	138	227	157	241	167
0.4	0.15	Cu	4	Paper	Pb	STA	290	201	331	229	351	243	241	167	274	190	291	202
0.4	0.2	Cu	4	Paper	Pb	STA	345	239	393	272	417	289	286	198	326	226	346	240
0.4	0.25	Cu	4	Paper	Pb	STA	395	274	450	312	478	331	328	227	374	259	397	275
0.4	0.3	Cu	4	Paper	Pb	STA	445	308	507	351	538	373	369	256	421	292	447	310

Table 10 - Cable Ratings - LV PILC Imperial (Four Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
0.4	70	Al	4	Paper	Pb	STA	185	128	211	146	224	155	154	106	175	121	186	129
0.4	95	Al	4	Paper	Pb	STA	225	156	257	178	272	189	187	129	213	147	226	157
0.4	120	Al	4	Paper	Pb	STA	255	177	291	201	309	214	212	147	241	167	256	177
0.4	185	Al	4	Paper	Pb	STA	330	229	376	261	399	277	274	190	312	216	331	230
0.4	300	Al	4	Paper	Pb	STA	430	298	490	340	520	360	357	247	407	282	432	299

Table 11 Cable Ratings - LV PILC Aluminium Metric (Four Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
0.4	35	Al	3	XLPE	Al	-	125	87	143	99	151	105	104	72	118	82	126	87
0.4	70	Al	3	XLPE	Al	-	185	128	211	146	224	155	154	106	175	121	186	129
0.4	120	Al	3	XLPE	Al	-	255	177	291	201	309	214	212	147	241	167	256	177
0.4	185	Al	3	XLPE	Al	-	330	229	376	261	399	277	274	190	312	216	331	230
0.4	300	Al	3	XLPE	Al	-	430	298	490	340	520	360	357	247	407	282	432	299

Table 12 - Cable Ratings - LV Waveform Aluminium/Aluminium Metric (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
0.4	35	Al	3	XLPE	Cu	-	125	87	143	99	151	105	104	72	118	82	126	87
0.4	70	Al	3	XLPE	Cu	-	185	128	211	146	224	155	154	106	175	121	186	129
0.4	95	Al	3	XLPE	Cu	-	235	163	268	186	284	197	195	135	222	154	236	164
0.4	120	Al	3	XLPE	Cu	-	255	177	291	201	309	214	212	147	241	167	256	177
0.4	185	Al	3	XLPE	Cu	-	335	232	382	265	405	281	278	193	317	220	336	233
0.4	300	Al	3	XLPE	Cu	-	435	301	496	344	526	365	361	250	412	285	437	303

Table 13 - Cable Ratings - LV Waveform Aluminium/Copper Metric (Three/Four Core)

Appendix 1b – HV Underground Cable Generic Static Ratings

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
11	0.04	Al	3	Paper (Belted)	Lead	SWA	89	1.70	97	1.85	104	1.98	77	1.46	84	1.59	90	1.71
11	0.05	Al	3	Paper (Belted)	Lead	SWA	100	1.91	110	2.10	117	2.23	86	1.64	95	1.81	101	1.92
11	0.06	Al	3	Paper (Belted)	Lead	SWA	112	2.13	124	2.36	133	2.53	97	1.84	107	2.04	115	2.18
11	0.075	Al	3	Paper (Belted)	Lead	SWA	126	2.40	140	2.67	150	2.86	109	2.07	121	2.30	129	2.46
11	0.1	Al	3	Paper (Belted)	Lead	SWA	150	2.86	166	3.16	180	3.43	129	2.46	143	2.73	155	2.96
11	0.15	Al	3	Paper (Belted)	Lead	SWA	186	3.54	208	3.96	226	4.31	160	3.05	179	3.42	195	3.71
11	0.2	Al	3	Paper (Belted)	Lead	SWA	220	4.19	248	4.73	271	5.16	190	3.61	214	4.07	234	4.45
11	0.25	Al	3	Paper (Belted)	Lead	SWA	250	4.76	284	5.41	311	5.93	216	4.11	245	4.66	268	5.11
11	0.3	Al	3	Paper (Belted)	Lead	SWA	281	5.35	321	6.12	352	6.71	242	4.62	277	5.27	303	5.78
11	0.4	Al	3	Paper (Belted)	Lead	SWA	332	6.33	381	7.26	421	8.02	286	5.45	328	6.26	363	6.91
11	0.5	Al	3	Paper (Belted)	Lead	SWA	371	7.07	429	8.17	476	9.07	320	6.09	370	7.05	410	7.82
11	0.04	Al	3	Paper (Screened)	Lead	SWA	96	1.83	107	2.04	114	2.17	83	1.58	92	1.76	98	1.87
11	0.05	Al	3	Paper (Screened)	Lead	SWA	110	2.10	123	2.34	132	2.51	95	1.81	106	2.02	114	2.17
11	0.06	Al	3	Paper (Screened)	Lead	SWA	122	2.32	136	2.59	146	2.78	105	2.00	117	2.23	126	2.40
11	0.075	Al	3	Paper (Screened)	Lead	SWA	138	2.63	155	2.95	167	3.18	119	2.27	134	2.55	144	2.74
11	0.1	Al	3	Paper (Screened)	Lead	SWA	163	3.11	183	3.49	200	3.81	141	2.68	158	3.01	172	3.28
11	0.15	Al	3	Paper (Screened)	Lead	SWA	201	3.83	227	4.32	250	4.76	173	3.30	196	3.73	216	4.11
11	0.2	Al	3	Paper (Screened)	Lead	SWA	235	4.48	268	5.11	297	5.66	203	3.86	231	4.40	256	4.88
11	0.25	Al	3	Paper (Screened)	Lead	SWA	267	5.09	305	5.81	340	6.48	230	4.39	263	5.01	293	5.58
11	0.3	Al	3	Paper (Screened)	Lead	SWA	298	5.68	343	6.54	384	7.32	257	4.89	296	5.63	331	6.31
11	0.4	Al	3	Paper (Screened)	Lead	SWA	351	6.69	406	7.74	461	8.78	303	5.77	350	6.67	397	7.57
11	0.5	Al	3	Paper (Screened)	Lead	SWA	391	7.45	454	8.65	514	9.79	337	6.42	391	7.46	443	8.44

Table 14 – Cable Ratings - 11kV PILCSWA Aluminium Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
11	0.04	Cu	3	Paper (Belted)	Lead	SWA	114	2.17	126	2.40	135	2.57	98	1.87	109	2.07	116	2.22
11	0.05	Cu	3	Paper (Belted)	Lead	SWA	130	2.48	142	2.71	151	2.88	112	2.14	122	2.33	130	2.48
11	0.06	Cu	3	Paper (Belted)	Lead	SWA	144	2.74	159	3.03	171	3.26	124	2.37	137	2.61	147	2.81
11	0.075	Cu	3	Paper (Belted)	Lead	SWA	163	3.11	181	3.45	194	3.70	141	2.68	156	2.97	167	3.19
11	0.1	Cu	3	Paper (Belted)	Lead	SWA	193	3.68	214	4.08	231	4.40	166	3.17	184	3.51	199	3.79
11	0.15	Cu	3	Paper (Belted)	Lead	SWA	239	4.55	268	5.11	291	5.54	206	3.93	231	4.40	251	4.78
11	0.2	Cu	3	Paper (Belted)	Lead	SWA	283	5.39	319	6.08	348	6.63	244	4.65	275	5.24	300	5.72
11	0.25	Cu	3	Paper (Belted)	Lead	SWA	321	6.12	264	5.03	399	7.60	277	5.27	228	4.34	344	6.55
11	0.3	Cu	3	Paper (Belted)	Lead	SWA	360	6.86	410	7.81	451	8.59	310	5.91	353	6.73	389	7.41
11	0.4	Cu	3	Paper (Belted)	Lead	SWA	421	8.02	485	9.24	535	10.19	363	6.91	418	7.97	461	8.79
11	0.5	Cu	3	Paper (Belted)	Lead	SWA	467	8.90	541	10.31	601	11.45	403	7.67	466	8.89	518	9.87
11	0.04	Cu	3	Paper (Screened)	Lead	SWA	124	2.36	138	2.63	150	2.86	107	2.04	119	2.27	129	2.46
11	0.05	Cu	3	Paper (Screened)	Lead	SWA	142	2.71	159	3.03	170	3.24	122	2.33	137	2.61	147	2.79
11	0.06	Cu	3	Paper (Screened)	Lead	SWA	157	2.99	175	3.33	192	3.66	135	2.58	151	2.87	166	3.15
11	0.075	Cu	3	Paper (Screened)	Lead	SWA	178	3.39	200	3.81	216	4.12	153	2.92	172	3.28	186	3.55
11	0.1	Cu	3	Paper (Screened)	Lead	SWA	209	3.98	236	4.50	260	4.95	180	3.43	203	3.88	224	4.27
11	0.15	Cu	3	Paper (Screened)	Lead	SWA	258	4.92	293	5.58	324	6.17	222	4.24	253	4.81	279	5.32
11	0.2	Cu	3	Paper (Screened)	Lead	SWA	302	5.75	344	6.55	383	7.30	260	4.96	297	5.65	330	6.29
11	0.25	Cu	3	Paper (Screened)	Lead	SWA	342	6.52	391	7.45	435	8.29	295	5.62	337	6.42	375	7.14
11	0.3	Cu	3	Paper (Screened)	Lead	SWA	381	7.26	438	8.35	490	9.34	328	6.26	378	7.19	422	8.05
11	0.4	Cu	3	Paper (Screened)	Lead	SWA	446	8.50	516	9.83	581	11.07	384	7.33	445	8.48	501	9.54
11	0.5	Cu	3	Paper (Screened)	Lead	SWA	492	9.37	573	10.92	646	12.31	424	8.08	494	9.41	557	10.61

Table 15 – Cable Ratings - 11kV PILCSWA Copper Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	mm²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
11	185	Al	3	Paper (Belted)	Lead	SWA	277	5.28	319	6.08	351	6.69	239	4.55	275	5.24	303	5.77
11	240	Al	3	Paper (Belted)	Lead	SWA	323	6.15	373	7.11	414	7.89	278	5.31	322	6.13	357	6.80
11	300	Al	3	Paper (Belted)	Lead	SWA	364	6.94	424	8.08	473	9.01	314	5.98	366	6.96	408	7.77
11	185	Al	3	Paper (Screened)	Lead	SWA	295	5.62	342	6.52	379	7.22	254	4.85	295	5.62	327	6.22
11	240	Al	3	Paper (Screened)	Lead	SWA	343	6.54	399	7.60	445	8.48	296	5.63	344	6.55	384	7.31
11	300	Al	3	Paper (Screened)	Lead	SWA	386	7.35	453	8.63	507	9.66	333	6.34	391	7.44	437	8.33

Table 16 - Cable Ratings - 11kV PILCSWA Aluminium Metric Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	mm²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
11	95	Al	3	Paper (Belted)	CAS	PVC	185	3.52	211	4.02	224	4.26	160	3.05	182	3.48	194	3.69
11	185	Al	3	Paper (Belted)	CAS	PVC	270	5.14	308	5.86	327	6.22	230	4.38	262	5.00	278	5.30
11	300	Al	3	Paper (Belted)	CAS	PVC	355	6.76	405	7.71	430	8.18	305	5.81	348	6.62	369	7.03
11	95	Al	3	Paper (Screened)	CAS	PVC	205	3.91	234	4.45	248	4.73	170	3.24	194	3.69	206	3.92
11	185	Al	3	Paper (Screened)	CAS	PVC	295	5.62	336	6.41	357	6.80	250	4.76	285	5.43	303	5.76
11	300	Al	3	Paper (Screened)	CAS	PVC	380	7.24	433	8.25	460	8.76	325	6.19	371	7.06	393	7.49
11	300	Cu	3	Paper (Belted)	CAS	PVC	434	8.27	495	9.43	525	10.01	374	7.13	427	8.13	453	8.63
11	300	Cu	3	Paper (Screened)	CAS	PVC	460	8.76	524	9.99	557	10.60	397	7.56	452	8.61	480	9.14

Table 17 - Cable Ratings - 11kV PICAS Metric Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted in one duct/*trefoil ducts)					
Voltage	mm^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
11	95	Al	1	XLPE	CWS	MDPE	245	4.67	279	5.32	296	5.65	205	3.91	241	4.59	256	4.87
11	185	Al	1	XLPE	CWS	MDPE	355	6.76	405	7.71	430	8.18	295	5.62	349	6.65	370	7.06
11	300	Al	1	XLPE	CWS	MDPE	460	8.76	524	9.99	557	10.60	385	7.34	452	8.61	480	9.14
11	400	Al	1	XLPE	CWS	MDPE	537	10.23	612	11.66	650	12.38	449	8.55	528	10.05	560	10.67
11	300	Cu	1	XLPE	CWS	MDPE	590	11.24	673	12.81	714	13.60	495	9.43	564	10.75	599	11.41
11	400	Cu	1	XLPE	CWS	MDPE	665	12.67	758	14.44	805	15.33	540	10.29	616	11.73	653	12.45
11	500*	Cu	1	XLPE	CWS	MDPE	750	14.29	855	16.29	908	17.29	655	12.48	747	14.23	793	15.10
11	630*	Cu	1	XLPE	CWS	MDPE	840	16.00	958	18.24	1016	19.37	730	13.91	832	15.86	883	16.83

Table 18 - Cable Ratings - 11kV XLPE Metric Conductor (Single Core Triplexed/Trefoil)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
20	0.04	Al	3	Paper (Belted)	Lead	SWA	82	2.8	93	3.2	99	3.4	73	2.5	83	2.9	88	3.1
20	0.06	Al	3	Paper (Belted)	Lead	SWA	100	3.5	114	3.9	121	4.2	90	3.1	103	3.6	109	3.8
20	0.1	Al	3	Paper (Belted)	Lead	SWA	140	4.8	160	5.5	169	5.9	125	4.3	143	4.9	151	5.2
20	0.15	Al	3	Paper (Belted)	Lead	SWA	170	5.9	194	6.7	206	7.1	150	5.2	171	5.9	182	6.3
20	0.2	Al	3	Paper (Belted)	Lead	SWA	205	7.1	234	8.1	248	8.6	185	6.4	211	7.3	224	7.8
20	0.25	Al	3	Paper (Belted)	Lead	SWA	235	8.1	268	9.3	284	9.9	205	7.1	234	8.1	248	8.6
20	0.3	Al	3	Paper (Belted)	Lead	SWA	265	9.2	302	10.5	321	11.1	235	8.1	268	9.3	284	9.9
20	0.04	Al	3	Paper (Screened)	Lead	SWA	95	3.3	106	3.7	113	3.9	82	2.8	91	3.2	97	3.4
20	0.06	Al	3	Paper (Screened)	Lead	SWA	119	4.1	134	4.6	144	5.0	103	3.6	116	4.0	124	4.3
20	0.1	Al	3	Paper (Screened)	Lead	SWA	158	5.5	179	6.2	193	6.7	136	4.7	154	5.3	166	5.8
20	0.15	Al	3	Paper (Screened)	Lead	SWA	196	6.8	223	7.7	241	8.3	169	5.9	192	6.7	208	7.2
20	0.2	Al	3	Paper (Screened)	Lead	SWA	229	7.9	263	9.1	285	9.9	197	6.8	227	7.9	246	8.5
20	0.25	Al	3	Paper (Screened)	Lead	SWA	260	9.0	299	10.4	326	11.3	224	7.8	258	8.9	281	9.7
20	0.3	Al	3	Paper (Screened)	Lead	SWA	290	10.0	336	11.6	367	12.7	250	8.7	290	10.0	316	11.0

Table 19 - Cable Ratings - 20kV PILCSWA Aluminium Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
20	0.04	Cu	3	Paper (Belted)	Lead	SWA	105	3.6	120	4.1	127	4.4	94	3.3	107	3.7	114	3.9
20	0.06	Cu	3	Paper (Belted)	Lead	SWA	130	4.5	148	5.1	157	5.4	115	4.0	131	4.5	139	4.8
20	0.1	Cu	3	Paper (Belted)	Lead	SWA	180	6.2	205	7.1	218	7.5	160	5.5	182	6.3	194	6.7
20	0.15	Cu	3	Paper (Belted)	Lead	SWA	220	7.6	251	8.7	266	9.2	195	6.8	222	7.7	236	8.2
20	0.2	Cu	3	Paper (Belted)	Lead	SWA	265	9.2	302	10.5	321	11.1	235	8.1	268	9.3	284	9.9
20	0.25	Cu	3	Paper (Belted)	Lead	SWA	300	10.4	342	11.8	363	12.6	265	9.2	302	10.5	321	11.1
20	0.3	Cu	3	Paper (Belted)	Lead	SWA	335	11.6	382	13.2	405	14.0	295	10.2	336	11.6	357	12.4
20	0.04	Cu	3	Paper (Screened)	Lead	SWA	122	4.2	137	4.7	146	5.1	105	3.6	118	4.1	126	4.4
20	0.06	Cu	3	Paper (Screened)	Lead	SWA	154	5.3	173	6.0	185	6.4	133	4.6	149	5.2	159	5.5
20	0.1	Cu	3	Paper (Screened)	Lead	SWA	204	7.1	231	8.0	248	8.6	176	6.1	199	6.9	214	7.4
20	0.15	Cu	3	Paper (Screened)	Lead	SWA	251	8.7	286	9.9	309	10.7	216	7.5	247	8.5	266	9.2
20	0.2	Cu	3	Paper (Screened)	Lead	SWA	294	10.2	337	11.7	366	12.7	253	8.8	291	10.1	316	10.9
20	0.25	Cu	3	Paper (Screened)	Lead	SWA	332	11.5	382	13.2	416	14.4	286	9.9	329	11.4	359	12.4
20	0.3	Cu	3	Paper (Screened)	Lead	SWA	370	12.8	428	14.8	468	16.2	319	11.0	369	12.8	403	14.0

Table 20 - Cable Ratings - 20kV PILCSWA Copper Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	mm²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
20	95	Al	3	Paper (Screened)	Lead	SWA	195	6.8	222	7.7	236	8.2	170	5.9	194	6.7	206	7.1
20	185	Al	3	Paper (Screened)	Lead	SWA	285	9.9	325	11.3	345	11.9	245	8.5	279	9.7	296	10.3

Table 21 - Cable Ratings 20kV PILCSWA Aluminium Metric Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted in one duct/*trefoil ducts)					
Voltage	mm²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
20	95	Al	1	XLPE		MDPE	245	8.5	279	9.7	296	10.3	205	7.1	234	8.1	248	8.6
20	150	Al	1	XLPE		MPDE	310	10.7	353	12.2	375	13.0	265	9.2	302	10.5	321	11.1
20	185	Al	1	XLPE		MDPE	355	12.3	405	14.0	430	14.9	295	10.2	336	11.6	357	12.4
20	240	Al	1	XLPE		MDPE	410	14.2	467	16.2	496	17.2	355	12.3	405	14.0	430	14.9
20	300	Al	1	XLPE		MDPE	460	15.9	524	18.2	557	19.3	400	13.9	456	15.8	484	16.8
20	150	Cu	1	XLPE		MDPE	405	14.0	462	16.0	490	17.0	340	11.8	388	13.4	411	14.3
20	185	Cu	1	XLPE		MDPE	455	15.8	519	18.0	551	19.1	385	13.3	439	15.2	466	16.1
20	240	Cu	1	XLPE		MDPE	525	18.2	599	20.7	635	22.0	455	15.8	519	18.0	551	19.1
20	300	Cu	1	XLPE		MDPE	590	20.4	673	23.3	714	24.7	510	17.7	581	20.1	617	21.4
20	400	Cu	1	XLPE		MDPE	670	23.2	764	26.5	811	28.1	540	18.7	616	21.3	653	22.6
20	500*	Cu	1	XLPE		MDPE	755	26.2	861	29.8	914	31.6	665	23.0	758	26.3	805	27.9
20	630*	Cu	1	XLPE		MDPE	845	29.3	963	33.4	1022	35.4	740	25.6	844	29.2	895	31.0

Table 22 - Cable Ratings 20kV XLPE Metric Conductor (Single Core Triplexed/Trefoil)

Appendix 1c – 33kV and 66kV Underground Cable Generic Static Ratings

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
33	0.1	Cu	3	Paper	Pb		205	11.7	234	13.4	248	14.2	145	8.3	165	9.4	175	10.0
33	0.15	Cu	3	Paper	Pb		255	14.6	291	16.6	309	17.6	175	10.0	200	11.4	212	12.1
33	0.2	Cu	3	Paper	Pb		295	16.9	336	19.2	357	20.4	205	11.7	234	13.4	248	14.2
33	0.25	Cu	3	Paper	Pb		335	19.1	382	21.8	405	23.2	230	13.1	262	15.0	278	15.9
33	0.3	Cu	3	Paper	Pb		370	21.1	422	24.1	448	25.6	255	14.6	291	16.6	309	17.6
33	0.35	Cu	3	Paper	Pb		400	22.9	456	26.1	484	27.7	275	15.7	314	17.9	333	19.0
33	0.4	Cu	3	Paper	Pb		435	24.9	496	28.3	526	30.1	300	17.1	342	19.5	363	20.7
33	0.45	Cu	3	Paper	Pb		450	25.7	513	29.3	545	31.1	310	17.7	353	20.2	375	21.4
33	0.5	Cu	3	Paper	Pb		480	27.4	547	31.3	581	33.2	335	19.1	382	21.8	405	23.2
33	0.55	Cu	3	Paper	Pb		505	28.9	576	32.9	611	34.9	350	20.0	399	22.8	424	24.2
33	0.6	Cu	3	Paper	Pb		530	30.3	604	34.5	641	36.7	365	20.9	416	23.8	442	25.2

Table 23 - Cable Ratings 33kV PILC Copper Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
33	0.1	Cu	3	Oil	Pb		240	13.7	274	15.6	290	16.6	200	11.4	274	15.6	242	13.8
33	0.15	Cu	3	Oil	Pb		295	16.9	336	19.2	357	20.4	250	14.3	336	19.2	303	17.3
33	0.2	Cu	3	Oil	Pb		340	19.4	388	22.2	411	23.5	290	16.6	388	22.2	351	20.1
33	0.25	Cu	3	Oil	Pb		390	22.3	445	25.4	472	27.0	330	18.9	445	25.4	399	22.8
33	0.3	Cu	3	Oil	Pb		430	24.6	490	28.0	520	29.7	365	20.9	490	28.0	442	25.2
33	0.35	Cu	3	Oil	Pb		470	26.9	536	30.6	569	32.5	405	23.1	536	30.6	490	28.0
33	0.4	Cu	3	Oil	Pb		495	28.3	564	32.3	599	34.2	435	24.9	564	32.3	526	30.1
33	0.45	Cu	3	Oil	Pb		525	30.0	599	34.2	635	36.3	460	26.3	599	34.2	557	31.8
33	0.5	Cu	3	Oil	Pb		550	31.4	627	35.8	666	38.0	480	27.4	627	35.8	581	33.2
33	0.55	Cu	3	Oil	Pb		575	32.9	656	37.5	696	39.8	505	28.9	656	37.5	611	34.9
33	0.6	Cu	3	Oil	Pb		600	34.3	684	39.1	726	41.5	530	30.3	684	39.1	641	36.7

Table 24 - Cable Ratings 33kV Oil Filled Copper Imperial Shaped Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
33	0.1	Cu	3	Gas	Pb		225	12.9	257	14.7	272	15.6	190	10.9	217	12.4	230	13.1
33	0.15	Cu	3	Gas	Pb		280	16.0	319	18.2	339	19.4	240	13.7	274	15.6	290	16.6
33	0.2	Cu	3	Gas	Pb		330	18.9	376	21.5	399	22.8	280	16.0	319	18.2	339	19.4
33	0.25	Cu	3	Gas	Pb		375	21.4	428	24.4	454	25.9	320	18.3	365	20.9	387	22.1
33	0.3	Cu	3	Gas	Pb		420	24.0	479	27.4	508	29.0	360	20.6	410	23.5	436	24.9
33	0.35	Cu	3	Gas	Pb		450	25.7	513	29.3	545	31.1	385	22.0	439	25.1	466	26.6
33	0.4	Cu	3	Gas	Pb		495	28.3	564	32.3	599	34.2	420	24.0	479	27.4	508	29.0
33	0.45	Cu	3	Gas	Pb		520	29.7	593	33.9	629	36.0	440	25.1	502	28.7	532	30.4
33	0.5	Cu	3	Gas	Pb		550	31.4	627	35.8	666	38.0	470	26.9	536	30.6	569	32.5
33	0.55	Cu	3	Gas	Pb		575	32.9	656	37.5	696	39.8	490	28.0	559	31.9	593	33.9
33	0.6	Cu	3	Gas	Pb		590	33.7	673	38.4	714	40.8	500	28.6	570	32.6	605	34.6

Table 25 - Cable Ratings 33kV Gas Filled Copper Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted – Trefoil ducts)					
Voltage	mm^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
33	120	Al	1	XLPE	Pb		285	16.3	325	18.6	345	19.7	270	15.4	308	17.6	327	18.7
33	150	Al	1	XLPE	Pb		320	18.3	365	20.9	387	22.1	300	17.1	342	19.5	363	20.7
33	185	Al	1	XLPE	Pb		360	20.6	410	23.5	436	24.9	340	19.4	388	22.2	411	23.5
33	240	Al	1	XLPE	Pb		420	24.0	479	27.4	508	29.0	390	22.3	445	25.4	472	27.0
33	300	Al	1	XLPE	Pb		475	27.1	542	31.0	575	32.9	440	25.1	502	28.7	532	30.4
33	400	Al	1	XLPE	Pb		540	30.9	616	35.2	653	37.3	495	28.3	564	32.3	599	34.2
33	500	Al	1	XLPE	Pb		620	35.4	707	40.4	750	42.9	560	32.0	638	36.5	678	38.7
33	630	Al	1	XLPE	Pb		700	40.0	798	45.6	847	48.4	630	36.0	718	41.1	762	43.6
33	800	Al	1	XLPE	Pb		785	44.9	895	51.2	950	54.3	695	39.7	792	45.3	841	48.1
33	120	Cu	1	XLPE	Pb		365	20.9	416	23.8	442	25.2	345	19.7	393	22.5	417	23.9
33	150	Cu	1	XLPE	Pb		410	23.4	467	26.7	496	28.4	385	22.0	439	25.1	466	26.6
33	185	Cu	1	XLPE	Pb		465	26.6	530	30.3	563	32.2	430	24.6	490	28.0	520	29.7
33	240	Cu	1	XLPE	Pb		535	30.6	610	34.9	647	37.0	495	28.3	564	32.3	599	34.2
33	300	Cu	1	XLPE	Pb		605	34.6	690	39.4	732	41.8	550	31.4	627	35.8	666	38.0
33	400	Cu	1	XLPE	Pb		685	39.2	781	44.6	829	47.4	620	35.4	707	40.4	750	42.9
33	500	Cu	1	XLPE	Pb		770	44.0	878	50.2	932	53.3	690	39.4	787	45.0	835	47.7
33	630	Cu	1	XLPE	Pb		965	55.2	1100	62.9	1168	66.7	755	43.2	861	49.2	914	52.2
33	800	Cu	1	XLPE	Pb		955	54.6	1089	62.2	1156	66.0	820	46.9	935	53.4	992	56.7
33	1000	Cu	1	XLPE	Pb		1025	58.6	1169	66.8	1240	70.9	870	49.7	992	56.7	1053	60.2

Table 26 - Cable Ratings 33kV XLPE Conductor/Lead Sheath (Single Core-Trefoil)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted – Trefoil Ducts)					
Voltage	mm²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
33	50	Al	1	XLPE	CWS		170	9.7	194	11.1	206	11.8	165	9.4	188	10.8	200	11.4
33	70	Al	1	XLPE	CWS		205	11.7	234	13.4	248	14.2	200	11.4	228	13.0	242	13.8
33	95	Al	1	XLPE	CWS		245	14.0	279	16.0	296	16.9	235	13.4	268	15.3	284	16.3
33	120	Al	1	XLPE	CWS		280	16.0	319	18.2	339	19.4	265	15.1	302	17.3	321	18.3
33	150	Al	1	XLPE	CWS		315	18.0	359	20.5	381	21.8	295	16.9	336	19.2	357	20.4
33	185	Al	1	XLPE	CWS		355	20.3	405	23.1	430	24.6	335	19.1	382	21.8	405	23.2
33	240	Al	1	XLPE	CWS		415	23.7	473	27.0	502	28.7	385	22.0	439	25.1	466	26.6
33	300	Al	1	XLPE	CWS		465	26.6	530	30.3	563	32.2	430	24.6	490	28.0	520	29.7
33	400	Al	1	XLPE	CWS		535	30.6	610	34.9	647	37.0	485	27.7	553	31.6	587	33.5
33	500	Al	1	XLPE	CWS		610	34.9	695	39.7	738	42.2	550	31.4	627	35.8	666	38.0
33	630	Al	1	XLPE	CWS		690	39.4	787	45.0	835	47.7	620	35.4	707	40.4	750	42.9
33	800	Al	1	XLPE	CWS		780	44.6	889	50.8	944	53.9	695	39.7	792	45.3	841	48.1
33	1000	Al	1	XLPE	CWS		865	49.4	986	56.4	1047	59.8	765	43.7	872	49.8	926	52.9
33	50	Cu	1	XLPE	CWS		215	12.3	245	14.0	260	14.9	210	12.0	239	13.7	254	14.5
33	70	Cu	1	XLPE	CWS		265	15.1	302	17.3	321	18.3	255	14.6	291	16.6	309	17.6
33	95	Cu	1	XLPE	CWS		320	18.3	365	20.9	387	22.1	300	17.1	342	19.5	363	20.7
33	120	Cu	1	XLPE	CWS		360	20.6	410	23.5	436	24.9	340	19.4	388	22.2	411	23.5
33	150	Cu	1	XLPE	CWS		405	23.1	462	26.4	490	28.0	375	21.4	428	24.4	454	25.9
33	185	Cu	1	XLPE	CWS		455	26.0	519	29.6	551	31.5	420	24.0	479	27.4	508	29.0
33	240	Cu	1	XLPE	CWS		525	30.0	599	34.2	635	36.3	480	27.4	547	31.3	581	33.2
33	300	Cu	1	XLPE	CWS		590	33.7	673	38.4	714	40.8	535	30.6	610	34.9	647	37.0
33	400	Cu	1	XLPE	CWS		670	38.3	764	43.7	811	46.3	600	34.3	684	39.1	726	41.5
33	500	Cu	1	XLPE	CWS		760	43.4	866	49.5	920	52.6	670	38.3	764	43.7	811	46.3
33	630	Cu	1	XLPE	CWS		850	48.6	969	55.4	1029	58.8	750	42.9	855	48.9	908	51.9
33	800	Cu	1	XLPE	CWS		940	53.7	1072	61.3	1137	65.0	825	47.2	941	53.8	998	57.1
33	1000	Cu	1	XLPE	CWS		1025	58.6	1169	66.8	1240	70.9	890	50.9	1015	58.0	1077	61.6

Table 27 - Cable Ratings 33kV XLPE Conductor/Copper Wire Screen (Single Core-Trefoil)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
66	0.1	Cu	3	Oil	Pb		240	27.4	274	31.3	290	33.2	210	24.0	239	27.4	254	29.0
66	0.15	Cu	3	Oil	Pb		295	33.7	336	38.4	357	40.8	260	29.7	296	33.9	315	36.0
66	0.2	Cu	3	Oil	Pb		345	39.4	393	45.0	417	47.7	300	34.3	342	39.1	363	41.5
66	0.25	Cu	3	Oil	Pb		390	44.6	445	50.8	472	53.9	340	38.9	388	44.3	411	47.0
66	0.3	Cu	3	Oil	Pb		435	49.7	496	56.7	526	60.2	375	42.9	428	48.9	454	51.9
66	0.35	Cu	3	Oil	Pb		475	54.3	542	61.9	575	65.7	415	47.4	473	54.1	502	57.4
66	0.4	Cu	3	Oil	Pb		505	57.7	576	65.8	611	69.9	445	50.9	507	58.0	538	61.6
66	0.45	Cu	3	Oil	Pb		535	61.2	610	69.7	647	74.0	470	53.7	536	61.3	569	65.0
66	0.5	Cu	3	Oil	Pb		565	64.6	644	73.6	684	78.2	495	56.6	564	64.5	599	68.5
66	0.55	Cu	3	Oil	Pb		585	66.9	667	76.2	708	80.9	515	58.9	587	67.1	623	71.2
66	0.6	Cu	3	Oil	Pb		620	70.9	707	80.8	750	85.8	540	61.7	616	70.4	653	74.7

Table 28 - Cable Ratings 66kV Oil Filled Copper Imperial Conductor (Three Core)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted- Trefoil Ducts)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
66	0.1	Cu	1	Oil	Pb		250	28.6	285	32.6	303	34.6	245	28.0	279	31.9	296	33.9
66	0.15	Cu	1	Oil	Pb		310	35.4	353	40.4	375	42.9	295	33.7	336	38.4	357	40.8
66	0.2	Cu	1	Oil	Pb		355	40.6	405	46.3	430	49.1	340	38.9	388	44.3	411	47.0
66	0.25	Cu	1	Oil	Pb		400	45.7	456	52.1	484	55.3	380	43.4	433	49.5	460	52.6
66	0.3	Cu	1	Oil	Pb		445	50.9	507	58.0	538	61.6	415	47.4	473	54.1	502	57.4
66	0.35	Cu	1	Oil	Pb		480	54.9	547	62.6	581	66.4	445	50.9	507	58.0	538	61.6
66	0.4	Cu	1	Oil	Pb		510	58.3	581	66.5	617	70.5	475	54.3	542	61.9	575	65.7
66	0.45	Cu	1	Oil	Pb		540	61.7	616	70.4	653	74.7	500	57.2	570	65.2	605	69.2
66	0.5	Cu	1	Oil	Pb		565	64.6	644	73.6	684	78.2	520	59.4	593	67.8	629	71.9
66	0.55	Cu	1	Oil	Pb		595	68.0	678	77.5	720	82.3	550	62.9	627	71.7	666	76.1
66	0.6	Cu	1	Oil	Pb		620	70.9	707	80.8	750	85.8	565	64.6	644	73.6	684	78.2
66	0.65	Cu	1	Oil	Pb		640	73.2	730	83.4	774	88.5	585	66.9	667	76.2	708	80.9
66	0.75	Cu	1	Oil	Pb		680	77.7	775	88.6	823	94.1	620	70.9	707	80.8	750	85.8
66	0.85	Cu	1	Oil	Pb		715	81.7	815	93.2	865	98.9	650	74.3	741	84.7	787	89.9
66	1	Cu	1	Oil	Pb		775	88.6	884	101.0	938	107.2	690	78.9	787	89.9	835	95.4

Table 29 - Cable Ratings 66kV Oil Filled Copper Imperial Conductor (Single Core Trefoil)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted – Trefoil Ducts)					
Voltage	mm²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
66	300	Al	1	XLPE	Pb		460	52.6	524	59.9	557	63.6	435	49.7	496	56.7	526	60.2
66	400	Al	1	XLPE	Pb		525	60.0	599	68.4	635	72.6	488	55.8	556	63.6	590	67.5
66	500	Al	1	XLPE	Pb		590	67.4	673	76.9	714	81.6	545	62.3	621	71.0	659	75.4
66	630	Al	1	XLPE	Pb		670	76.6	764	87.3	811	92.7	609	69.6	694	79.4	737	84.2
66	800	Al	1	XLPE	Pb		755	86.3	861	98.4	914	104.4	675	77.2	770	88.0	817	93.4
66	1000	Al	1	XLPE	Pb		830	94.9	946	108.2	1004	114.8	737	84.3	840	96.0	892	101.9
66	300	Cu	1	XLPE	Pb		585	66.9	667	76.2	708	80.9	531	60.7	605	69.2	643	73.4
66	400	Cu	1	XLPE	Pb		660	75.4	752	86.0	799	91.3	587	67.1	669	76.5	710	81.2
66	500	Cu	1	XLPE	Pb		740	84.6	844	96.4	895	102.4	649	74.2	740	84.6	785	89.8
66	630	Cu	1	XLPE	Pb		830	94.9	946	108.2	1004	114.8	714	81.6	814	93.0	864	98.8
66	800	Cu	1	XLPE	Pb		910	104.0	1037	118.6	1101	125.9	781	89.3	890	101.8	945	108.0
66	1000	Cu	1	XLPE	Pb		990	113.2	1129	129.0	1198	136.9	839	95.9	956	109.3	1015	116.1

Table 30 - Cable Ratings 66kV XLPE Metric Conductor (Single Core-Trefoil)

Appendix 1d –132kV Underground Cable Generic Static Ratings

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted – Trefoil Ducts)					
Voltage	in²	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
132	0.1	Cu	1	Oil	Pb		245	56.0	279	63.9	296	67.8	235	53.7	268	61.3	284	132
132	0.15	Cu	1	Oil	Pb		300	68.6	342	78.2	363	83.0	285	65.2	325	74.3	345	132
132	0.2	Cu	1	Oil	Pb		345	78.9	393	89.9	417	95.4	330	75.4	376	86.0	399	132
132	0.25	Cu	1	Oil	Pb		390	89.2	445	101.6	472	107.9	365	83.5	416	95.1	442	132
132	0.3	Cu	1	Oil	Pb		430	98.3	490	112.1	520	119.0	400	91.5	456	104.3	484	132
132	0.35	Cu	1	Oil	Pb		460	105.2	524	119.9	557	127.3	430	98.3	490	112.1	520	132
132	0.4	Cu	1	Oil	Pb		495	113.2	564	129.0	599	136.9	460	105.2	524	119.9	557	132
132	0.45	Cu	1	Oil	Pb		520	118.9	593	135.5	629	143.9	480	109.7	547	125.1	581	132
132	0.5	Cu	1	Oil	Pb		545	124.6	621	142.0	659	150.8	505	115.5	576	131.6	611	132
132	0.55	Cu	1	Oil	Pb		575	131.5	656	149.9	696	159.1	530	121.2	604	138.1	641	132
132	0.6	Cu	1	Oil	Pb		595	136.0	678	155.1	720	164.6	545	124.6	621	142.0	659	132
132	0.65	Cu	1	Oil	Pb		615	140.6	701	160.3	744	170.1	565	129.2	644	147.3	684	132
132	0.75	Cu	1	Oil	Pb		655	149.8	747	170.7	793	181.2	590	134.9	673	153.8	714	132
132	0.85	Cu	1	Oil	Pb		690	157.8	787	179.8	835	190.9	620	141.8	707	161.6	750	132
132	1	Cu	1	Oil	Pb		745	170.3	849	194.2	901	206.1	665	152.0	758	173.3	805	132

Table 31 - Cable Ratings 132kV Oil Filled Copper Imperial Conductor (Single Core Trefoil)

	Conductors			Construction			Current Rating (Laid Direct)						Current Rating (Ducted – Trefoil Ducts)					
Voltage	in^2	Material	No.	Insulation	Sheath	Protection	Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency	
kV							Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	MVA
132	300	Al	1	XLPE	Pb		455	104.0	519	118.6	551	125.9	405	92.6	462	105.6	490	112.0
132	400	Al	1	XLPE	Pb		515	117.7	587	134.2	623	142.5	450	102.9	513	117.3	545	124.5
132	500	Al	1	XLPE	Pb		580	132.6	661	151.2	702	160.5	496	113.4	565	129.3	600	137.2
132	630	Al	1	XLPE	Pb		655	149.8	747	170.7	793	181.2	545	124.6	621	142.0	659	150.8
132	800	Al	1	XLPE	Pb		735	168.0	838	191.6	889	203.3	592	135.3	675	154.3	716	163.8
132	1000	Al	1	XLPE	Pb		810	185.2	923	211.1	980	224.1	637	145.6	726	166.0	771	176.2
132	300	Cu	1	XLPE	Pb		541	123.7	617	141.0	655	149.7	488	111.6	556	127.2	590	135.0
132	400	Cu	1	XLPE	Pb		597	136.5	681	155.6	722	165.2	531	121.4	605	138.4	643	146.9
132	500	Cu	1	XLPE	Pb		661	151.1	754	172.3	800	182.9	578	132.1	659	150.6	699	159.9
132	630	Cu	1	XLPE	Pb		733	167.6	836	191.0	887	202.8	628	143.6	716	163.7	760	173.7
132	800	Cu	1	XLPE	Pb		796	182.0	907	207.5	963	220.2	675	154.3	770	175.9	817	186.7
132	1000	Cu	1	XLPE	Pb		849	194.1	968	221.3	1027	234.9	717	163.9	817	186.9	868	198.4
132	1200	Cu	1	XLPE	Pb		912	208.5	1040	237.7	1104	252.3	761	174.0	868	198.3	921	210.5

Table 32 - Cable Ratings 132kV XLPE Metric Conductor (Single Core - Trefoil)[21]

[21] The current ratings for 132kV Copper cable are based on the cable datasheet from the Telefonika cable manufacturer for the cable installation where cable metallic screen is solidly bonded to earth at both the ends.

Appendix 2a – De-Rating Factors for Depth

Depth of laying	LV cables			HV and EHV cables	
(m)	Up to 50mm²	70mm² to 300mm²	Above 300mm²	Up to 300mm²	Above 300mm²
0.50	1.00	1.00	1.00	-	-
0.60	0.99	0.98	0.97	-	-
0.80	0.97	0.96	0.94	1.00	1.00
1.00	0.95	0.94	0.92	0.98	0.97
1.25	0.94	0.92	0.90	0.96	0.95
1.50	0.93	0.91	0.89	0.95	0.94
1.75	0.92	0.89	0.87	0.94	0.92
2.00	0.91	0.88	0.86	0.92	0.90
2.50	0.90	0.87	0.85	0.91	0.89
Greater than 3.00	0.89	0.86	0.83	0.90	0.88

Appendix 2b – De-Rating Factors for Thermal Resistivity of Soil

Cable type and laying conditions	Soil thermal resistivity, average value in °C.m/W							
	0.8	0.9	1.0	1.2	1.5	2.0	2.5	3.0
Three core								
Up to 16mm^2	1.09	1.06	1.04	1.00	0.95	0.86	0.79	0.74
25mm^2 to 150mm^2	1.14	1.10	1.07	1.00	0.93	0.84	0.76	0.70
185mm^2 to 400mm^2	1.16	1.11	1.07	1.00	0.92	0.82	0.74	0.68
Single core								
Up to 150mm^2	1.16	1.11	1.07	1.00	0.91	0.81	0.73	0.67
185mm^2 to 400mm^2	1.17	1.12	1.07	1.00	0.90	0.80	0.72	0.66
500mm^2 to 1200mm^2	1.18	1.13	1.08	1.00	0.9	0.79	0.71	0.65

Appendix 2c – De-Rating Factors for Ambient Temperature

Cable insulation	Max conductor operating temperature °C	Ground temperature °C							
		10	15	20	25	30	35	40	45
Paper	65	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63
Paper	70	1.04	1.00	0.95	0.90	0.85	0.80	0.74	0.67
Paper	75	1.04	1.00	0.96	0.92	0.88	0.83	0.78	0.73
PVC	70	1.04	1.00	0.95	0.90	0.85	0.80	0.74	0.67
XLPE	90	1.03	1.00	0.97	0.93	0.89	0.85	0.81	0.77

Appendix 2d – De-Rating Factors for Proximity, Single Cores Laid Direct

Voltage	No of circuits	Spacing (between cable centres)							
		Touching							
		Trefoil	Laid flat	0.15m	0.3m	0.45m	0.6m	0.75m	0.9m
230 / 400V	2	0.77	0.80	0.82	0.88	0.90	0.93		
	3	0.65	0.68	0.72	0.79	0.83	0.87		
	4	0.59	0.63	0.67	0.75	0.81	0.85		
	5	0.55	0.58	0.63	0.72	0.78	0.83		
	6	0.52	0.56	0.60	0.70	0.77	0.82		
11kV	2	0.78	0.80	0.81	0.85	0.88	0.90		
	3	0.66	0.69	0.71	0.76	0.80	0.83		
	4	0.60	0.63	0.65	0.72	0.76	0.80		
	5	0.55	0.58	0.61	0.68	0.73	0.77		
	6	0.52	0.55	0.58	0.66	0.72	0.76		
33kV	2	0.79	0.81	0.81	0.85	0.88	0.90	0.93	0.95
	3	0.67	0.70	0.71	0.76	0.80	0.83	0.87	0.90
	4	0.62	0.65	0.65	0.72	0.76	0.80	0.83	0.88
	5	0.57	0.60	0.60	0.68	0.73	0.77		
	6	0.54	0.57	0.57	0.66	0.72	0.76		

Appendix 2e – De-Rating Factors for Proximity, Single Cores Laid in Ducts

Voltage	No of circuits	Spacing (between duct centres)					
		Touching	0.3m	0.45m	0.6m	0.75m	0.9m
230 / 400V	2	0.86		0.90	0.93		
	3	0.77		0.83	0.87		
	4	0.73		0.81	0.85		
	5	0.70		0.78	0.83		
	6	0.68		0.77	0.82		
11kV	2	0.85		0.88	0.90		
	3	0.75		0.80	0.83		
	4	0.70		0.76	0.80		
	5	0.67		0.73	0.77		
	6	0.64		0.71	0.76		
33kV	2	0.85		0.88	0.90	0.94	0.96
	3	0.76		0.80	0.83	0.88	0.91
	4	0.71		0.76	0.80	0.85	0.88
	5	0.67		0.73	0.77		
	6	0.65		0.71	0.76		

Appendix 2f – De-Rating Factors for Proximity, Multi-Core Cables Laid Direct

Voltage	No of circuits	Spacing (between cable centres)						
		Touching	0.15m	0.3m	0.45m	0.6m	0.75m	0.9m
230 / 400V	2	0.81	0.87	0.91	0.93	0.94		
	3	0.70	0.78	0.84	0.87	0.90		
	4	0.63	0.74	0.81	0.86	0.89		
	5	0.59	0.70	0.78	0.83	0.87		
	6	0.55	0.67	0.76	0.82	0.86		
11kV	2	0.80	0.85	0.89	0.90	0.92		
	3	0.69	0.75	0.80	0.84	0.86		
	4	0.63	0.70	0.77	0.80	0.84		
	5	0.57	0.66	0.73	0.78	0.81		
	6	0.55	0.63	0.71	0.76	0.80		
33kV	2	0.80	0.83	0.87	0.89	0.91	0.94	0.95
	3	0.70	0.73	0.78	0.82	0.85	0.88	0.90
	4	0.64	0.68	0.74	0.78	0.82	0.85	0.88
	5	0.59	0.63	0.70	0.75	0.79		
	6	0.56	0.60	0.68	0.74	0.78		

Appendix 2g – De-Rating Factors for Proximity, Multi-Core Cables Laid in Ducts

Voltage	No of circuits	Spacing (between duct centres)					
		Touching	0.3m	0.45m	0.6m	0.75m	0.9m
230 / 400V	2	0.90	0.93	0.95	0.96		
	3	0.82	0.87	0.90	0.93		
	4	0.78	0.85	0.89	0.91		
	5	0.75	0.82	0.87	0.90		
	6	0.72	0.81	0.86	0.90		
11kV	2	0.88	0.91	0.93	0.94		
	3	0.80	0.84	0.87	0.89		
	4	0.75	0.81	0.84	0.87		
	5	0.71	0.77	0.82	0.85		
	6	0.69	0.75	0.80	0.84		
33kV	2	0.87	0.89	0.92	0.93	0.95	0.96
	3	0.78	0.82	0.85	0.87	0.92	0.94
	4	0.73	0.78	0.82	0.85	0.90	0.92
	5	0.69	0.75	0.79	0.83		
	6	0.67	0.73	0.73	0.82		

Appendix 3a –LV Cable Impedance Data

Voltage	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)				
(kV)	in^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω /km	Earth Resistance Ω /km
0.23	0.007	Cu	1	Paper	Split Conc		4.10	5.125	0.120	4.10	4.10
0.23	0.0225	Cu	1	Paper	Split Conc		1.26	1.575	0.086	1.26	1.26
0.23	0.04	Cu	1	Paper	Split Conc		0.70	0.879	0.078	0.70	0.70
0.23	0.007	Cu	2	Paper	Lead	STA	4.10	5.125	0.100	4.10	4.10
0.23	0.0225	Cu	2	Paper	Lead	STA	1.26	1.575	0.086	1.26	1.26
0.23	0.04	Cu	2	Paper	Lead	STA	0.70	0.879	0.078	0.70	0.70

Table 33 - Impedance Data - LV Services Imperial

Voltage	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)				
(kV)	mm^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω /km	Earth Resistance Ω /km
0.23	4	Cu	1	PVC	Split Conc	PVC	4.61	5.76	0.12	4.80	4.80
0.23	16	Al	1	PVC	Split Conc	PVC	1.90	2.38	0.08	1.90	1.90
0.23	4	Cu	1	PVC	Concentric	PVC	4.61	5.76	0.10	-	4.61
0.23	25	Al	1	PVC	Concentric	PVC	1.20	1.50	0.08	-	1.20
0.23	35	Al	1	PVC	Concentric	PVC	0.87	1.09	0.08	-	0.87

Table 34 - Impedance Data - LV Services Metric

Voltage	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)				
(kV)	in^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω /km	Earth Resistance Ω /km
0.4	0.06	Al	4	Paper	Pb	STA	0.767	0.952	0.075	0.767	1.990
0.4	0.1	Al	4	Paper	Pb	STA	0.456	0.596	0.073	0.456	1.700
0.4	0.15	Al	4	Paper	Pb	STA	0.312	0.394	0.070	0.312	1.325
0.4	0.2	Al	4	Paper	Pb	STA	0.234	0.295	0.069	0.234	1.090
0.4	0.25	Al	4	Paper	Pb	STA	0.187	0.241	0.068	0.187	0.917
0.4	0.3	Al	4	Paper	Pb	STA	0.152	0.197	0.068	0.152	0.747
0.4	0.0225	Cu	4	Paper	Pb	STA	1.260	1.553	0.086	1.257	2.270
0.4	0.04	Cu	4	Paper	Pb	STA	0.703	0.875	0.078	0.703	2.140
0.4	0.05	Cu	4	Paper	Pb	STA	0.583	0.680	0.076	0.544	2.067
0.4	0.06	Cu	4	Paper	Pb	STA	0.464	0.580	0.075	0.464	1.990
0.4	0.075	Cu	4	Paper	Pb	STA	0.376	0.480	0.074	0.376	1.930
0.4	0.1	Cu	4	Paper	Pb	STA	0.276	0.339	0.073	0.276	1.700
0.4	0.15	Cu	4	Paper	Pb	STA	0.188	0.241	0.070	0.188	1.325
0.4	0.2	Cu	4	Paper	Pb	STA	0.142	0.186	0.069	0.142	1.090
0.4	0.25	Cu	4	Paper	Pb	STA	0.113	0.153	0.067	0.113	0.917
0.4	0.3	Cu	4	Paper	Pb	STA	0.092	0.131	0.067	0.142	0.747

Table 35 - Impedance Data - LV PILC Imperial

Voltage	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)				
(kV)	mm^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω /km	Earth Resistance Ω /km
0.4	70	Al	4	Paper	Pb	STA	0.443	0.550	0.071	0.443	1.630
0.4	95	Al	4	Paper	Pb	STA	0.320	0.398	0.070	0.320	1.340
0.4	120	Al	4	Paper	Pb	STA	0.253	0.315	0.068	0.253	1.140
0.4	185	Al	4	Paper	Pb	STA	0.164	0.205	0.068	0.164	0.790
0.4	300	Al	4	Paper	Pb	STA	0.100	0.126	0.067	0.164	0.550

Table 36 - Impedance Data - LV PILC Aluminium Metric

Voltage	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)				
(kV)	mm^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω /km	Earth Resistance Ω /km
0.4	35	Al	3	XLPE	Al	-	0.857	1.078	0.074	-	0.857
0.4	70	Al	3	XLPE	Al	-	0.443	0.558	0.073	-	0.443
0.4	120	Al	3	XLPE	Al	-	0.253	0.320	0.075	-	0.253
0.4	185	Al	3	XLPE	Al	-	0.164	0.205	0.074	-	0.164
0.4	300	Al	3	XLPE	Al	-	0.100	0.126	0.073	-	0.164

Table 37 –Impedance Data LV Waveform Aluminium/Aluminium Metric (Three Core)

Voltage	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)				
(kV)	mm^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω /km	Earth Resistance Ω /km
0.4	35	Al	3	XLPE	Cu	-	0.868	1.078	0.076	-	0.433
0.4	70	Al	3	XLPE	Cu	-	0.443	0.558	0.074	-	0.320
0.4	95	Al	3	XLPE	Cu	-	0.320	0.398	0.073	-	0.320
0.4	120	Al	3	XLPE	Cu	-	0.253	0.320	0.074	-	0.164
0.4	185	Al	3	XLPE	Cu	-	0.164	0.205	0.073	-	0.164
0.4	300	Al	3	XLPE	Cu	-	0.100	0.126	0.073	-	0.164
0.4	95	Al	4	XLPE	Cu	-	0.320	0.398	0.074	0.320	0.320
0.4	185	Al	4	XLPE	Cu	-	0.164	0.205	0.074	0.164	0.164
0.4	300	Al	4	XLPE	Cu	-	0.100	0.126	0.073	0.100	0.164

Table 38 – Impedance Data - LV Waveform Aluminium/Copper Metric (Three/Four Core)

Appendix 3b –HV Cable Impedance Data

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
11	0.04	Al	3	Paper (Belted)	Pb	SWA	1.106	1.433	0.119	0.280	88	0.56	2.93	0.176	0.233	73	118.4	9.83	0.0106	242.6	14.55	0.0089
11	0.05	Al	3	Paper (Belted)	Pb	SWA	0.918	1.110	0.114	0.303	95	0.60	2.66	0.169	0.253	79	91.8	9.42	0.0115	220.2	13.97	0.0096
11	0.06	Al	3	Paper (Belted)	Pb	SWA	0.730	0.918	0.108	0.327	103	0.65	2.30	0.162	0.273	86	75.9	8.93	0.0124	189.7	13.39	0.0104
11	0.075	Al	3	Paper (Belted)	Pb	SWA	0.594	0.739	0.102	0.358	112	0.71	2.02	0.153	0.298	94	61.0	8.43	0.0136	167.0	12.64	0.0113
11	0.1	Al	3	Paper (Belted)	Pb	SWA	0.434	0.540	0.096	0.403	127	0.80	1.78	0.146	0.336	106	44.6	7.93	0.0153	147.4	12.07	0.0128
11	0.15	Al	3	Paper (Belted)	Pb	SWA	0.297	0.368	0.092	0.459	144	0.92	1.61	0.138	0.383	120	30.4	7.60	0.0174	133.0	11.40	0.0145
11	0.2	Al	3	Paper (Belted)	Pb	SWA	0.223	0.273	0.086	0.500	157	1.00	1.36	0.132	0.417	131	22.6	7.11	0.0190	112.0	10.91	0.0158
11	0.25	Al	3	Paper (Belted)	Pb	SWA	0.178	0.221	0.080	0.502	158	1.00	1.16	0.131	0.418	131	18.2	6.61	0.0191	95.7	10.83	0.0159
11	0.3	Al	3	Paper (Belted)	Pb	SWA	0.145	0.185	0.078	0.534	168	1.07	0.94	0.128	0.445	140	15.3	6.45	0.0203	78.1	10.58	0.0169
11	0.4	Al	3	Paper (Belted)	Pb	SWA	0.108	0.139	0.075	0.584	183	1.17	0.85	0.123	0.487	153	11.5	6.20	0.0222	70.6	10.17	0.0185
11	0.5	Al	3	Paper (Belted)	Pb	SWA	0.088	0.114	0.073	0.628	197	1.25	0.77	0.119	0.523	164	9.4	6.03	0.0239	63.3	9.83	0.0199
11	0.04	Al	3	Paper (Screened)	Pb	SWA	1.106	1.463	0.124	0.351	110	0.70	2.93	0.163	0.351	110	120.9	10.25	0.0133	242.1	13.47	0.0133
11	0.05	Al	3	Paper (Screened)	Pb	SWA	0.918	1.134	0.118	0.388	122	0.77	2.66	0.156	0.388	122	93.7	9.75	0.0147	220.2	12.89	0.0147
11	0.06	Al	3	Paper (Screened)	Pb	SWA	0.730	0.938	0.112	0.423	133	0.84	2.30	0.150	0.423	133	77.5	9.26	0.0161	189.7	12.40	0.0161
11	0.075	Al	3	Paper (Screened)	Pb	SWA	0.594	0.754	0.106	0.468	147	0.93	2.02	0.145	0.468	147	62.3	8.76	0.0178	167.0	11.98	0.0178
11	0.1	Al	3	Paper (Screened)	Pb	SWA	0.434	0.551	0.093	0.503	158	1.00	1.78	0.140	0.503	158	45.6	7.69	0.0191	147.4	11.57	0.0191
11	0.15	Al	3	Paper (Screened)	Pb	SWA	0.297	0.376	0.087	0.579	182	1.16	1.61	0.131	0.579	182	31.1	7.19	0.0220	133.0	10.83	0.0220
11	0.2	Al	3	Paper (Screened)	Pb	SWA	0.223	0.279	0.082	0.652	205	1.30	1.36	0.126	0.652	205	23.1	6.78	0.0248	112.0	10.41	0.0248
11	0.25	Al	3	Paper (Screened)	Pb	SWA	0.178	0.225	0.080	0.712	224	1.42	1.16	0.122	0.712	224	18.62	6.61	0.0271	95.7	10.08	0.0271
11	0.3	Al	3	Paper (Screened)	Pb	SWA	0.145	0.189	0.079	0.765	240	1.53	0.94	0.119	0.765	240	15.61	6.53	0.0291	78.1	9.83	0.0291
11	0.4	Al	3	Paper (Screened)	Pb	SWA	0.108	0.142	0.075	0.861	270	1.72	0.85	0.115	0.861	270	11.75	6.20	0.0327	70.6	9.50	0.0327
11	0.5	Al	3	Paper (Screened)	Pb	SWA	0.088	0.116	0.074	0.940	295	1.88	0.77	0.111	0.940	295	9.60	6.12	0.0357	63.3	9.17	0.0357

Table 39 – Impedance data - 11kV PILCSWA Aluminium Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
11	0.04	Cu	3	Paper (Belted)	Lead	SWA	0.675	0.844	0.119	0.280	88	0.56	2.45	0.176	0.233	73	69.8	9.83	0.0106	202.5	14.55	0.0089
11	0.05	Cu	3	Paper (Belted)	Lead	SWA	0.530	0.654	0.114	0.303	95	0.60	2.08	0.169	0.253	79	54.0	9.42	0.0115	171.9	13.97	0.0096
11	0.06	Cu	3	Paper (Belted)	Lead	SWA	0.446	0.541	0.108	0.327	103	0.65	1.86	0.162	0.273	86	44.7	8.93	0.0124	153.7	13.39	0.0104
11	0.075	Cu	3	Paper (Belted)	Lead	SWA	0.362	0.435	0.102	0.358	112	0.71	1.70	0.153	0.298	94	36.0	8.43	0.0136	140.5	12.64	0.0113
11	0.1	Cu	3	Paper (Belted)	Lead	SWA	0.265	0.318	0.096	0.403	127	0.80	1.57	0.146	0.336	106	26.3	7.93	0.0153	129.8	12.07	0.0128
11	0.15	Cu	3	Paper (Belted)	Lead	SWA	0.181	0.217	0.092	0.459	144	0.92	1.31	0.138	0.383	120	17.9	7.60	0.0174	108.3	11.40	0.0145
11	0.2	Cu	3	Paper (Belted)	Lead	SWA	0.136	0.161	0.086	0.500	157	1.00	1.11	0.132	0.417	131	13.3	7.11	0.0190	91.7	10.91	0.0158
11	0.25	Cu	3	Paper (Belted)	Lead	SWA	0.108	0.130	0.080	0.502	158	1.00	0.90	0.131	0.418	131	10.7	6.61	0.0191	74.4	10.83	0.0159
11	0.3	Cu	3	Paper (Belted)	Lead	SWA	0.088	0.109	0.078	0.534	168	1.07	0.83	0.128	0.445	140	9.01	6.45	0.0203	68.6	10.58	0.0169
11	0.4	Cu	3	Paper (Belted)	Lead	SWA	0.066	0.082	0.075	0.584	183	1.17	0.74	0.123	0.487	153	6.78	6.20	0.0222	61.2	10.17	0.0185
11	0.5	Cu	3	Paper (Belted)	Lead	SWA	0.054	0.067	0.073	0.628	197	1.25	0.65	0.119	0.523	164	5.54	6.03	0.0239	53.7	9.83	0.0199
11	0.04	Cu	3	Paper (Screened)	Lead	SWA	0.675	0.861	0.124	0.351	110	0.70	2.45	0.163	0.351	110	71.2	10.25	0.0133	202.5	13.47	0.0133
11	0.05	Cu	3	Paper (Screened)	Lead	SWA	0.530	0.667	0.118	0.388	122	0.77	2.08	0.156	0.388	122	55.1	9.75	0.0147	171.9	12.89	0.0147
11	0.06	Cu	3	Paper (Screened)	Lead	SWA	0.446	0.552	0.112	0.423	133	0.84	1.86	0.150	0.423	133	45.6	9.26	0.0161	153.7	12.40	0.0161
11	0.075	Cu	3	Paper (Screened)	Lead	SWA	0.362	0.444	0.106	0.468	147	0.93	1.70	0.145	0.468	147	36.7	8.76	0.0178	140.5	11.98	0.0178
11	0.1	Cu	3	Paper (Screened)	Lead	SWA	0.265	0.324	0.093	0.503	158	1.00	1.57	0.140	0.503	158	26.8	7.69	0.0191	129.8	11.57	0.0191
11	0.15	Cu	3	Paper (Screened)	Lead	SWA	0.181	0.221	0.087	0.579	182	1.16	1.31	0.131	0.579	182	18.3	7.19	0.0220	108.3	10.83	0.0220
11	0.2	Cu	3	Paper (Screened)	Lead	SWA	0.136	0.164	0.082	0.652	205	1.30	1.11	0.126	0.652	205	13.6	6.78	0.0248	91.7	10.41	0.0248
11	0.25	Cu	3	Paper (Screened)	Lead	SWA	0.108	0.133	0.080	0.712	224	1.42	0.90	0.122	0.712	224	10.96	6.61	0.0271	74.4	10.08	0.0271
11	0.3	Cu	3	Paper (Screened)	Lead	SWA	0.088	0.111	0.079	0.765	240	1.53	0.83	0.119	0.765	240	9.19	6.53	0.0291	68.6	9.83	0.0291
11	0.4	Cu	3	Paper (Screened)	Lead	SWA	0.066	0.084	0.075	0.861	270	1.72	0.74	0.115	0.861	270	6.91	6.20	0.0327	61.2	9.50	0.0327
11	0.5	Cu	3	Paper (Screened)	Lead	SWA	0.054	0.068	0.074	0.940	295	1.88	0.65	0.111	0.940	295	5.65	6.12	0.0357	53.7	9.17	0.0357

Table 40 - Impedance data - 11kV PILCSWA Copper Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
11	185	Al	3	Paper (Belted)	Lead	SWA	0.320	0.379	0.087	0.450	141	0.900	0.495	0.099	0.375	118	31.3	7.19	0.0171	40.9	8.18	0.0143
11	240	Al	3	Paper (Belted)	Lead	SWA	0.164	0.195	0.080	0.580	182	1.160	0.270	0.092	0.483	152	16.1	6.61	0.0220	22.3	7.60	0.0184
11	300	Al	3	Paper (Belted)	Lead	SWA	0.100	0.120	0.077	0.710	223	1.420	0.171	0.088	0.592	186	9.9	6.36	0.0270	14.1	7.27	0.0225
11	185	Al	3	Paper (Screened)	Lead	SWA	0.320	0.384	0.087	0.600	188	1.200	0.495	0.099	0.600	188	31.7	7.19	0.0228	40.9	8.18	0.0228
11	240	Al	3	Paper (Screened)	Lead	SWA	0.164	0.198	0.081	0.810	254	1.620	0.270	0.092	0.810	254	16.4	6.69	0.0308	22.3	7.60	0.0308
11	300	Al	3	Paper (Screened)	Lead	SWA	0.100	0.122	0.077	1.000	314	2.000	0.171	0.088	1.000	314	10.1	6.36	0.0380	14.1	7.27	0.0380

Table 41 - Impedance data - 11kV PILCSWA Aluminium Metric Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
11	95	Al	3	Paper (Belted)	CAS	PVC	0.320	0.379	0.087	0.450	141	0.900	0.495	0.099	0.375	118	31.3	7.19	0.0171	40.9	8.18	0.0143
11	185	Al	3	Paper (Belted)	CAS	PVC	0.164	0.195	0.080	0.580	182	1.160	0.270	0.092	0.483	152	16.1	6.61	0.0220	22.3	7.60	0.0184
11	300	Al	3	Paper (Belted)	CAS	PVC	0.100	0.120	0.077	0.710	223	1.420	0.171	0.088	0.592	186	9.9	6.36	0.0270	14.1	7.27	0.0225
11	95	Al	3	Paper (Screened)	CAS	PVC	0.320	0.384	0.087	0.600	188	1.200	0.495	0.099	0.600	188	31.7	7.19	0.0228	40.9	8.18	0.0228
11	185	Al	3	Paper (Screened)	CAS	PVC	0.164	0.198	0.081	0.810	254	1.620	0.270	0.092	0.810	254	16.4	6.69	0.0308	22.3	7.60	0.0308
11	300	Al	3	Paper (Screened)	CAS	PVC	0.100	0.122	0.077	1.000	314	2.000	0.171	0.088	1.000	314	10.1	6.36	0.0380	14.1	7.27	0.0380
11	300	Cu	3	Paper (Belted)	CAS	PVC	0.060	0.072	0.077	0.710	223	1.42	0.131	0.088	0.592	186	5.95	6.36	0.0270	10.8	7.3	0.0225
11	300	Cu	3	Paper (Screened)	CAS	PVC	0.060	0.075	0.077	1.000	314	2.00	0.131	0.088	1.000	314	6.20	6.36	0.0380	10.8	7.3	0.0380

Table 42 - Impedance data - 11kV PICAS Metric Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
11	95	Al	1	XLPE	MDPE		0.320	0.410	0.119	0.311	98	0.62	0.86	0.06	0.311	98	33.9	9.83	0.0118	71.2	4.79	0.0118
11	185	Al	1	XLPE	MDPE		0.164	0.211	0.108	0.400	126	0.80	0.748	0.052	0.400	126	17.4	8.93	0.0152	61.8	4.30	0.0152
11	300	Al	1	XLPE	MDPE		0.100	0.130	0.100	0.489	154	0.98	0.642	0.043	0.489	154	10.7	8.26	0.0186	53.1	3.55	0.0186
11	400	Al	1	XLPE	MDPE		0.078	0.102	0.096	0.555	174	1.11	0.621	0.042	0.555	174	8.43	7.93	0.0211	51.3	3.47	0.0211
11	300	Cu	1	XLPE	MDPE		0.060	0.079	0.099	0.512	161	1.02	0.603	0.042	0.512	161	6.53	8.18	0.0195	49.8	3.47	0.0195
11	400	Cu	1	XLPE	MDPE		0.047	0.063	0.096	0.577	181	1.15	0.590	0.039	0.577	181	5.21	7.93	0.0219	48.8	3.22	0.0219
11	500	Cu	1	XLPE	MDPE		0.037	0.051	0.092	0.647	203	1.29	0.580	0.037	0.647	203	4.20	7.60	0.0246	47.9	3.06	0.0246
11	630	Cu	1	XLPE	MDPE		0.028	0.041	0.089	0.727	228	1.45	0.572	0.035	0.727	228	3.42	7.36	0.0276	47.3	2.89	0.0276

Table 43 - Impedance data - 11kV XLPE Metric Conductor (Triplex/Trefoil)

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
20	0.04	Al	3	Paper (Belted)	Lead	SWA	1.106	1.433	0.118	0.208	65	0.75	2.17	0.162	0.173	54	35.82	2.95	0.0261	54.2	4.04	0.0218
20	0.06	Al	3	Paper (Belted)	Lead	SWA	0.730	0.918	0.110	0.241	76	0.87	1.76	0.148	0.201	63	22.96	2.76	0.0302	44.1	3.69	0.0252
20	0.1	Al	3	Paper (Belted)	Lead	SWA	0.434	0.540	0.102	0.274	86	0.99	1.28	0.138	0.228	72	13.50	2.54	0.0344	32.1	3.46	0.0286
20	0.15	Al	3	Paper (Belted)	Lead	SWA	0.297	0.368	0.096	0.306	96	1.11	1.08	0.134	0.255	80	9.21	2.41	0.0385	27.1	3.34	0.0321
20	0.2	Al	3	Paper (Belted)	Lead	SWA	0.223	0.273	0.092	0.350	110	1.27	0.98	0.126	0.292	92	6.83	2.30	0.0440	24.5	3.15	0.0367
20	0.25	Al	3	Paper (Belted)	Lead	SWA	0.178	0.221	0.090	0.383	120	1.39	0.84	0.121	0.319	100	5.52	2.24	0.0481	21.0	3.04	0.0401
20	0.3	Al	3	Paper (Belted)	Lead	SWA	0.145	0.185	0.088	0.416	131	1.51	0.80	0.120	0.346	109	4.63	2.19	0.0522	20.0	2.99	0.0435
20	0.04	Al	3	Paper (Screened)	Lead	SWA	1.106	1.463	0.138	0.289	91	1.05	1.71	0.173	0.289	91	36.6	3.45	0.0363	42.7	4.33	0.0363
20	0.06	Al	3	Paper (Screened)	Lead	SWA	0.730	0.938	0.124	0.339	106	1.23	1.46	0.158	0.339	106	23.4	3.10	0.0426	36.5	3.95	0.0426
20	0.1	Al	3	Paper (Screened)	Lead	SWA	0.434	0.551	0.104	0.399	125	1.45	1.10	0.148	0.399	125	13.8	2.60	0.0501	27.6	3.70	0.0501
20	0.15	Al	3	Paper (Screened)	Lead	SWA	0.297	0.376	0.095	0.459	144	1.67	0.96	0.143	0.459	144	9.40	2.38	0.0577	24.0	3.58	0.0577
20	0.2	Al	3	Paper (Screened)	Lead	SWA	0.223	0.279	0.091	0.513	161	1.86	0.89	0.135	0.513	161	6.98	2.28	0.0645	22.2	3.38	0.0645
20	0.25	Al	3	Paper (Screened)	Lead	SWA	0.178	0.225	0.088	0.554	174	2.01	0.77	0.130	0.554	174	5.63	2.20	0.0696	19.2	3.25	0.0696
20	0.3	Al	3	Paper (Screened)	Lead	SWA	0.145	0.189	0.086	0.593	186	2.15	0.74	0.128	0.593	186	4.72	2.15	0.0745	18.5	3.20	0.0745

Table 44 - Impedance data - 20kV PILCSWA Aluminium Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
20	0.04	Cu	3	Paper (Belted)	Lead	SWA	0.675	0.844	0.118	0.208	65	0.75	1.71	0.162	0.173	54	21.10	2.95	0.0261	42.7	4.04	0.0218
20	0.06	Cu	3	Paper (Belted)	Lead	SWA	0.446	0.541	0.110	0.241	76	0.87	1.46	0.148	0.201	63	13.53	2.76	0.0302	36.5	3.69	0.0252
20	0.1	Cu	3	Paper (Belted)	Lead	SWA	0.265	0.318	0.102	0.274	86	0.99	1.10	0.138	0.228	72	7.95	2.54	0.0344	27.6	3.46	0.0286
20	0.15	Cu	3	Paper (Belted)	Lead	SWA	0.181	0.217	0.096	0.306	96	1.11	0.96	0.134	0.255	80	5.43	2.41	0.0385	24.0	3.34	0.0321
20	0.2	Cu	3	Paper (Belted)	Lead	SWA	0.136	0.161	0.092	0.350	110	1.27	0.89	0.126	0.292	92	4.03	2.30	0.0440	22.2	3.15	0.0367
20	0.25	Cu	3	Paper (Belted)	Lead	SWA	0.108	0.130	0.090	0.383	120	1.39	0.77	0.121	0.319	100	3.25	2.24	0.0481	19.2	3.04	0.0401
20	0.3	Cu	3	Paper (Belted)	Lead	SWA	0.088	0.109	0.088	0.416	131	1.51	0.74	0.120	0.346	109	2.73	2.19	0.0522	18.5	2.99	0.0435
20	0.04	Cu	3	Paper (Screened)	Lead	SWA	0.675	0.861	0.138	0.289	91	1.05	1.35	0.173	0.289	91	21.5	3.45	0.0363	33.8	4.33	0.0363
20	0.06	Cu	3	Paper (Screened)	Lead	SWA	0.446	0.552	0.124	0.339	106	1.23	1.20	0.158	0.339	106	13.8	3.10	0.0426	29.9	3.95	0.0426
20	0.1	Cu	3	Paper (Screened)	Lead	SWA	0.265	0.324	0.104	0.399	125	1.45	0.95	0.148	0.399	125	8.11	2.60	0.0501	23.6	3.70	0.0501
20	0.15	Cu	3	Paper (Screened)	Lead	SWA	0.181	0.221	0.095	0.459	144	1.67	0.85	0.143	0.459	144	5.53	2.38	0.0577	21.4	3.58	0.0577
20	0.2	Cu	3	Paper (Screened)	Lead	SWA	0.136	0.164	0.091	0.513	161	1.86	0.81	0.135	0.513	161	4.11	2.28	0.0645	20.2	3.38	0.0645
20	0.25	Cu	3	Paper (Screened)	Lead	SWA	0.108	0.133	0.088	0.554	174	2.01	0.70	0.130	0.554	174	3.32	2.20	0.0696	17.6	3.25	0.0696
20	0.3	Cu	3	Paper (Screened)	Lead	SWA	0.088	0.111	0.086	0.593	186	2.15	0.69	0.128	0.593	186	2.78	2.15	0.0745	17.1	3.20	0.0745

Table 45 - Impedance data - 20kV PILCSWA Copper Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
20	95	Al	3	Paper (Screened)	Lead	SWA	0.320	0.378	0.100	0.390	123	1.415	0.981	0.141	0.390	123	9.45	2.50	0.0490	24.5	3.53	0.0490
20	185	Al	3	Paper (Screened)	Lead	SWA	0.164	0.195	0.091	0.510	160	1.850	0.738	0.128	0.510	160	4.88	2.28	0.0641	18.5	3.21	0.0641

Table 46 - Impedance data - 20kV PILCSWA Aluminium Metric Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
20	95	Al	1	XLPE		MDPE	0.320	0.411	0.129	0.219	69	0.79	0.862	0.070	0.219	69	10.3	3.23	0.0275	21.6	1.75	0.0275
20	150	Al	1	XLPE		MPDE	0.206	0.265	0.12	0.254	80	0.92	0.748	0.062	0.254	80	6.63	3.00	0.0319	18.7	1.55	0.0319
20	185	Al	1	XLPE		MDPE	0.164	0.211	0.116	0.274	86	0.99	0.706	0.059	0.274	86	5.28	2.90	0.0344	17.7	1.48	0.0344
20	240	Al	1	XLPE		MDPE	0.125	0.161	0.111	0.303	95	1.10	0.667	0.054	0.303	95	4.03	2.78	0.0381	16.7	1.35	0.0381
20	300	Al	1	XLPE		MDPE	0.100	0.129	0.107	0.330	104	1.20	0.642	0.051	0.330	104	3.23	2.68	0.0415	16.1	1.28	0.0415
20	150	Cu	1	XLPE		MDPE	0.124	0.159	0.119	0.265	83	0.96	0.666	0.061	0.265	83	3.98	2.98	0.0333	16.7	1.53	0.0333
20	185	Cu	1	XLPE		MDPE	0.0991	0.128	0.115	0.287	90	1.04	0.641	0.057	0.287	90	3.20	2.88	0.0361	16.0	1.43	0.0361
20	240	Cu	1	XLPE		MDPE	0.0754	0.098	0.111	0.314	99	1.14	0.618	0.054	0.314	99	2.45	2.78	0.0395	15.5	1.35	0.0395
20	300	Cu	1	XLPE		MDPE	0.0601	0.079	0.106	0.344	108	1.25	0.603	0.050	0.344	108	1.98	2.65	0.0432	15.1	1.25	0.0432
20	400	Cu	1	XLPE		MDPE	0.047	0.063	0.102	0.385	121	1.40	0.590	0.047	0.385	121	1.57	2.55	0.0484	14.8	1.18	0.0484
20	500	Cu	1	XLPE		MDPE	0.0366	0.0503	0.099	0.434	136	1.57	0.580	0.044	0.434	136	1.26	2.48	0.0545	14.5	1.10	0.0545
20	630	Cu	1	XLPE		MDPE	0.0283	0.0408	0.095	0.484	152	1.76	0.572	0.041	0.484	152	1.02	2.38	0.0608	14.3	1.03	0.0608

Table 47 - Impedance data - 20kV XLPE Metric Conductor (Triplex/Trefoil)

Appendix 3c –33kV and 66kV Cable Impedance Data

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
33	0.1	Cu	3	Paper	Pb		0.276	0.318	0.157	0.219	69	1.31	1.42	0.166	0.219	69	2.92	1.45	0.0748	13.0	1.52	0.0748
33	0.15	Cu	3	Paper	Pb		0.188	0.218	0.114	0.262	82	1.57	1.24	0.155	0.262	82	2.00	1.04	0.0898	11.4	1.42	0.0898
33	0.2	Cu	3	Paper	Pb		0.142	0.164	0.109	0.295	93	1.77	1.13	0.148	0.295	93	1.51	1.00	0.101	10.4	1.36	0.101
33	0.25	Cu	3	Paper	Pb		0.113	0.131	0.104	0.328	103	1.96	1.05	0.142	0.328	103	1.21	0.95	0.112	9.63	1.31	0.112
33	0.3	Cu	3	Paper	Pb		0.092	0.108	0.101	0.361	113	2.16	0.99	0.138	0.361	113	0.99	0.92	0.123	9.06	1.27	0.123
33	0.35	Cu	3	Paper	Pb		0.078	0.094	0.098	0.380	119	2.27	0.94	0.135	0.380	119	0.86	0.90	0.130	8.61	1.24	0.130
33	0.4	Cu	3	Paper	Pb		0.068	0.082	0.096	0.405	127	2.42	0.90	0.132	0.405	127	0.75	0.88	0.138	8.24	1.21	0.138
33	0.45	Cu	3	Paper	Pb		0.062	0.074	0.094	0.424	133	2.54	0.86	0.129	0.424	133	0.68	0.86	0.145	7.92	1.19	0.145
33	0.5	Cu	3	Paper	Pb		0.056	0.068	0.093	0.437	137	2.62	0.83	0.127	0.437	137	0.62	0.85	0.150	7.65	1.16	0.150
33	0.55	Cu	3	Paper	Pb		0.051	0.061	0.087	0.463	145	2.77	0.81	0.125	0.463	145	0.56	0.80	0.158	7.41	1.15	0.158
33	0.6	Cu	3	Paper	Pb		0.046	0.056	0.083	0.480	151	2.87	0.78	0.123	0.480	151	0.51	0.77	0.164	7.20	1.13	0.164

Table 48 -Impedance data - 33kV PILC Copper Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
33	0.1	Cu	3	Oil	Pb		0.276	0.347	0.096	0.372	117	2.23	2.238	0.138	0.37	117	3.18	0.88	0.127	20.6	1.27	0.127
33	0.15	Cu	3	Oil	Pb		0.188	0.237	0.090	0.438	137	2.62	1.973	0.129	0.44	137	2.18	0.82	0.150	18.1	1.18	0.150
33	0.2	Cu	3	Oil	Pb		0.142	0.179	0.084	0.492	155	2.95	1.664	0.123	0.49	155	1.65	0.77	0.168	15.3	1.13	0.168
33	0.25	Cu	3	Oil	Pb		0.113	0.143	0.083	0.536	168	3.21	1.571	0.119	0.54	168	1.32	0.76	0.183	14.4	1.09	0.183
33	0.3	Cu	3	Oil	Pb		0.092	0.117	0.080	0.591	186	3.54	1.480	0.116	0.59	186	1.07	0.73	0.202	13.6	1.07	0.202
33	0.35	Cu	3	Oil	Pb		0.078	0.100	0.079	0.624	196	3.73	1.372	0.114	0.62	196	0.91	0.72	0.213	12.6	1.05	0.213
33	0.4	Cu	3	Oil	Pb		0.068	0.089	0.078	0.667	210	3.99	1.262	0.112	0.67	210	0.81	0.71	0.228	11.6	1.03	0.228
33	0.45	Cu	3	Oil	Pb		0.062	0.080	0.077	0.700	220	4.19	1.222	0.110	0.70	220	0.73	0.70	0.240	11.2	1.01	0.240
33	0.5	Cu	3	Oil	Pb		0.056	0.073	0.077	0.733	230	4.39	1.174	0.108	0.73	230	0.67	0.70	0.251	10.8	0.99	0.251
33	0.55	Cu	3	Oil	Pb		0.051	0.068	0.075	0.766	241	4.58	1.118	0.106	0.77	241	0.62	0.69	0.262	10.3	0.97	0.262
33	0.6	Cu	3	Oil	Pb		0.046	0.061	0.074	0.799	251	4.78	1.063	0.104	0.80	251	0.56	0.68	0.273	9.76	0.96	0.273

Table 49 - Impedance data - 33kV Oil Filled Copper Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in^2	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
33	0.1	Cu	3	Gas	Pb		0.276	0.342	0.089	0.437	137	2.62	1.79	0.158	0.437	137	3.14	0.813	0.150	16.4	1.45	0.150
33	0.15	Cu	3	Gas	Pb		0.188	0.233	0.083	0.514	161	3.08	1.51	0.149	0.514	161	2.14	0.763	0.176	13.9	1.37	0.176
33	0.2	Cu	3	Gas	Pb		0.142	0.177	0.081	0.580	182	3.47	1.34	0.143	0.580	182	1.63	0.743	0.198	12.3	1.31	0.198
33	0.25	Cu	3	Gas	Pb		0.113	0.142	0.078	0.689	216	4.12	1.23	0.138	0.689	216	1.31	0.713	0.236	11.3	1.27	0.236
33	0.3	Cu	3	Gas	Pb		0.092	0.117	0.077	0.755	237	4.52	1.14	0.135	0.755	237	1.07	0.703	0.258	10.4	1.24	0.258
33	0.35	Cu	3	Gas	Pb		0.078	0.102	0.075	0.799	251	4.78	1.07	0.132	0.799	251	0.937	0.689	0.273	9.81	1.21	0.273
33	0.4	Cu	3	Gas	Pb		0.068	0.088	0.073	0.864	271	5.17	1.01	0.129	0.864	271	0.809	0.673	0.296	9.28	1.18	0.296
33	0.45	Cu	3	Gas	Pb		0.062	0.080	0.073	0.906	285	5.42	0.96	0.127	0.906	285	0.735	0.670	0.310	8.84	1.17	0.310
33	0.5	Cu	3	Gas	Pb		0.056	0.073	0.072	0.951	299	5.69	0.92	0.125	0.951	299	0.671	0.663	0.326	8.47	1.15	0.326
33	0.55	Cu	3	Gas	Pb		0.051	0.066	0.071	1.001	314	5.99	0.89	0.123	1.001	314	0.606	0.652	0.342	8.15	1.13	0.342
33	0.6	Cu	3	Gas	Pb		0.046	0.062	0.071	1.039	326	6.22	0.86	0.121	1.039	326	0.565	0.652	0.355	7.86	1.11	0.355

Table 50 - Impedance data - 33kV Gas Filled Copper Imperial Conductor

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
33	120	Al	1	XLPE	Pb		0.253	0.325	0.138	0.188	59	1.13	1.10	0.082	0.19	59	2.98	1.27	0.0643	10.1	0.753	0.0643
33	150	Al	1	XLPE	Pb		0.206	0.265	0.133	0.200	63	1.20	1.06	0.078	0.20	63	2.43	1.22	0.0684	9.77	0.716	0.0684
33	185	Al	1	XLPE	Pb		0.164	0.211	0.128	0.216	68	1.29	1.03	0.073	0.22	68	1.94	1.18	0.0739	9.45	0.670	0.0739
33	240	Al	1	XLPE	Pb		0.125	0.161	0.122	0.239	75	1.43	0.98	0.067	0.24	75	1.48	1.12	0.0818	9.02	0.615	0.0818
33	300	Al	1	XLPE	Pb		1.000	0.129	0.118	0.255	80	1.53	0.88	0.064	0.26	80	1.18	1.08	0.0872	8.06	0.588	0.0872
33	400	Al	1	XLPE	Pb		0.078	0.101	0.113	0.285	90	1.71	0.80	0.059	0.29	90	0.927	1.04	0.0975	7.35	0.542	0.0975
33	500	Al	1	XLPE	Pb		0.061	0.080	0.110	0.328	103	1.96	0.68	0.057	0.33	103	0.735	1.01	0.112	6.27	0.523	0.112
33	630	Al	1	XLPE	Pb		0.047	0.063	0.107	0.360	113	2.15	0.58	0.053	0.36	113	0.579	0.983	0.123	5.30	0.487	0.123
33	800	Al	1	XLPE	Pb		0.037	0.050	0.103	0.398	125	2.38	0.53	0.050	0.40	125	0.459	0.946	0.136	4.86	0.459	0.136
33	120	Cu	1	XLPE	Pb		0.153	0.196	0.138	0.188	59	1.13	1.002	0.082	0.19	59	1.80	1.27	0.0643	9.20	0.753	0.0643
33	150	Cu	1	XLPE	Pb		0.124	0.159	0.133	0.200	63	1.20	0.983	0.078	0.20	63	1.46	1.22	0.0684	9.03	0.716	0.0684
33	185	Cu	1	XLPE	Pb		0.099	0.127	0.128	0.216	68	1.29	0.964	0.073	0.22	68	1.17	1.18	0.0739	8.85	0.670	0.0739
33	240	Cu	1	XLPE	Pb		0.075	0.098	0.123	0.234	74	1.40	0.943	0.068	0.23	74	0.90	1.13	0.0801	8.66	0.624	0.0801
33	300	Cu	1	XLPE	Pb		0.060	0.078	0.118	0.255	80	1.53	0.839	0.064	0.26	80	0.72	1.08	0.0872	7.70	0.588	0.0872
33	400	Cu	1	XLPE	Pb		0.047	0.062	0.113	0.283	89	1.69	0.773	0.059	0.28	89	0.57	1.04	0.0968	7.10	0.542	0.0968
33	500	Cu	1	XLPE	Pb		0.037	0.050	0.111	0.326	102	1.95	0.663	0.057	0.33	102	0.46	1.02	0.112	6.09	0.523	0.112
33	630	Cu	1	XLPE	Pb		0.028	0.040	0.107	0.360	113	2.15	0.559	0.053	0.36	113	0.37	0.983	0.123	5.13	0.487	0.123
33	800	Cu	1	XLPE	Pb		0.022	0.033	0.103	0.398	125	2.38	0.515	0.050	0.40	125	0.30	0.946	0.136	4.73	0.459	0.136

Table 51 – Impedance Data - 33kV XLPE Lead Sheath (Single Core Trefoil)

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
33	50	Al	1	XLPE	CWS		0.641	0.822	0.152	0.144	45	0.86	1.183	0.094	0.14	45	7.55	1.40	0.0493	10.9	0.863	0.0493
33	70	Al	1	XLPE	CWS		0.443	0.568	0.144	0.159	50	0.95	0.985	0.087	0.16	50	5.22	1.32	0.0544	9.04	0.799	0.0544
33	95	Al	1	XLPE	CWS		0.320	0.411	0.137	0.175	55	1.05	0.862	0.080	0.18	55	3.77	1.26	0.0599	7.92	0.735	0.0599
33	120	Al	1	XLPE	CWS		0.253	0.325	0.132	0.188	59	1.13	0.795	0.076	0.19	59	2.98	1.21	0.0643	7.30	0.698	0.0643
33	150	Al	1	XLPE	CWS		0.206	0.265	0.128	0.201	63	1.20	0.748	0.071	0.20	63	2.43	1.18	0.0688	6.87	0.652	0.0688
33	185	Al	1	XLPE	CWS		0.164	0.211	0.123	0.216	68	1.29	0.706	0.067	0.22	68	1.94	1.13	0.0739	6.48	0.615	0.0739
33	240	Al	1	XLPE	CWS		0.125	0.161	0.117	0.239	75	1.43	0.667	0.062	0.24	75	1.48	1.07	0.0818	6.12	0.569	0.0818
33	300	Al	1	XLPE	CWS		0.100	0.129	0.114	0.255	80	1.53	0.642	0.059	0.26	80	1.18	1.05	0.0872	5.90	0.542	0.0872
33	400	Al	1	XLPE	CWS		0.078	0.101	0.109	0.285	90	1.71	0.620	0.054	0.29	90	0.927	1.00	0.0975	5.69	0.496	0.0975
33	500	Al	1	XLPE	CWS		0.061	0.080	0.105	0.321	101	1.92	0.603	0.051	0.32	101	0.735	0.964	0.110	5.54	0.468	0.110
33	630	Al	1	XLPE	CWS		0.047	0.063	0.102	0.352	111	2.11	0.590	0.048	0.35	111	0.579	0.937	0.120	5.42	0.441	0.120
33	800	Al	1	XLPE	CWS		0.037	0.051	0.098	0.390	123	2.33	0.580	0.045	0.39	123	0.468	0.900	0.133	5.33	0.413	0.133
33	1000	Al	1	XLPE	CWS		0.029	0.042	0.095	0.429	135	2.57	0.573	0.042	0.43	135	0.386	0.872	0.147	5.26	0.386	0.147
33	50	Cu	1	XLPE	CWS		0.387	0.494	0.153	0.143	45	0.86	0.929	0.095	0.14	45	4.54	1.40	0.0489	8.53	0.872	0.0489
33	70	Cu	1	XLPE	CWS		0.268	0.342	0.144	0.159	50	0.95	0.810	0.087	0.16	50	3.14	1.32	0.0544	7.44	0.799	0.0544
33	95	Cu	1	XLPE	CWS		0.193	0.247	0.137	0.174	55	1.04	0.735	0.080	0.17	55	2.27	1.26	0.0595	6.75	0.735	0.0595
33	120	Cu	1	XLPE	CWS		0.153	0.196	0.132	0.188	59	1.13	0.695	0.076	0.19	59	1.80	1.21	0.0643	6.38	0.698	0.0643
33	150	Cu	1	XLPE	CWS		0.124	0.159	0.128	0.200	63	1.20	0.666	0.072	0.20	63	1.46	1.18	0.0684	6.12	0.661	0.0684
33	185	Cu	1	XLPE	CWS		0.099	0.127	0.123	0.216	68	1.29	0.641	0.067	0.22	68	1.17	1.13	0.0739	5.89	0.615	0.0739
33	240	Cu	1	XLPE	CWS		0.075	0.098	0.118	0.234	74	1.40	0.618	0.063	0.23	74	0.900	1.08	0.0801	5.67	0.579	0.0801
33	300	Cu	1	XLPE	CWS		0.060	0.078	0.114	0.255	80	1.53	0.603	0.059	0.26	80	0.716	1.05	0.0872	5.54	0.542	0.0872
33	400	Cu	1	XLPE	CWS		0.047	0.062	0.109	0.283	89	1.69	0.590	0.055	0.28	89	0.569	1.00	0.0968	5.42	0.505	0.0968
33	500	Cu	1	XLPE	CWS		0.037	0.050	0.106	0.318	100	1.90	0.580	0.052	0.32	100	0.459	0.973	0.109	5.33	0.478	0.109
33	630	Cu	1	XLPE	CWS		0.028	0.040	0.102	0.352	111	2.11	0.572	0.048	0.35	111	0.367	0.937	0.120	5.25	0.441	0.120
33	800	Cu	1	XLPE	CWS		0.022	0.034	0.098	0.390	123	2.33	0.566	0.045	0.39	123	0.312	0.900	0.133	5.20	0.413	0.133
33	1000	Cu	1	XLPE	CWS		0.018	0.029	0.095	0.429	135	2.57	0.562	0.042	0.43	135	0.266	0.872	0.147	5.16	0.386	0.147

Table 52 - Impedance Data - 33kV XLPE Copper Wire Screen (Single Core)

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
66	0.1	Cu	3	Oil	Pb		0.276	0.347	0.116	0.263	82	3.17	1.586	0.152	0.263	82	0.796	0.266	0.359	3.64	0.348	0.359
66	0.15	Cu	3	Oil	Pb		0.188	0.237	0.106	0.317	100	3.83	1.359	0.143	0.317	100	0.545	0.244	0.434	3.12	0.329	0.434
66	0.2	Cu	3	Oil	Pb		0.142	0.178	0.102	0.361	113	4.38	1.218	0.138	0.361	113	0.409	0.234	0.494	2.80	0.316	0.494
66	0.25	Cu	3	Oil	Pb		0.113	0.142	0.097	0.405	127	4.81	1.119	0.133	0.405	127	0.326	0.224	0.554	2.57	0.306	0.554
66	0.3	Cu	3	Oil	Pb		0.092	0.117	0.094	0.438	137	5.25	1.044	0.130	0.438	137	0.269	0.216	0.599	2.40	0.299	0.599
66	0.35	Cu	3	Oil	Pb		0.078	0.100	0.092	0.481	151	5.80	0.984	0.127	0.481	151	0.229	0.211	0.659	2.26	0.292	0.659
66	0.4	Cu	3	Oil	Pb		0.068	0.088	0.089	0.525	165	6.24	0.935	0.125	0.525	165	0.201	0.203	0.719	2.15	0.287	0.719
66	0.45	Cu	3	Oil	Pb		0.062	0.080	0.088	0.547	172	0.66	0.894	0.123	0.547	172	0.183	0.201	0.749	2.05	0.282	0.749
66	0.5	Cu	3	Oil	Pb		0.056	0.072	0.086	0.569	179	6.78	0.859	0.121	0.569	179	0.166	0.198	0.778	1.97	0.278	0.778
66	0.55	Cu	3	Oil	Pb		0.051	0.068	0.085	0.602	189	7.22	0.829	0.119	0.602	189	0.156	0.196	0.823	1.90	0.274	0.823
66	0.6	Cu	3	Oil	Pb		0.046	0.061	0.084	0.635	199	7.55	0.802	0.118	0.635	199	0.141	0.193	0.868	1.84	0.271	0.868

Table 53 - Impedance Data - 66kV Oil Filled Copper Imperial Conductor (Three Core)

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
66	0.1	Cu	1	Oil	Pb		0.269	0.339	0.114	0.449	141	5.36	1.07	0.062	0.449	141	0.779	0.261	0.614	2.46	0.142	0.614
66	0.15	Cu	1	Oil	Pb		0.181	0.228	0.110	0.481	151	5.80	0.92	0.059	0.481	151	0.522	0.254	0.659	2.12	0.136	0.659
66	0.2	Cu	1	Oil	Pb		0.137	0.173	0.107	0.525	165	6.24	0.83	0.057	0.525	165	0.397	0.246	0.719	1.90	0.131	0.719
66	0.25	Cu	1	Oil	Pb		0.110	0.138	0.109	0.492	155	5.91	0.76	0.056	0.492	155	0.316	0.251	0.674	1.75	0.128	0.674
66	0.3	Cu	1	Oil	Pb		0.090	0.114	0.107	0.514	162	6.13	0.71	0.055	0.514	162	0.261	0.246	0.704	1.64	0.126	0.704
66	0.35	Cu	1	Oil	Pb		0.078	0.098	0.105	0.547	172	6.56	0.67	0.054	0.547	172	0.226	0.241	0.749	1.54	0.123	0.749
66	0.4	Cu	1	Oil	Pb		0.067	0.085	0.103	0.580	182	6.89	0.64	0.053	0.580	182	0.196	0.236	0.793	1.47	0.122	0.793
66	0.45	Cu	1	Oil	Pb		0.061	0.078	0.102	0.602	189	7.22	0.61	0.052	0.602	189	0.178	0.234	0.823	1.41	0.120	0.823
66	0.5	Cu	1	Oil	Pb		0.055	0.070	0.102	0.624	196	7.44	0.59	0.052	0.624	196	0.161	0.234	0.853	1.35	0.119	0.853
66	0.55	Cu	1	Oil	Pb		0.049	0.062	0.100	0.645	203	7.77	0.57	0.051	0.645	203	0.143	0.229	0.883	1.31	0.117	0.883
66	0.6	Cu	1	Oil	Pb		0.045	0.059	0.098	0.667	210	7.99	0.55	0.051	0.667	210	0.136	0.226	0.913	1.26	0.116	0.913
66	0.65	Cu	1	Oil	Pb		0.042	0.055	0.098	0.689	217	8.21	0.53	0.050	0.689	217	0.126	0.226	0.943	1.23	0.115	0.943
66	0.75	Cu	1	Oil	Pb		0.037	0.048	0.096	0.733	230	8.75	0.51	0.049	0.733	230	0.111	0.221	1.00	1.16	0.113	1.00
66	0.85	Cu	1	Oil	Pb		0.032	0.043	0.095	0.777	244	9.30	0.48	0.049	0.777	244	0.098	0.218	1.06	1.11	0.112	1.06
66	1	Cu	1	Oil	Pb		0.026	0.036	0.092	0.842	265	10.06	0.46	0.048	0.842	265	0.083	0.211	1.15	1.05	0.110	1.15

Table 54 –Impedance Data - 66kV Oil Filled Copper Imperial Conductor (Single Core Trefoil)

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	mm²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
66	300	Al	1	XLPE	Pb		0.100	0.128	0.133	0.190	60	2.27	0.375	0.087	0.190	60	0.294	0.305	0.260	0.861	0.200	0.260
66	400	Al	1	XLPE	Pb		0.078	0.100	0.128	0.205	64	2.45	0.353	0.063	0.205	64	0.230	0.294	0.281	0.810	0.145	0.281
66	500	Al	1	XLPE	Pb		0.061	0.079	0.123	0.225	71	2.69	0.336	0.059	0.225	71	0.181	0.282	0.308	0.770	0.135	0.308
66	630	Al	1	XLPE	Pb		0.047	0.062	0.118	0.250	79	2.99	0.322	0.054	0.250	79	0.142	0.271	0.342	0.739	0.124	0.342
66	800	Al	1	XLPE	Pb		0.037	0.050	0.114	0.270	85	3.23	0.312	0.065	0.270	85	0.115	0.262	0.369	0.716	0.149	0.369
66	1000	Al	1	XLPE	Pb		0.029	0.041	0.110	0.295	93	3.53	0.304	0.061	0.295	93	0.094	0.253	0.404	0.698	0.140	0.404
66	300	Cu	1	XLPE	Pb		0.060	0.078	0.133	0.190	60	2.27	0.335	0.087	0.190	60	0.179	0.305	0.260	0.769	0.200	0.260
66	400	Cu	1	XLPE	Pb		0.047	0.062	0.128	0.205	64	2.45	0.322	0.063	0.205	64	0.142	0.294	0.281	0.739	0.145	0.281
66	500	Cu	1	XLPE	Pb		0.037	0.049	0.123	0.225	71	2.69	0.312	0.059	0.225	71	0.112	0.282	0.308	0.715	0.135	0.308
66	630	Cu	1	XLPE	Pb		0.028	0.040	0.118	0.250	79	2.99	0.303	0.054	0.250	79	0.092	0.271	0.342	0.696	0.124	0.342
66	800	Cu	1	XLPE	Pb		0.022	0.033	0.114	0.270	85	3.23	0.297	0.065	0.270	85	0.076	0.262	0.369	0.682	0.149	0.369
66	1000	Cu	1	XLPE	Pb		0.018	0.028	0.110	0.295	93	3.53	0.293	0.061	0.295	93	0.064	0.253	0.404	0.672	0.140	0.404

Table 55 - Impedance Data - 66kV XLPE Metric Conductor (Trefoil Single Core)

Appendix 3d – 132kV Cable Impedance Data

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
132	0.1	Cu	1	Oil	Pb		0.270	0.339	0.127	0.274	86	6.56	0.800	0.086	0.274	86	0.195	0.0728	1.50	0.459	0.0491	1.50
132	0.15	Cu	1	Oil	Pb		0.181	0.228	0.123	0.317	100	7.55	0.690	0.081	0.317	100	0.131	0.0703	1.74	0.396	0.0465	1.74
132	0.2	Cu	1	Oil	Pb		0.138	0.173	0.118	0.317	100	7.55	0.622	0.078	0.317	100	0.0992	0.0678	1.74	0.357	0.0448	1.74
132	0.25	Cu	1	Oil	Pb		0.110	0.138	0.121	0.306	96	7.33	0.573	0.076	0.306	96	0.0791	0.0697	1.68	0.329	0.0435	1.68
132	0.3	Cu	1	Oil	Pb		0.090	0.114	0.119	0.317	100	7.55	0.536	0.074	0.317	100	0.0653	0.0684	1.74	0.308	0.0425	1.74
132	0.35	Cu	1	Oil	Pb		0.078	0.098	0.116	0.339	107	8.10	0.507	0.072	0.339	107	0.0565	0.0666	1.86	0.291	0.0416	1.86
132	0.4	Cu	1	Oil	Pb		0.067	0.085	0.114	0.361	113	8.64	0.483	0.071	0.361	113	0.0490	0.0653	1.98	0.277	0.0409	1.98
132	0.45	Cu	1	Oil	Pb		0.061	0.077	0.113	0.372	117	8.86	0.462	0.070	0.372	117	0.0440	0.0647	2.04	0.265	0.0402	2.04
132	0.5	Cu	1	Oil	Pb		0.055	0.070	0.110	0.383	120	9.08	0.445	0.069	0.383	120	0.0402	0.0634	2.10	0.255	0.0397	2.10
132	0.55	Cu	1	Oil	Pb		0.049	0.062	0.108	0.405	127	9.74	0.430	0.068	0.405	127	0.0358	0.0622	2.22	0.247	0.0392	2.22
132	0.6	Cu	1	Oil	Pb		0.045	0.058	0.107	0.416	131	9.96	0.416	0.068	0.416	131	0.0333	0.0615	2.28	0.239	0.0387	2.28
132	0.65	Cu	1	Oil	Pb		0.042	0.055	0.107	0.427	134	10.17	0.404	0.067	0.427	134	0.0314	0.0615	2.34	0.232	0.0383	2.34
132	0.75	Cu	1	Oil	Pb		0.037	0.048	0.105	0.449	141	10.72	0.384	0.066	0.449	141	0.0276	0.0603	2.46	0.220	0.0376	2.46
132	0.85	Cu	1	Oil	Pb		0.032	0.043	0.103	0.481	151	11.49	0.367	0.064	0.481	151	0.0245	0.0590	2.63	0.210	0.0370	2.63
132	1	Cu	1	Oil	Pb		0.026	0.035	0.100	0.525	165	12.58	0.345	0.063	0.525	165	0.0201	0.0571	2.87	0.198	0.0362	2.87

Table 56 - Impedance Data - 132kV Oil Filled Copper Imperial Conductor (Single Core Trefoil)

	Conductors			Construction			Positive & Negative Sequence (Ohmic per km)						Zero Sequence (Ohmic per km)				Positive & Negative Sequence (100MVA % per km)			Zero Sequence (100MVA % per km)		
Voltage kV	in²	Material	No.	Insulation	Sheath	Protection	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	Charging Current A/km	AC Resistance Ω/km	Reactance Ω/km	Capacitance µF/km	Susceptance µS/km	AC Resistance at max insulator temp	Reactance	Susceptance	AC Resistance	Reactance	Susceptance
U							R_{dc}	$R_1=R_2$	$X_1=X_2$	$C_1=C_2$	$B_1=B_2$	I_C	R_0	X_0	C_0	B_0	$R_1=R_2$	$X_1=X_2$	$B_1=B_2$	R_0	X_0	B_0
132	300	Al	1	XLPE	Pb		0.100	0.128	0.153	0.130	41	3.11	0.375	0.097	0.130	41	0.0735	0.0878	0.712	0.215	0.0556	0.712
132	400	Al	1	XLPE	Pb		0.078	0.100	0.146	0.140	44	3.35	0.353	0.088	0.140	44	0.0574	0.0838	0.766	0.202	0.0503	0.766
132	500	Al	1	XLPE	Pb		0.061	0.079	0.138	0.160	50	3.83	0.336	0.083	0.160	50	0.0453	0.0792	0.876	0.193	0.0477	0.876
132	630	Al	1	XLPE	Pb		0.047	0.062	0.133	0.170	53	4.07	0.322	0.079	0.170	53	0.0356	0.0763	0.931	0.185	0.0452	0.931
132	800	Al	1	XLPE	Pb		0.037	0.049	0.126	0.195	61	4.67	0.312	0.074	0.195	61	0.0281	0.0723	1.07	0.179	0.0425	1.07
132	1000	Al	1	XLPE	Pb		0.029	0.041	0.122	0.210	66	5.03	0.304	0.070	0.210	66	0.0235	0.0700	1.15	0.175	0.0403	1.15
132	300	Cu	1	XLPE	Pb		0.060	0.078	0.153	0.130	41	3.11	0.335	0.096	0.130	41	0.0448	0.0878	0.712	0.192	0.0552	0.712
132	400	Cu	1	XLPE	Pb		0.047	0.062	0.135	0.170	53	4.07	0.198	0.077	0.170	53	0.0356	0.0775	0.93	0.114	0.0442	0.93
132	500	Cu	1	XLPE	Pb		0.037	0.049	0.130	0.182	57	4.36	0.183	0.072	0.182	57	0.0282	0.0746	1.00	0.105	0.0413	1.00
132	630	Cu	1	XLPE	Pb		0.028	0.393	0.122	0.206	65	4.93	0.180	0.067	0.206	65	0.2256	0.0700	1.13	0.103	0.0385	1.13
132	800	Cu	1	XLPE	Pb		0.022	0.032	0.117	0.225	71	5.39	0.174	0.062	0.225	71	0.0185	0.0671	1.23	0.100	0.0356	1.23
132	1000	Cu	1	XLPE	Pb		0.018	0.027	0.114	0.242	76	5.79	0.170	0.059	0.242	76	0.0157	0.0654	1.32	0.098	0.0339	1.32
132	1200	Cu	1	XLPE	Pb		0.015	0.022	0.113	0.264	83	6.32	0.164	0.057	0.264	83	0.0127	0.0649	1.45	0.094	0.0327	1.45

Table 57 - Impedance Data - 132kV XLPE Metric Conductor (Trefoil Single Core)[22]

[22] The ratings for 132kV Copper cable are based on the cable datasheet from the Telefonika cable manufacturer.