ElectraNet

Substation HV Cables

Document Number: 1-11-FR-07

VERSION 1.0 June 2018

This functional requirements document is in line with the organisation's 1-11-ACS-07 Substation HV Cables Asset Class Strategy

Contents

1. Definitions

In this document, the following words and expressions will have the following meanings:

Item	Meaning
AS	Australian Standard, as publication by Standards Australia (Standards Association of Australia).
Contractor	A contractor engaged by ElectraNet or a Customer (including a third party IUSA provider engaged by a Customer or any contractor engaged by such third party IUSA provider) to perform any design, construction or related services in relation to assets or infrastructure which are connected, or to be connected, to ElectraNet's transmission network
Customer	A party who wants to establish or modify a connection to ElectraNet's transmission network but does not include a third party IUSA provider
DC	Direct Current
ECC	Earth Continuity Conductor
FTB	Fluidised Thermal Backfill
high voltage or HV	Nominal voltage exceeding 1000 volts alternating current or exceeding 1500 volts direct current.
IR	Insulation Resistance
kV	Kilo Volt
low voltage or LV	Nominal voltage exceeding 50 volts alternating current or 120 volts direct current, but not exceeding 1000 volts alternating current or 1500 volts direct current.
m	Metre
mm	Millimetre
SPB	Single Point Bonded - the cable is bonded to earth at one end only
Standard Drawing	A drawing developed by ElectraNet as a complete design to be used for construction. Standard Drawings are not intended to be revised or renumbered.
SVL	Sheath Voltage Limiter
third party IUSA	Has the same meaning as defined in the National Electricity Rules
Template Drawing	A drawing developed by ElectraNet as the basis for design. Template Drawings are intended to be revised and renumbered as required to complete the design.
TR	Thermal Resistivity

Item	Meaning
VLF	Very Low Frequency, typically 0.5 Hz
XLPE	Cross-linked polyethylene

2. Purpose and Scope

The purpose of this document is to describe the functional requirements for Substation HV Cable and its integration into a substation.

This document details the HV cable selection, rating, procurement and installation in ElectraNet substations and covers all HV cables with a voltage rating greater than 1 kV. This document only applies where the HV cables are totally installed inside the substation perimeter fence. This document does not apply where HV cables are used for transmission or sub transmission connections between two substations.

3. Referenced Documents

The table below lists applicable legislations, standards, referenced documents:

Legislation	
SAEA	Electricity Act 1996 (SA)
SAER	South Australia Electricity (General) Regulations 2012 (SA) under the SAEA
NER	National Electricity Rules
ETC	Electricity Transmission Code TC/08
International Standards	
IEEE Std 400.2:2013	Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)
IEEE Std 442:1981 (r2003)	Guide for Soil Thermal Resistivity Measurements.
AS/ISO 1000:1998	The international system of units (SI) and its applications.
AS 1012.1:2014	Methods of Testing Concrete - Sampling of concrete
AS/NZS 1125:2001 + Amdt 1:2004 (R2017)	Conductors in insulated electric cables and flexible cords
AS 1141:various	Methods for sampling and testing aggregates
AS 1289.2.1.1:2005 (R2016)	Determination of the moisture content of a soil - oven drying method
AS 1289:various	Methods of Testing Soils for Engineering Purposes
AS 1319:1994	Safety signs for the occupational environment
AS 1379:2007	Specification and supply of Concrete
AS/NZS 1429.1:2006 (R2017)	Electric cables – Polymeric insulated – For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV
AS/NZS 1429.2:2009	Electric cables – Polymeric insulated – For working voltages above 19/33 (36) kV up to and including 76/132(145) kV
AS/NZS 2053.2:2001 (R2016)	Conduits and fittings for electrical installations - Rigid plain conduits and fittings of insulating material
AS 2067:2016	Substations and high voltage installations exceeding 1 kV a.c.
AS/NZS 2648.1:1995	Underground Marking Tape - Non-detectable tape
AS 2758.1:2014	Aggregates and rock for engineering purposes. Part 1: Concrete aggregates

AS/NZS 2857:1996 (R2017)	Timber drums for insulated electric cables and bare conductors
AS/NZS 3582:various	Supplementary cementitious materials
AS 3972:2010	General purpose and blended cements
AS 3983:1991 (R2016)	Metal Drums
AS 4436:1996 (R2016)	Guide for the selection of insulators in respect of polluted conditions.
AS 4702:2000 (R2013)	Polymeric Cable Protection Covers
AS/NZS 60137:2008	Insulated bushings for alternating voltages above 1000 V (IEC 60137 Ed 5 (2003) MOD)
IEC 60099	Surge Arresters
IEC 60332:various	Tests on electric and optical fibre cables under fire conditions
IEC 60754:various	Test on gases evolved during combustion on materials from cables
IEC 60287-1-1 Ed.2.1:2014	Electric cables - Calculation of the current rating - Part 1-1: Current rating equations (100% load factor) and calculation of losses - General
IEC 60502-2 Ed 3.0:2014	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV)
IEC 60840 Ed.4.0.:Bilingual 2011	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test methods and requirements
IEC 60853-1 Ed.1.0:1985 + Amd.1 & .2:2008	Calculation of the cyclic and emergency current rating of cables. Part 1: Cyclic rating factor for cables up to and including 18/30 (36) kV
IEC 60853-2 Ed.1.0:1989 + Amd.1:2008	Calculation of the cyclic and emergency current rating of cables. Part 2: Cyclic rating of cables greater than 18/30 (36)kV and emergency ratings for cables of all voltages
IEC 62271-209 Ed 1.0:2007	Cable connections for gas-insulated metal enclosed switchgear for rated voltages of 72.5 kV and above-Fluid filled and extruded insulated cables – Fluid filled and dry type cable-terminations
I.S. EN 50181:2010	Plug-In Type Bushings Above 1 kV up to 33 kV and from 250 A to 2500 A for equipment other than liquid filled transformers.
ASTM D5334-08:	Standard Test Method for Determining the Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure.

ESAA Guide D(b) 26:1995	Guide for Working on Cables and Ancillary Equipment under Induced Voltage Conditions and Transferred Earth Potentials
CIGRE Technical Brochure 303:	Revision of qualification procedures for high voltage and extra high voltage AC extruded cable systems
ElectraNet's Documentation	
1-11-FR-10	Substation Insulation Coordination

4. Substation HV Cables

4.1 Introduction

4.1.1.1 This document details the scope of works for the HV cables approved by ElectraNet.

4.1.1.2 Substation HV cables are used for the connection between major substation equipment. Typical applications are for 11 kV, 33 kV and 66 kV HV equipment. In rare occasions 132 kV HV cables may be required.

4.1.1.3 Typical applications cover interconnecting transformer loadable tertiary bushings to station auxiliary transformers or interconnecting transformer secondary bushings to the associated switching bay when the use of bus bars is not practical.

4.2 Design, Construction and Installation

4.2.1 Cable

4.2.1.1 Cables must be manufactured and tested in accordance with AS/NZ 1429.1 (for voltages up to and including 33 kV) and AS/NZ 1429.2 (for voltages above 33 kV) and with IEC 60502-2.

4.2.1.2 Cables must be XLPE insulated.

4.2.1.3 Cables must be manufactured through an extrusion process.

4.2.1.4 Cables must be single core.

4.2.1.5 No cable joints are to be used for substation applications.

4.2.1.6 The maximum continuous design operating temperature of the cable conductor is 90°C. The cable selection process for a specific application must ensure that this operating temperature is not exceeded even under overload conditions. The conductor design temperature shall not exceed 250°C under fault conditions.

4.2.1.7 Continuous current rating must be determined in accordance with IEC 60287.

4.2.1.8 Cable conductor must be rated for the cyclic current specified in accordance with IEC 60853-1 for design voltages up to and including 33 kV. Cable conductor must be rated for the cyclic current specified in accordance with IEC 60853-2 for design voltages greater than 33 kV.

4.2.1.9 Cable conductor must be rated for the emergency current specified in accordance with IEC 60853-1 for design voltages up to and including 33 kV. Cable conductor must be rated for the emergency current specified in accordance with IEC 60853-2 for design voltages greater than 33 kV.

4.2.1.10 Cables must be rated for the overload rating of the associated substation plant it connects to.

4.2.1.11 Cable conductors must be designed to meet the ultimate fault rating requirements for the substation in which they are to be used.

4.2.1.12 All calculations and supporting documentation for cable sizing and installation method shall be submitted to ElectraNet as part of the design review process.

4.2.1.13 Design calculations in CYMCAP software to determine cable ratings.

4.2.1.14 Cable sizing must consider the native soil thermal resistivity tested on site.

4.2.1.15 The ambient temperature of the soil must be 30° C.

4.2.1.16 Cables must have termite and moisture protection layers incorporated in the design. The use of paint for termite protection may be considered on a case by case basis.

4.2.2 Cable Screens

4.2.2.1 The cable screen or metallic sheath must be capable of passing rated fault current for the duration of the backup protection time.

4.2.2.2 The cable screen design temperature shall not exceed 250°C under fault conditions.

4.2.2.3 ElectraNet policy is to ensure that HV neutral points are effectively earthed.

4.2.2.4 Cable screens must be bonded to earth either solidly or through a method where any voltage rises during normal operation or during fault conditions are considered safe.

4.2.2.5 For solidly bonded circuits, the cable screens must be bonded to earth at both ends. This must be achieved via Earth Bars for circuits up to and including 33 kV.

4.2.2.6 An insulated copper ECC must be laid with circuits using SPB and sized to meet the short circuit requirements specified above. The ECC must be transposed at the midpoint and bonded to the earth system adjacent to the terminations at each end.

4.2.3 Link Boxes and Sheath Voltage Limiters

4.2.3.1 The use of link boxes and SVLs will be as per the project technical specification.

4.2.3.2 The link boxes and SVLs (where provided) must be designed to withstand periodic testing of the cable sheaths.

4.2.3.3 Link boxes must be constructed of stainless steel and have a bolted lid and be effectively sealed to IP 64 according to AS 60529. They must be designed to ensure safe and reliable operation under normal and transient conditions.

4.2.3.4 Internal link circuitry must meet the short circuit ratings as specified for each individual project.

4.2.3.5 Where used, the link boxes must be installed as per ElectraNet's Standard Drawings and Template Drawings.

4.2.3.6 Where link boxes are used for SPB circuits, the cable screens at the "Transformer end" must be earthed via a removable link contained in the Link Box while at the other end the cable screens must be earthed via SVLs also contained in a Link Box.

4.2.4 Terminations

4.2.4.1 Outdoor terminations must be of the polymeric type. Porcelain bushings are not acceptable for outdoor terminations.

4.2.4.2 For voltages up to and including 66 kV, polymeric terminations may be of a type involving heat shrink components.

4.2.4.3 For 132 kV cables, polymeric terminations must be of pre-moulded type and be self-supporting (i.e. not dependent on external bus bars for support).

4.2.4.4 SF_6 cable terminations shall interface with corresponding switchgear details. For SF_6 cable terminations up to and including 33 kV interfaces shall comply with EN 50181. Interfaces for SF_6 terminations above 33 kV shall be coordinated in line with IEC 62271-209 or as approved by ElectraNet.

4.2.4.5 The creepage distance of outdoor termination insulation must be Level (e) – very heavy (31 mm/kV) as per IEC 60137 and AS 4436-1996 (IEC 60815-1986) “Guide for the selection of insulators in respect of polluted conditions”.

4.2.5 Use of Surge Arresters

4.2.5.1 In accordance with the requirements of document 1-11-FR-10, covering insulation coordination requirements, surge arresters must be installed at both ends of the cable.

4.2.5.2 HV Surge Arresters must be mounted as close as practical to the cable terminations and in accordance with the Manufacturer’s recommended clearances and the project site-specific requirements. Surge Arrester connecting conductors and earth cables must be as short and direct as possible.

4.2.6 Use of Cable Conduits versus Direct Burial in Cable Trenches

4.2.6.1 For substation applications, and where rating calculations permit, the cables must be installed in heavy duty orange cable conduits.

4.2.6.2 HV Cables must be direct buried in cable trenches where rating calculations indicate that it is uneconomical to install in cable conduits.

4.2.7 Installation

4.2.7.1 Cable Drums must be protected from damage during transport.

4.2.7.2 Adequate cable laying rollers, particularly at corners and vertical bends must be provided.

4.2.7.3 Pulling tension calculations must ensure that the cable Manufacturer’s recommended maximum loadings are not exceeded.

4.2.7.4 The installation of the HV cables must be in trefoil or flat configuration.

4.2.7.5 The minimum depth of installation must be in accordance with AS 2067.

4.2.7.6 Any mechanical protection requirements must be in accordance with AS 2067.

4.2.7.7 Thermally stable back fill must be installed beneath, around and above HV power cables or their associated conduits.

4.2.7.8 The minimum thickness of the thermally stable backfill at the bottom of the cable trench or under the cable conduits is 150 mm.

4.2.7.9 FTB is the preferred trench backfill material. An approved thermally stable backfill material of 14:1 sand / cement mix may also be considered as defined in project site-specific requirements.

4.2.7.10 Where there are multiple HV cable runs for independently switched circuits physical separation of at least 3.5 metres between circuits is preferred.

4.2.7.11 Polymeric cable protection covers to AS 4702 and warning tapes to AS/NZS 2648.1 must be incorporated into the entire width of the cable trench in accordance with the latest revision of ElectraNet's Template Drawings.

4.2.7.12 Permanent cable markers must be placed at ground surface level above the centre-line of each cable circuit.

4.2.7.13 Permanent cable markers must be located at the ends, changes of direction and elsewhere at 25 m maximum intervals.

4.2.7.14 Only formally accredited cable termination personnel must install cable terminations.

4.3 Testing Requirements

4.3.1 Type Testing

4.3.1.1 Type test certificates must be provided in accordance with AS/NZS 1429.1 or 1429.2, as applicable.

4.3.1.2 The test certificates must be submitted to ElectraNet with the cable proposal.

4.3.1.3 132 kV cables with design stress above 8 kV/mm on the conductor or 4 kV/mm over the insulation are not acceptable as discussed in CIGRE Technical Brochure 303.

4.3.2 Routine Testing

4.3.2.1 The following routine tests must be performed in accordance with AS/NZS 1429.1 or 1429.2 as applicable on 100% of cable drums:

a) Partial Discharge test; and

b) AC voltage test.

4.3.2.2 In addition, for cables with metallic sheaths, the Sheath IR test must be 25 kV DC/1 min.

4.3.2.3 Test reports must be submitted by the Contractor within two weeks of performance of the tests.

4.3.2.4 Cables must not be installed prior to acceptance of the test reports by ElectraNet.

4.3.3 Sample Tests

4.3.3.1 The following sample tests must be performed in accordance with AS/NZS 1429.2 and IEC 60840 on cables with metallic sheaths. They must be performed on 10% of drums for each cable type and conductor size, or a minimum of 10% of a total purchase order:

a) Conductor resistance test;

b) Measurement of capacitance;

c) Measurement of insulation thickness;

d) Measurement of sheath thickness;

e) Measurement of metallic sheath thickness;

f) Measurement of cable overall diameter;

g) XLPE (insulation) hot set test;

h) XLPE hot shrinkage; and

i) Inspection in hot silicon oil of insulation and screen voids, contaminants, protrusions and irregularity.

4.3.4 Witnessing of Tests

4.3.4.1 ElectraNet must be permitted to inspect cable manufacturing plant and process, as well as witness the type, routine and sample tests. ElectraNet must be permitted to nominate a third party to witness on their behalf.

4.3.4.2 ElectraNet must be provided with 14 days written notice (30 days in the case of overseas manufacture) of the date of cable manufacture and testing.

4.3.5 Site Commissioning

4.3.5.1 Cable core insulation must be tested by VLF as defined in IEEE Standard 400.2 after cable termination and prior to energisation.

Cable Voltage	Test Voltage (Phase to Ground)	Application Time
	rms or (peak volts)	Minutes
22	25 (33)	30
33	37 (50)	30
66	74 (110)	30

4.3.5.2 For cables greater than 66 kV, testing voltages and times will be subject to the agreement of ElectraNet.

4.3.5.3 A sinusoidal VLF voltage of 0.1 Hz (Waveform of 0.707 rms of the peak with distortion <5%) is applied.

4.3.5.4 The cable is tested, including the sealing ends, and isolated from the plant.

4.3.5.5 Cable outer sheaths must be tested by DC.

Cable Rating (kV)	Test Duration (minimum)	HV Test Voltage	Ins Resistance (Mega-ohm)
Cables without metallic sheaths (Test applied from screen to earth)			
22	1 minute	1 kV DC	>1000
33	1 minute	1 kV DC	>1000
66	1 minute	1 kV DC	>1000
132	1 minute	1 kV DC	>1000

4.3.5.6 Associated insulated bonding leads and earth continuity cables must also be tested (conductor to earth) to the same voltage values as the associated cable over sheaths.

4.3.5.7 The test voltage must be applied for 1 minute minimum and/or until a steady IR measurement is obtained.

4.3.5.8 Phase identification must also be verified as part of this test.

4.3.5.9 Link contact resistance in all link boxes must be less than or equal to 20 micro-ohms.

4.3.5.10 The contact resistance of the interface between the earthing or bonding lugs of terminations, joints, auxiliary metal enclosures and local earthing mats must be less than or equal to 20 micro-ohms.

4.3.5.11 The cable must be ‘soaked’ according to the manufacturer recommendations.

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