NATIONAL TRANSMISSION AND DESPATCH COMPANY

NTDC SPECIFICATION P-29:2010

15,000 VOLT XLPE INSULATED STRANDED CIRCULAR COMPACTED ALUMINIUM/COPPER CONDUCTOR POWER CABLES

DESIGN DEPARTMENT NTDC

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NTDC SPECIFICATION P-29:2010

0 FOREWORD

0.1 This specification has been prepared by the Standards & Research Directorate of the Design Department NTDC. This second edition cancels and replaces the first edition published in 1989 and its amendments.

0.2 This specification is intended for the procurement of material and does not include all the necessary provisions of a contract.

0.3 It is subject to periodical revision as and when required by S&R directorate of Design NTDC. No other department is authorized to issue any change/amendment in it.

1 SCOPE

1.1 This standard specifies the construction, dimensions and test requirements of single & three core power cables with extruded solid cross-linked Polyethylene (XLPE) insulating compound.

1.2 The designed cable voltage shall be as mentioned below:

U_o = 8.7 kV
U = 15 kV
U_m = 17.5 kV

1.3 Type of sheathing PVC compound shall be ST_2.

2. REFERENCE SPECIFICATIONS

2.1 The power cables shall comply with the requirements of following International Standards amended to date:

- IEC 60502-2, Power cables with extruded insulation and their accessories for rated voltage from 6kV up to 30kV.

IEC 60811-1-1 IEC 60811-1-2 IEC 60811-1-3 IEC 60811-1-4 IEC 60811-2-1 IEC 60811-3-1 IEC 60811-3-2 IEC 60811-4-1	Common Test methods for insulating and sheathing materials of electric cables

- IEC 60885-3, Electrical test methods for electric cables
- IEC 60986, Short circuit temperature limits of electric cables
- IEC 60228, Conductors for insulated cables
- IEC 60229, Tests on cable oversheaths
- IEC 60230, Impulse test on cables

2.2 In case the requirements laid down herein differ from those given in the above standards in any particular, the cables shall comply with the requirements indicated herein.

3 DEFINITIONS

3.1 Rated Voltage

The rated voltage U_o/U (U_m) of the Power Cable is 8.7/15 (17.5) kV where,

-U_o is the rated power frequency voltage between conductor and the earth or metallic screen for which the cable is designed.

-U is the power frequency voltage between conductors for which the cable is designed.

-U_m is the maximum value of the "highest system voltage" for which the cable may be used.

3.2 Insulating Compound

Insulation shall be extruded dielectric type cross-linked Polyethylene (XLPE).

3.3 Sheathing Compound

Polyvinyle Chloride (PVC) type ST_2.

3.4 Conductor

The conductor shall be plain Aluminium or Aluminium alloy or Annealed Copper in accordance with IEC 60228.

4. RATING & SERVICE CONDITIONS

4.1 The cables shall be suitable for operation in 15,000 volts, 50 c/s three phase distribution system. Three core cables shall be operated in a three phase three wire system with the power transformer neutral solidly grounded. Single core cables shall be used on either three phase four wire or a single phase two wire system.

4.2 The cables shall be suitable for direct burial or installation in ducts. The duct and soil conditions vary form dry to wet. Highly corrosive salts are encountered in the soils. The ambient temperature ranges from minus °C to 50°C.

4.3 The maximum conductor temperature for the insulating XLPE compound shall be as follows:

Normal Operation	=	90°C
Short Circuit (5 s max. duration)	=	250°C

5 CONSTRUCTION REQUIREMENTS

5.1 Single Core Cables

5.1.1 The conductor shall consist of stranded circular compacted Aluminium/Copper of electrical grade purity in accordance with IEC-60228 having tensile strength between 843.6 and 1406 kg/cm² for Aluminium conductor.

5.1.2 The stranded compacted conductor shall be covered by an extruded semi-conducting compound layer having minimum thickness of 0.7mm which shall adhere firmly to it.

5.1.3 The cross-linked polyethylene (XLPE) insulation shall be applied over the semi-conducting layer and shall be permanently and completely bounded to it without any voids.

5.1.4 A layer of semi-conducting compound having a minimum thickness of 0.7mm shall be extruded directly upon the cross-linked polyethylene (XLPE) insulation of each core and consist of either a bonded or strippable semi-conducting compound.

5.1.5 A metallic screen of one or more annealed copper shielding tapes or a combination of copper wires and tapes shall be applied helically to the surface of the insulation over the semi-conducting layer with an over-lap of 50% of the tape width. The minimum DC resistance of copper shielding screen of each core shall not exceed the values given in Table-1.

5.1.6 An aluminium wire armouring if required in the tender/order shall be applied helically over the inner PVC bedding (Separation Sheath type ST_2 extruded over the metallic screen).

5.1.7 The polyvinyl chloride oversheath (ST_2 Type) of black colour shall then be applied over the copper shielding and shall fit tightly over it.

5.2 Three Core Cables

5.2.1 The construction of the individual core of three core cable shall be the same as for single metallic shielded core cable stated in clause 5.1 above, except that the over all sheath as indicated in sub clause 5.1.6 shall not be applied on the individual cores.

5.2.2 The three individual metallic shielded cores shall be laid up having m contact with each other. The minimum resistance of copper shielding scree of complete three cores shall not exceed the values given in Table-I. The length of the lay of individual core shall not exceed 30 times the assembled core diameter. The interstices shall be filled with polypropylene fillers.

A suitable thick non-hygroscopic binding tape made of polypropylene shall then be applied helically over the laid up cores with a suitable overlap to form compact circular assembly.

5.2.3 The cable shall then be covered tightly with a separator sheath made of extruded layer of black polyvinyl chloride compatible with the operating temperature of the cable and complying with the requirements for type ST_2 of sheathing compound based on PVC.

5.2.4 A steel wire armouring shall be applied helically over the inner PVC bedding (separator sheath).

5.2.5 An extruded layer of overall black PVC compound type ST_2 oversheath shall then be applied over the armouring.

5.2.6 The cores shall be positively identified with colours preferably Red, Yellow & Blue by applying coloured tape along each core for which necessary approval of Design NTDC be obtained.

6. DIMENSIONS AND CHARACTERISTICS

6.1 The size of cables for both single core and three core cables are as under:-

Sr.No.	Cross-Sectional area of cable	Cores
1.	35 mm^2	Single & Three
2.	120 mm^2	-do-
3.	240 mm^2	-do-
4.	500 mm^2	Single

6.2 The dimensions of the conductor, insulation, semi-conducting layer, PVC separation sheath and armouring shall be in accordance with Table-1.

6.3 The diameter of stranded compacted circular conductor shall not exceed the max. values and shall not be less than the min. values given in Table-1.

6.4 The D.C. resistance of the complete compacted conductor shall not exceed the values given in table-1.

6.5 The average thickness of the XLPE insulation, semi-conducting compound, separation sheath and oversheath shall not be less than the specified nominal value given in Table -1. The negative tolerance at any point shall not be more than 5% of the nominal value.

6.6 The tolerance on the nominal dimension of armour wire given in Table -1 shall not fall below the nominal value by more than 5%.

6.7 In case of stranded compacted circular conductor, the ratio of the diameters of two different wires in the same conductor shall not exceed 2.

TABLE-1

1.	Nominal Cross-Sectional area of Conductor (sq.mm)	35	120	240	500
2.	Minimum No. of Aluminium wires	6	15	30	53
3.	Minimum No. of copper wires	6	18	34	53
4.	Complete Conductor diameter (mm) - Min.	6.6	12.3	17.6	25.3
	- Max	7.5	13.5	19.2	27.6
5.	Complete Aluminium Conductor max. D.C. Resistance at 20°C (ohms/km)	0.868	0.253	0.125	0.0605
6.	Complete copper Conductor max. D.C. Resistance at 20°C (ohms/km)	0.524	0.153	0.0754	0.0366
7.	Nominal thickness of XLPE Insulation (mm)	4.5	4.5	4.5	4.5
8.	Nominal thickness of semi-conducting compound layer over Conductor (mm)	0.7	0.7	0.7	0.7
9.	Nominal thickness of semi-conducting compound over Insulation (mm)	0.7	0.7	0.7	0.7
10.	DC resistance of copper screen at 20°C (Ω/km)	1.15	1.15	0.727	0.524
11.	Nominal thickness of PVC oversheath (mm) - Single Core (Unarmoured)	1.6	1.8	2.0	2.3
	- Single Core (Armoured)	1.8	2.1'	2.3	2.6
	- Three Core	2.7	3.2	3.6	-
12.	Nominal thickness of PVC separation Sheath (mm) - Single Core (Armoured)	1.2	1.2	1.2	1.3
	- Three Core	1.4	1.7	1.9	-
13.	Dia. of aluminium armouring wire (mm) for single core cable	1.6	2.0	2.0	2.5
14.	Dia. of Galvanised armouring wire (mm) for three core cable	2.5	2.5	3.15	-
15.	Power frequency test voltage for 4 hours on 5 meter sample cable (kV rms)	35	35	35	35
16.	Power Frequency Test voltage for 5 minutes on each manufactured length of individual core on a reel (kV rms)	30.5	30.5	30.5	30.5
17.	Partial Discharge on each manufactured length of cable for routine tests (Max.)	10pC	10pC	10pC	10pC
18.	Partial Discharge on each manufactured length of cable for prototype tests (Max.)	5pC	5pC	5pC	5pC

7. INSULATION

7.1 Cross-linked Polyethylene (XLPE)

7.1.1 The cross-linked polyethylene (XLPE) insulation shall be suitable for use in wet and dry locations, and a continuous conductor operating temperature of 90°C throughout its life and for service under the conditions described in clause 3. The XLPE insulation shall meet the following requirements

7.1.2 Mechanical Properties

(i) Without Ageing

a)	Tensile strength, minimum	12.5 N/mm² (1.275 kg/mm²)
b)	Elongation at break, minimum	200%

(ii) After Ageing in Air oven Without Conductor

Air oven exposure at 135±3°C for 168 hours.

a)	Tensile strength, Variation of unaged value, maximum	±25%
b)	Elongation, Variation of unaged value, maximum	±25%

7.1.3 Water Absorbtion

When tested after immersion in water at 85 ± 2°C for 336 hours, the maximum increase of mass shall not exceed 1.0 mg/cm².

7.1.4 Hot Set Test

a)	Temperature	200±3°C
b)	Time under load	15 minutes
c)	Mechanical Stress	20 N/cm²
d)	Max. elongation under load	175%
e)	Max. permanent elongation after cooling	15%

7.1.5 Shrinkage Test

a)	Length of sample	200mm
b)	Temperature	130±3°C
c)	Duration	1 hr
d)	Max. shrinkage	4%

8 OVERSHEATH

8.1 Polyvinyl Chloride (PVC) Oversheaths

8.1.1 The PVC sheaths type ST_2 shall be made from sulphur free polyvinyl chloride compound suitable for a minimum installation temperature of -10 °C and shall meet the following requirements.

8.1.2 Mechanical Properties

(i) Without Ageing

a)	Tensile strength, minimum	12.5 N/mm² (1.275 kg/mm²)
b)	Elongation at break, minimum	150%

ii) After Ageing In An Air Oven Without Conductor

Air oven exposure at 100±2°C for 168 hrs

a)	Tensile strength, minimum	12.5 N/mm² (1.275 kg/mm²)
	Variation of unaged value, Maximum	±25%
b)	Elongation at break, minimum	150%
	Variation of unaged value, aximum	±25%

8.1.3 Loss of mass after ageing, Maximum 1.5mg/cm²

8.1.4 Pressure Test at 90°C ±2°C as per IEC 60811-3-1, Clause 8

8.1.5 Heat Shock test at 150 ± 3°C for 1 hour as per IEC 60811-3-1, Clause 9

8.1.6 Behaviour at -15°C±2°C as per IEC 60811-1-4, Clause 8
- Cold Bending Test
- Cold Elongation Test on dumb-bell
- Cold impact test

9 WIRE ARMOURING

9.1 The nominal dia of the aluminium/steel wire armour shall not be less than the value given in Table-1. A joint in any wire shall not be less than 1m from the nearest joint in any other armour wire.

9.2 The wire armour shall be made closed i.e. with minimum gap between adjacent wires.

9.3 The steel wire shall be hot dip galvanized only.

9.4 The weight of zinc coating shall be 195 gm/m². The coating shall not fl... and none of it may be removed by rubbing of the fingers.

9.5 The tensile strength of the steel wire shall be in range of 2812-4921 kg/cm² in gauge length of 250mm and minimum elongation shall be 10%.

9.6 The aluminium wire shall have the same characteristics as used in the aluminium conductor.

9.7 Armouring shall be laid up with a left or right hand lay but in opposite direction to the lay of cores. The length of lay shall not exceed 30 times, the diameter over the inner PVC (separator) sheath.

10 TESTS

10.1 The power cables shall be tested in accordance with the latest relevant IEC standards. The tests shall be made at an ambient temperature of -5°C to 40°C. The cable manufacturer shall submit the test reports with the bid, in case of non-submission, the bid be considered as non-responsive.

10.2 Routine Tests

The following routine tests shall be carried out on each manufactured length of cable supplied on a reel.

i) Measurement of electrical resistance of the conductor (Clause 16.2 of IEC 60502-2)
ii) Measurement of partial discharges (Clause 16.3 of IEC 60502-2)
iii) Power frequency voltage test

10.2.1 Partial Discharge Test

Each length of cable shall comply with the minimum partial discharge given in Table-1. The test voltage shall be raised to and held at $2U_o$ for 10 seconds then slowly reduced to $1.73U_o$ for measurement of partial discharge.

10.2.2 Power Frequency Voltage Test

Each length of cable on a reel shall withstand the power frequency test voltage of 30.5kV rms for 5 minutes between conductor & metallic screen. The frequency of alternating test voltage shall be in the range of 49 Hz to 61 Hz. The waveform shall be sinusoidal.

10.3 Sample Tests

The following sample tests shall be carried out on the randomly selected samples from the offered cable lengths. The No. of samples to be selected shall be 10% of the number of lengths offered for inspection with a min. of two samples:

i) Conductor examination (Clause 17.4 of IEC 60502)
ii) Check of dimensions & visual inspection
iii) Power frequency voltage test for 4 hours on atleast 5 meter in length (Clause 17.9 of IEC 60502-2)
iv) Hot set test for XLPE insulations (Clause 17.10 of IEC 60502-2)
v) Resistivity of semi-conducting screens before ageing (Clause 18.1.9 of IEC 60502)
vi) Hot Pressure test at high temperature on PVC oversheath (IEC 60811-3-1 clause 8)
vii) Behaviour of PVC oversheath at low temperature (IEC 60811-1-4 clause 8)
viii) Heat shock test on PVC oversheath (IEC 60811-3-1 clause 9)
ix) Hot set test for XLPE insulations
x) Flame spread test on single cable
xi) Shrinkage test for XLPE insulation

10.4 **Type Test**

10.4.1 These tests are of such a nature that after they have been made, they need not to be repeated, unless changes are made in the cable material or design or manufacturing process. However, in order to ensure/check the quality of the material, the purchaser reserves the right to repeat the type tests on randomly selected samples of power cable after every five years at the cost & arrangement of the cable manufacturer.

10.4.2 **Electrical Tests:**

Following electrical type tests shall be carried out on a sample of 10meter to 15meter in length in accordance with clause 18 of IEC 60502. The sequence of the tests shall be as follows:

i) Bending test followed by a partial discharge test (Clause 18.1.3 & Clause 18.1.4 of IEC 60502)
ii) Tangent δ measurement (Clause 18.1.2 & Clause 18.1.5 of IEC 60502)
iii) Heating cycle test followed by a partial discharge test (Clause 18.1.6 of IEC 60502)
iv) Impulse voltage withstand test followed by a power frequency voltage test (Clause 15.3 & Clause 18.1.7 of IEC 60502)
v) Power frequency voltage test for 4 hours (Clause 18.1.8 of IEC 60502)
vi) Resistivity of semi-conducting screen before and after ageing (Clause 18.1.9 of IEC 60502)

10.4.2.1 Electrical type tests successfully performed on a higher size of c... covered by this standard with a specific conductor cross-sectional area an... rated voltage, the prototype approval shall be accepted as valid for cables of same type with other cross-sectional area or rated voltage provided following conditions are satisfied:

i) Same material i.e. insulation & semi-conducting screen & same manufacturing process is used.
ii) Same rated voltage as that of tested/approved cable.
iii) The conductor cross-sectional area is not larger than that of the tested/approved cable.
iv) The properties of the conductor are same as that used in the tested/approved cable.

10.4.2.2 The prototype testing performed on the armoured cable shall also be valid/applicable on the same rating/size/construction of unarmoured tested/approved cable.

10.4.3 Non-Electrical Tests:

Following non-electrical type tests shall be carried out in accordance with clause 19 of IEC 60502.

i) Check of Dimensions including measurement of thickness of insulation & sheaths
ii) Resistivity of extruded semi-conducting screens applied over the conductor and insulation (Clause 18.1.9 of IEC 60502)
iii) Test for determining the mechanical properties of insulation & oversheath before and after ageing
iv) Additional Ageing Test on pieces of completed cable (Clause 19.5 of IEC 60502)
v) Hot Pressure test at high temperature on PVC oversheath (IEC 60811-3-1 clause 8)
vi) Behaviour of PVC oversheath at low temperature (IEC 60811-1-4 clause 8)
vii) Loss of mass test on PVC oversheath of type ST_2 (IEC 60811-3-2 clause 8.2)
viii) Heat shock test on PVC oversheath (IEC 60811-3-1 clause 9)
ix) Hot set test for XLPE insulations
x) Flame spread test on single cable
xi) Water absorption test on XLPE insulation (IEC 60811-1-3)
xii) Shrinkage test for XLPE insulation

11 MARKING AND PACKING

11.1 Name of manufacturer & purchaser with order No. & date and year of manufacturing shall be superscribed after every meter length of all the cables on the outer surface of PVC oversheath in the form of protruding mould.

11.2 The cable shall be placed on non-returnable wood reels. The complete periphery of each reel shall be protected with heavy wood lagging bound with galvanized steel straps. The reels and lagging shall be sufficiently strong to withstand the rigors of marine shipment. The lagging and reels shall be pentachlorophenol treated for protection against vermin. The cable shall be supplied in the manufacture's standard lengths with a minimum as given below:

Sr. No.	Cross-Sectional area of cable	Minimum Length (meters)	
		Single Core	Three Core
1.	35 mm^2	600	300
2.	120 mm^2	500	250
3.	240 mm^2	400	200
4.	500 mm^2	300	-

11.3 Each reel shall be marked with the following particulars together with the direction of unrolling and the position of the cable end:

i) Conductor/metal designation viz Aluminium/Copper
ii) Conductor nominal sectional area
iii) Number of cores
iv) Length
v) Weight (net gross)
vi) Manufacturer's name
vii) Year of manufacture

12 TECHNICAL DATA

12.1 The following detailed technical data of power cables offered shall be furnished with the bid. Non-submission of the said technical data may render the bid as non-responsive.

SCHEDULE OF TECHNICAL DATA OF 15KV XLPE POWER CABLE (NTDC SPECIFICATION P-29:2010)

GENERAL

1. Power Cable Manufacturer's name _____
2. Address of Correspondence _____
3. Fax No./ Email _____
4. Type of cable _____
5. Rated voltage _____
6. Type Test Certificate (Attach Copy)
   a) Issuing Authority _____
   b) No. and date _____

CONDUCTOR

7. Material of conductor _____
8. Crosslinked Polyethylene cable conductor operating Temperature for:
   a) Continuous Operations _____
   b) Short – circuit _____
9. Cross-Sectional Area of conductor _____
10. Dia of conductor of each core _____
11. No. of wires in a conductor _____
12. Max. Complete Conductor D.C. resistance at 20° C _____
13. Current rating
    a) In air _____
    b) In ducts _____
    c) Laid direct _____
14. Short-current rating 1 second _____

CONDUCTOR SHEILDING

(Attach catalogue(s)/broucher(s) of semi conducting compound manufacturer(s) with the bid)

15. Name of Semi Conducting Compound Manufacturer(s) with Complete addresses(es) _____
16. Material of semi-conducting layer over the conductor _____
17. Thickness of semi-conducting layer over the conductor _____
18. Process of making semi-conducting layer over the conductor _____

CROSS-LINKED POLYETHYLENE INSULATION (XLPE)

(Attach catalogue(s)/broucher(s) of XLPE manufacturer(s) with the bid)

19. Name of XLPE insulation Manufacturer(s) with Complete address(es) _____
20. Material of insulation _____
21. Thickness of insulation _____
22. Dia over insulation _____
23. Dia under insulation _____
24. Tensile strength _____
25. Elongation at rupture, min. percent _____
26. Tensile strength after exposure to air oven for 168 hours at 135 ± 3°C _____
27. Elongation after exposure to air oven for 168 hours at 135 ± 3°C _____
28. Water absorption after remaining immersed in water for 336 hours at 85 ± 2°C. _____
29. Elongation after hot set test Max. permanent elongation after Cooling _____
30. Power frequency Voltage withstand for 5 minutes _____ kV
31. Partial Discharge _____
32. Insulation resistance _____

INSULATION SHIELDING

(Attach catalogue(s)/broucher(s) of Semi-conducting compound manufacturer(s) with the bid)

33. Name of Semi-Conducting compound manufacturer(s) with complete address(es) _____
34. Material of semi-conducting layer over the insulation _____
35. Thickness of semi-conducting layer over the insulation _____
36. Resistivity of semi-conductor screen Before ageing
    - Conductor screen _____
    - Insulation screen _____
37. Resistivity of semi-conductor screen after ageing
    - Conductor screen _____
    - Insulation screen _____

METALLIC SCREEN
(Attach catalogue(s)/broucher(s) of metallic screen manufacturer(s) with the bid)

38. Name of Metallic Screen
Manufacturer(s) with complete address(es) _____
39. Max. DC resistance of copper screen _____
40. Thickness of Copper tape _____
41. Width of Copper tape _____
42. No. & size of copper wires used _____

FILLERS AND BINDING

43. Material of fillers _____
44. Material of binding tape _____
45. Thickness of binding tape _____
46. Overlap of binding tape
(percent of tape width) _____
47. Direction of lay of the three cores _____
48. Length of lay (multiple of individual
core dia) _____
49. Minimum bending radius (mm) _____

WIRE ARMOUR

50. Dia of Aluminium/steel wire _____
51. Tensile strength of aluminium/steel wire
armour _____
52. Process of galvanizing the wire _____
53. Weight of zinc coating on wire _____

P.V.C OVERSHEATH
(Attach catalogue(s)/broucher(s) of PVC manufacturer(s) with the bid)

54. Name(s) of PVC Manufacturer(s)
with complete address(es) _____
55. Thickness of inner PVC oversheath _____
56. Type of PVC _____
57. Thickness of PVC oversheath _____
58. Minimum installation temperature
of PVC _____
59. Tensile strength of PVC oversheath _____
60. Elongation at rupture of PVC
oversheath _____

61. Results before & after exposure to Air Oven:
    a) Tensile Strength _____
    b) Elongation _____
    c) Tensile strength, minimum percent of unaged value _____
    d) Elongation, minimum percent of unaged value _____
62. Loss of mass _____

PACKING AND SHIPPING

63. Nominal length of cable on reel _____
64. Net weight of cable on reel/ total weight of reel _____
65. Dimensions of reel:
    a) Drum diameter _____
    b) Flange diameter _____
    c) Flange thickness _____
    d) Drum length between flanges _____

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