SECTION 2-07

INSTRUMENTATION & COMMUNICATION CABLES

1.0.0 General

The Bidder shall supply, store at site, lay, erect, and terminate all types of cables required for the complete plant (BESS Yard, Transformer Yards, 132 kV Switchyards, MCR) including but not limited to control, instrumentation, and communication cables.

It is not the intent of this specification to describe every detail of design and construction. However, all cables shall meet high standards of engineering design and workmanship in every aspect and shall be capable of continuous and reliable operation to the satisfaction of the Purchaser.

All cables including special cables, internal wiring, and electrical field construction materials shall conform to this specification. Cable laying and termination shall follow Purchaser-approved detailed engineering drawings and documents, as well as the latest editions of the relevant standards and guidelines. The Bidder shall furnish all materials and services required to complete the work defined within the scope of this specification.

Except where specifically stated otherwise, all materials, cables, and construction practices shall conform to the Indian Electricity Act and Rules, and the applicable Indian and international standards, with all latest revisions and amendments.

Cables shall be designed and manufactured to withstand handling, transit, storage, installation, and operation under all climatic and operating conditions to which they may be exposed. The outer sheath of the cables shall possess rodent- and termite-resistant properties.

Cables shall be suitable for installation in conduits, ducts, trenches, trays, or direct burial in both dry and wet locations.

Cables shall operate satisfactorily under the supply voltage and frequency variations specified in the contract. The current ratings and derating factors of the cables shall be not inferior to those specified in IS: 3961.

2.0.0 CODES AND STANDARDS

2.1.0 The design, manufacture, inspection, testing, covered under this specification shall conform to the latest editions of codes and standards mentioned below and all other and their equivalents.

2.2.0 The design, material, construction features, manufacture, inspection and testing of communication cables shall comply with all currently applicable statutes, regulations and safety codes in the locality where the cables will be installed. The Cable shall also conform to the latest applicable standards.

2.3.0 Other recognized equivalent international standards will be utilized as required to serve design, fabrication, and construction guidelines when not in conflict with the above listed standards. Such acts of the Bidder shall be brought to the Owner / consultants notice before proceeding with the same.

2.4.0 The equipment, systems and services furnished as per this specification shall conform to the codes and standards mentioned in this Section below. However, in the event of any conflict between the requirements of two standards or between the requirements of any standard and this specification, the more stringent requirements shall apply unless confirmed otherwise by the Purchaser in writing. The decision of the Purchaser shall be final and binding in all such cases.

2.5.0 **Cables standard**

General Cable Construction	IS 8130	Conductors for insulated electric cables (India equivalent of IEC 60228).
	IEC 60228	Conductor classes, resistance, construction.
	IS 1554 (Part 1)	PVC insulated cables up to 1100 V.
	IS 7098 (Part 1/2/3)	XLPE insulated cables.
	IS 3975	Steel wires, strips, tapes for armouring.
	IS 10810 Series	Complete suite of mechanical, electrical & environmental test methods.
	IS 5831	PVC insulation & sheath requirements.
Fire, Smoke & Halogen Tests	IEC 60332-1 / 60332-3	Flame-retardance (single & bundled cable).
	IEC 61034 (1 & 2)	Smoke density test.
	IEC 60754 (1 & 2)	Halogen acid gas emission test.
	IS 14255	LSZH cable performance test.
	IS 10810-53 / 58	Flammability & temperature index tests.
Instrumentation & Control Cables	IEC 60502-1	Construction & insulation requirements.
	IEC 60092-376	Screened instrumentation pairs.

	IS 10810 (Part 20, 21)	Armouring adhesion, tensile, tear tests.
	IS 10810 (Part 32, 34)	Conductor resistance & insulation resistance tests.
	IS 10810 (Part 43)	High-voltage withstand (HV) test.
RS-485 Cables	TIA/EIA-485-A	Electrical characteristics of balanced digital circuits (RS-485).
	IEC 61156 Series	Twisted-pair construction & performance.
	IEC 61000-6-2	EMC immunity test (industrial).
	IEC 61000-6-4	EMC emission compliance.
	IS 10810-52	Capacitance & characteristic impedance testing.
CAT-6 / CAT-6A Ethernet Cables	ANSI/TIA-568.2-D	Category-6 electrical performance.
	ISO/IEC 11801-1	Structured cabling systems.
	IEC 61156-5	Electrical performance of balanced twisted pair.
	ISO/IEC 14763	Installation/testing of structured cabling.
	Channel tests	NEXT, FEXT, RL, IL, PS-NEXT, propagation delay, delay skew.
Fiber-Optic Cables	ITU-T G.652.D	Single-mode fiber specification.
	ITU-T G.651.1	Multimode fiber specification.
	IEC 60793-2-50	SM fiber characteristics & attenuation.
	IEC 60793-2-10	MM fiber characteristics.
	IEC 60794 Series	FO cable construction & mechanical/environmental tests.
	IEC 60794-1-21	Tensile, crush, impact, bending, torsion tests.
	IEC 60794-1-22	Temperature cycling, water penetration.

	OTDR Test	End-to-end attenuation/ reflectance test.
	IEC 61300-3-4	Insertion & return loss testing for connectors.
CAN Bus Cables	ISO 11898-2	Physical layer requirements for high-speed CAN.
	IEC 60068 Series	Vibration, humidity & thermal cycling tests.
	IEC 61000-6-2	EMC immunity for industrial systems.
	IS 10810	High-voltage, insulation resistance, tensile & ageing tests.
	Impedance Test	TDR test for 120 Ω characteristic impedance.
	Signal Integrity Test	Propagation delay, skew, attenuation.
Environmental & Chemical Compliance	RoHS II (EU 2011/65/EU)	Restriction of hazardous substances.
	REACH (EC 1907/2006)	Chemical safety compliance.

Where

Abbreviation	Full Form
IS	Indian Standards (Bureau of Indian Standards)
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
TIA	Telecommunications Industry Association
EIA	Electronic Industries Alliance
RoHS	Restriction of Hazardous Substances
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals

3.0.0 DESIGN BASIS FOR COMMUNICATION CABLES

3.1.0 All communication cables covered under this specification shall comply with the latest editions of the applicable standards and their amendments, read in conjunction with this specification.

3.2.0 All cables shall be new, unused, and of tested quality, conforming to the applicable international standards.

3.3.0 All cable materials shall be transportable and suitable for installation at site without damage. They shall provide continuous and reliable operation over long periods under the worst-case site conditions specified.

3.4.0 All cables shall be designed to withstand the full range of magnetic, electrical, mechanical, and thermal stresses encountered during normal and abnormal operating conditions.

3.5.0 Cables shall be designed and manufactured to prevent damage during handling, transit, storage, installation, and operation under all climatic and operating conditions. The outer sheath shall be resistant to rodents and termites.

3.6.0 Cables shall be suitable for installation in conduits, ducts, trenches, trays, or for direct burial in the ground, including wet locations.

3.7.0 Fibre-optic cables shall be suitable for installation on cable trays, duct banks, trenches, racks, or direct burial as required. Spliced or repaired fibre-optic cables are not acceptable.

3.8.0 All cables shall be provided with clear and durable markings including:

- manufacturer's name,
- insulation material,
- conductor size,
- number of pairs/cores,
- voltage rating,
- cable type,
- progressive metre-marking at 1-metre intervals, and
- "FRLS" marking where applicable.

3.9.0 Instrumentation cables shall operate without breakdown under surge conditions present in the control system. Voltage class and insulation levels shall be compatible with the signals they carry.

3.10.0 All materials shall be anti-rodent, anti-termite, moisture-resistant, and UV-resistant (as applicable for outdoor or armoured cables).

3.11.0 All instrumentation data cables (e.g., RS-485, CAN Bus) shall be of FRLS type.

3.12.0 CAT-6 cables shall be:

Unarmoured indoor type: PVC / FR-PVC jacket
Armoured outdoor type: FRLS / PE jacket

3.13.0 Fibre-optic cables for outdoor applications shall be dual-jacket armoured type with UV-resistant PE outer sheath.

3.14.0 All instrumentation cables shall be of Flame Retardant Low Smoke (FRLS) type.

3.15.0 Fillers used in multi-conductor cables shall be flame-retardant.

3.16.0 All cables shall be suitable for continuous operation at 85°C, except high-temperature Teflon-insulated cables, which shall be suitable for continuous operation at 205°C.

3.17.0 A minimum of 10% spare pairs or 1 spare pair (whichever is greater) shall be provided for all paired cables having more than four (4) pairs, except pre-fabricated cables which shall follow the manufacturer's standard design. For multi-core cables having more than three (3) cores, 10% spare cores or 1 spare core (whichever is greater) shall be provided.

3.18.0 Adequate separation distances shall be maintained between instrumentation cables and HT/LT power cables to minimise electrical interference.

3.19.0 The Bidder shall supply all required cable-laying and erection hardware, such as cable trays/sub-trays, supports, flexible conduits, cable glands, lugs, pull boxes, etc., including hardware for the main trunk routes.

3.20.0 Instrumentation cables operate reliably without breakdown under surge conditions present in the control system. Voltage class and insulation levels shall match the characteristics of the signals transmitted.

3.21.0 Cable sheath colors are standardized:

Cable Type	**Outer Jacket Colour**
RS-485	Blue
CAN Bus	Green
CAT-6 (Indoor)	Grey
CAT-6 (Armoured	Black
Fibre Optic	Orange
Instrument Cable	Grey
Fire and Gas	Red

4.1.0 TECHNICAL SPECIFICATION

4.2.0 RS485 COMMUNICATION CABLE

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
A.	**CABLE**	
1.	Armouring	Armoured
2.	Voltage grade (Volts)	300 V
3.	Temperature rating	70 Deg.C
4.	No of Pairs	2 Pair
B.	**CONDUCTOR**	
5.	Conductor size (Sq.mm)	0.5
6.	Conductor material	Annealed tinned copper
7.	Conductor type	Multi strand
8.	Dia of each strand (approx.) (before stranding) (mm)	0.307
9.	Number of strands	7
10.	Conductor reference standard	IEC 60228, Class 5
C.	**INSULATION**	
11.	Insulation material	PE / Foam-PE
12.	Insulation reference standard	IEC 60811 (Material Tests), IEC 60332-1-2 (Flame Test)
13.	Insulation thickness (Nom.) (mm)	0.3
14.	Insulation thickness (Min.) (mm)	t − 10%
15.	Insulation color (Pair)	As per IEC
16.	Number of twists (Max.)	25–40 Twists / mtr.
17.	Lay	≤ 50 mm
D.	**INDIVIDUAL SHIELDING**	
18.	Individual drain wire material	Annealed tinned copper
19.	Individual drain wire size (Sq.mm)	0.5

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
20.	Individual drain wire type	Multi
21.	Individual drain wire No of strand	7
22.	Individual drain wire dia. of strand (approx.) (before stranding)	0.3
23.	Individual shielding tape type	Al Mylar tape
24.	Individual shielding tape thickness (mm)	0.06
25.	Individual shielding overlap (%)	25
E.	**OVERALL SHIELDING**	
26.	Overall drain wire material	Annealed tinned copper
27.	Overall drain wire size (Sq.mm)	0.5
28.	Overall drain wire type	Multi
29.	Overall drain wire no of strand	7
30.	Overall drain wire diameter of strand (approx.) (before stranding) (mm)	0.3
31.	Overall shielding tape type	Al Mylar tape
32.	Overall shielding tape thickness (mm)	0.06
33.	Overall shielding overlap (%)	25
F.	**INNER SHEATH**	
34.	Non-metallic rip cord under the Inner sheath	Shall be provided
35.	Inner sheath material	FRLS PVC ST2
36.	Inner sheath reference standard	IEC 60332-1-2
37.	Inner sheath color	Black
38.	Inner sheath thickness (Minimum)	0.3 mm (IEC 60092-359)
39.	Diameter over inner sheath (mm)	Bidder to specify
G.	**ARMORING**	
40.	Armor material & size	Galvanised steel round wire 0.9
41.	Diameter over armor (mm)	Bidder to specify

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
H.	**OUTER SHEATH**	
42.	Outer sheath material	FRLS-HR PVC (Anti-rodent, anti-termite, UV)
43.	Outer sheath material reference standard	IEC 60811, IEC 61034-2
44.	Outer sheath color	Blue
45.	Outer sheath thickness (Min)	1.4–1.6 mm
46.	Diameter over outer sheath (mm)	Bidder to specify
I.	**ELECTRICAL PARAMETER**	
47.	Conductor resistance Max.)	73.4 Ω/km (loop) @ 20°C
48.	Insulation resistance (Min)	≥ 100 MΩ·km
49.	HV Test (C–C)	2KV for 1 Minute
50.	HV Test (C–Shield)	0.5KV for 1 Minute
51.	Mutual Capacitance	≤ 40 pF/m
52.	Characteristic impedance	120 Ω ±10% @ 100 kHz (±15% from 3 kHz–1 MHz)
53.	Attenuation @ 100 kHz	≤ 3 dB/100m
54.	Attenuation @ 1 MHz	≤ 10 dB/100m
55.	Cross talk attenuation at 0.8KHz	≥ 65 dB/km
56.	Pair coupling capacitance	≤ 60 pF/m
57.	Inductance	0.6 – 0.8 mH/km
58.	L/R Ratio (Max.)	≤ 10 µH/Ω
59.	Drain wire resistance	≤ 39 Ω/km @ 20°C
J.	**TEST PARAMETERS**	
60.	Oxygen index as per ASTM D 2863-77 at 20 Deg C % (Min.)	29
61.	Temperature index @ 21% of O2 as per ASTM D	250
62.	Flammability as per IEC-60332 Part-I (Min.)	50

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
63.	HCL gas emission as per IEC-754-1 % (Max.)	20
64.	Smoke density rating as per ASTM D 2843-77(Less than)	60
65.	Rodent & termite proof	Yes
K.	**ADDITIONAL DETAILS**	
66.	Marking of length	Sequential marking for every one meter
67.	Non-returnable cable drums (Material suitable for seaworthy transportation)	Required
L.	**CABLE PRINTING TEXT**	
68.	Printing text	Number of pairs, cable size, FRLS, voltage grade, cable type, make, year

4.3.0 SINGLE MODE FIBRE OPTIC CABLE

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
A.	**Fiber & Core**	
1.	Fiber	The optical fibre core shall be of ultra-pure fused silica glass coated with UV-cured acrylate suitable to withstand temperature of about 80 Deg.C continuously
2.	Mode	Single mode Fibre Cable
3.	Core diameter	9 ± 1 microns
4.	Cladding diameter	125 ± 1 micron
5.	Cladding non-circularity	1 % max.
6.	Core /cladding concentricity error	0.5 microns max.
7.	Attenuation@ 1310 nm	0.35 dB/Km max
8.	Attenuation@ 1550 nm	0.22 dB/Km max
9.	Number of Fibers per core / tube	6 (minimum)
10.	Fibre colouring	Shall conform to EIA/TIA-598
11.	Fiber proof test	As per IEC/EIA & other international standard.

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
12.	Coating diameter test	As per IEC/EIA & other international standard.
13.	Strength member	Aramid Yarn to reinforce the integrity of data transmission
14.	Buffer tube filling	Thixotropic jelly or better material
15.	Core wrapping /Moisture barrier	Water swellable tape / Suitable water blocking gel
16.	Loose tube	Polyamide / PBTP or other acceptable thermoplastic material
B.	**Cable Construction**	
17.	Design	Loose Tube design
18.	Type	Dual jacket armoured with polyethylene sheathing (for outdoor applications)
19.	Buffer Tubes	Shall be stranded around the central member utilizing reverse oscillating lay (ROL)
20.	Interstices / cable filling	Thixotropic jelly or better material
21.	Blank fillers	Shall be used as necessary to maintain circular cable structure. Fillers shall be flame retardant and moisture resistant.
22.	Inner Sheath	Flame retardant & UV resistant Polyethylene
23.	Outer Jacket	High density Polyethylene (HDPE) minimum 1.5 mm thick, Flame retardant & UV resistant
24.	Outer Color	Orange
25.	Armour	Co-polymer coated steel tape, corrugated and wrapped around the inner jacket to provide additional compression strength and termite & rodent protection
26.	Ripcord	Two highly visible ripcords shall be placed under the jacket / armour for easy outer jacket / sheath removal.
27.	Central Strength member	Shall be provided for outdoor/indoor application so as to prevent any physical damage. Consists of a dielectric fiber glass reinforced plastic (GRP) and buckle resistant material to provide both tensile and anti-buckling strength to the cable
C.	**Cable Specifications**	
28.	Details marked at every meter on outer sheath.	Manufacturer's Name, Month and Year of Manufacturer, Coded description of the cable based on telcodia's (bellcore) SR-2014 suggested optical cable code (SOCC), Sheath

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
		identification Number, Sequential Length marking in meter, A telephone Handset symbol to distinguish communication from power cable as per NESC section-35G.
29.	Life expectancy	Fiber optic cable shall provide a long-life expectancy of minimum 25 years under continuous operation without degradation to optical or mechanical performance.
30.	Stripping ability	All layers easily removed with Commercially available tools
31.	Storage temperature	- 20 °C to 60 °C
32.	Operating temperature	- 20 °C to 70 °C
33.	Data speed performance	1 Gbps minimum
34.	Drum	The cables shall be provided in non-returnable drums. Drum packing material shall be suitable for seaworthy transportation provided with lagging of adequate strength, constructed to protect the cable against any damage and displacement during transit, storage and subsequent handling and stringing operations in the field.
D.	**Installation / Mechanical characteristics:**	
35.	Minimum bending radius (IEC 60794-1-2-E11A)	20 X D (D=core Diameter) - During Installation, Short Term, loaded 15 X D (D=core Diameter) – Installed, Long Term, No load
36.	Maximum Tensile Load/Strength (IEC 60794-1-2-E1)	During Installation: 2000 N at 0.25 % strain Installed: 1000N
37.	Method of laying	Directly laid in cable trays / duct bank / clamped with available structure
38.	Pulling	Ordinary cable grips
E.	**Test Specification (EIA/TIA – STD455 or Equivalent):**	
39.	Impact resistance	2000 Impacts minimum
40.	Crush resistance	4000 N/10cm minimum
41.	Compressive strength	3000 N minimum
42.	Moisture/water resistance	Water blocking layer, cable shall withstand water penetration when tested with a one-meter static head or equivalent continuous pressure

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
		applied at one end of a one-meter length of filled cable for one hour. No water shall leak through the open cable end.
F.	**Tests**	Following minimum test as per any approved standard shall be carried out on the cables: a. Attenuation and Dispersion characteristics tests b. Proof Tests c. Macro-Bend resistance Test d. Mechanical Test e. Low and High Temperature cable Bend Test f. Impact resistance Test g. Compressive strength Test h. Tensile strength Test i. Cable Twist test j. Cable cyclic flexing test k. Environmental characteristics Test l. Temperature cycling test m. Colour permanence Test n. Cable Aging test o. Water penetration test p. Lightning Test q. Kink Test r. Crush Test
G.	**Standards**	Optical cable shall conform to a. IEC 60794/IEC 60793 & EIA/TIA 455. b. Low smoke (IEC 1034 –light transmittance of 80%) c. Halogen free (IEC 754: 1&2 - maximum acid gas generation shall be 2% by weight and PH >4.3) d. Fire & flame retarded (IEC 331, IEEE 383) e. Rodent resistant f. Crush Resistant (EIA -455-41) g. Impact Resistant (EIA -455-25) Bidder shall submit Type test report for review, conform to IEC 60794, IEC 60793, IEEE 383, IEC 754: 1 & 2, IEC331, IEEE 1034 and EIA/TIA standard. Colour codes shall be as per EIA/TIA 598-A.

4.4.0 CAT-6 COMMUNICATION CABLE (Unarmoured)

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
A.	**Conductor**	
1.	No of Pairs	4 Pairs
2.	Material	Bare copper
3.	Size	23 AWG
B.	**Insulation**	
1.	Material	FR-PE
C.	**Outer shield**	
1.	Outer shield	Unshielded
D.	**Binder Tape**	
1.	Material	Polyester
2.	Coverage	NA
E.	**Outer Jacket**	
1.	Material	PVC (CMR)
2.	Outer jacket nominal wall thickness	0.6 mm
3.	Outer jacket ripcord	Yes
F.	**Mechanical Characteristics (Overall)**	
1.	Installation temperature range	-25 to +75 Deg.C
2.	Operating temperature range	-40 to +75 Deg.C
3.	Tensile strength	
4.	Max. recommended pulling tension	200.169 N
5.	Min. bend radius/minor axis	63.500 mm
G.	NEC/(UL) specification	CMR
H.	**Electrical Characteristics**	
1.	Nominal mutual capacitance	50.8555 pF/m

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
2.	Nominal velocity of propagation (VP)	67%
3.	Max. delay	538 ns/100m
4.	Max delay skew	38 ns/100m
5.	Max. conductor DC resistance @ 20deg. C	8.2 Ohm/100m
6.	Impedance	100 Ω ± 15 Ω
7.	Attenuation min. At 100m	18.9 dB at 100 Mhz
I.	Applicable standards	EU Directive 2011/65/EU(RoHSII)
J.	**Test**	
1.	Flame test	UL 1666 Vertical Riser, CSA FT4, IEEE 1202
K.	**Pair Colour Code**	
1.	1st Pair	White / Blue Strip & Blue
2.	2nd Pair	White / Orange Strip & Orange
3.	3rd Pair	White / Green Strip & Green
4.	4th Pair	White / Brown Strip & Brown

4.5.0 CAT-6 COMMUNICATION CABLE (Armoured)

A.	**Conductor**	
1.	No. of Pairs	4 Pairs
2.	Material	Bare copper
3.	Size	23 AWG
B.	**Insulation**	
1.	Material	FR-PE
C.	**Outer Shield**	
1.	Shield Type	Unshielded (U/UTP) or Shielded as required (F/UTP optional)
D.	**Binder Tape**	

1.	Material	Polyester
2.	Coverage	NA
E.	**Inner Jacket**	
1.	Material	FRLS PVC, 0.6 mm
F.	**Armouring**	
1.	Type of Armouring	Galvanized Steel Wire Armour (SWA)
2.	Wire Diameter	As per manufacturer standard
3.	Armouring Coverage	> 90% mechanical coverage
G.	**Outer Jacket**	
1.	Material	PE / FR-PE
2.	Nominal Outer Jacket Wall Thickness	≥ 1.8 mm
3.	Ripcord	Yes
H.	**Mechanical Characteristics (Overall)**	
1.	Installation temperature range	–25°C to +75°C
2.	Operating temperature range	–40°C to +75°C
3.	Tensile strength	As per manufacturer
4.	Max. recommended pulling tension	200.169 N
5.	Min. bend radius	63.500 mm
I.	**NEC / UL Specification**	CMR / CMX / Outdoor Rated
J.	**Electrical Characteristics**	
1.	Nominal mutual capacitance	50.8555 pF/m
2.	Nominal velocity of propagation (VP)	67%
3.	Max. delay	538 ns/100m
4.	Max. delay skew	38 ns/100m
5.	Max. conductor DC resistance @ 20°C	8.2 Ω/100m
6.	Impedance	100 Ω ± 15 Ω

7.	Attenuation @ 100m	18.9 dB at 100 MHz
K.	**Applicable Standards**	EU Directive 2011/65/EU (RoHS II), TIA/EIA-568-C.2, IEC 61156-5
L.	**Tests**	
1.	Flame test	UL 1666 Vertical Riser, CSA FT4, IEEE 1202
2.	Armouring test	Bend test / crush resistance per IEC 60794
M.	**Pair Colour Code**	
1.	1st Pair	White / Blue Stripe & Blue
2.	2nd Pair	White / Orange Stripe & Orange
3.	3rd Pair	White / Green Stripe & Green
4.	4th Pair	White / Brown Stripe & Brown

4.6.0 CAN BUS CABLE

4.5.1 This specification covers the design, manufacture, testing, supply, and delivery of high-speed CAN bus cable for Battery Energy Storage System (BESS) applications to interconnect Battery Management System (BMS) and Power Conversion System (PCS) controllers. The cable shall be suitable for industrial substation/BESS rooms with high EMI, elevated temperatures, and stringent fire-safety requirements. The cable shall support CAN 2.0B (and optionally CAN-FD, if specified) at baud rates up to 500 kbit/s (default) and 1 Mbit/s (optional), with primary runs installed inside cabinets and on cable trays.

4.5.2 CAN Cable, 1×2 TP, 22–24 AWG, 120 Ω, Foil+Braid Shield, FR-LSZH, ISO 11898-2 compliant.

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
A.	**Application & Description**	
1.	Application	High-speed CAN bus cable for Battery Energy Storage System (BESS)
2.	Use	Interconnection of BMS and PCS controllers in high-EMI industrial BESS rooms
3.	Supported Standards	CAN 2.0B (500 kbit/s default), optional CAN-FD up to 1 Mbit/s
4.	Installation Zones	Inside control cabinets, cable trays in BESS
B.	**Cable Type**	
1.	Construction Type	1×2 Twisted Pair, Overall Shielded (F/UTP or SF/UTP)

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
2.	Differential Pair	CAN_H and CAN_L
3.	Compliance	ISO 11898-2 physical-layer requirements
C.	**Conductor**	
1.	Material	Stranded tinned copper
2.	Size	22–24 AWG
D.	**Insulation**	
1.	Material	PE / XLPE (low-capacitance preferred)
2.	Twist Rate	≥ 25–40 twists/m
E.	**Shielding**	
1.	Shield Type	100% Aluminum Foil + Braided Copper Shield
2.	Braid Coverage	≥ 80%
3.	Drain Wire	Tinned copper, 22 AWG
F.	**Jacket**	
1.	Material	FR LSZH (Low Smoke Zero Halogen)
2.	Color	Green
3.	UV Resistance	Required
G.	**Temperature Ratings**	
1.	Operating Temperature	–20 °C to +85 °C (min.)
2.	Preferred Continuous Rating	Up to +105 °C
3.	Bend Radius (Static)	≥ 10 × cable OD
4.	Bend Radius (Dynamic)	≥ 15 × cable OD
H.	**Electrical Parameters**	
1.	Characteristic Impedance (Z0)	120 Ω ±10% (100 kHz–1 MHz)
2.	Conductor DC Resistance	≤ 70 Ω/km
3.	Loop Resistance	≤ 110 Ω/km

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
4.	Capacitance (Core-to-Core)	≤ 50 pF/m
5.	Propagation Delay	≤ 5 ns/m
6.	Insulation Resistance	≥ 5000 MΩ·km @ 20 °C
7.	Dielectric Withstand	1.5 kV AC/1 min (pair to shield)
I.	**Environmental, Fire & Mechanical**	
1.	Flammability	UL 94 V-0 preferred; LSZH mandatory
2.	Vibration	IEC 60068-2-6 compliant
3.	Humidity	95% RH, non-condensing
4.	Chemical Resistance	Jacket resistant to Li-ion electrolyte vapors and cleaning agents
J.	**Routine Factory Tests**	
1.	Conductor Continuity	Required
2.	DC Resistance	Required
3.	Insulation Resistance	Required
4.	Pair Capacitance	Required
5.	Impedance Test (TDR)	100 kHz–1 MHz
6.	High-Potential Test	1.5 kV AC for 1 minute
K.	**Type Tests**	
1.	Propagation Delay Profile	Required
2.	Shield Effectiveness	Verification of foil + braid coverage
3.	Environmental Testing	IEC 60068 (Temp/Humidity/Vibration)
4.	Flammability & LSZH Smoke Test	As per jacket compound
L.	**Applicable Standards**	
1.	ISO 11898-2	High-speed CAN physical layer
2.	IEC 60068 Series	Environmental tests
3.	IEC/EN 61000-6-2 & 6-4	EMC immunity/emissions guidance

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
4.	UL 94	Flammability
5.	RoHS / REACH	Compliance required

4.7.0 PAIR CABLES (INDIVIDUAL AND OVER ALL SCREENING)

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
1.	Application	For Analog Signals)
2.	Voltage Grade & Type	650V grade, single and multiple pair, individual pair instrumentation cable.
3.	Conductor type and Size	Nominal 0.5 sq.mm. area concentric lay annealed tinned high conductivity 7 x 0.307 mm. Dia copper conductor as per IS: 8130.
4.	Insulation type and size	Extruded HR PVC type – C to IS: 5831 Colour coded. Nominal Insulation thickness shall be 0.3 mm.
5.	Lay	Twisted pair with 50mm max lay
6.	Screening and Shielding	Individual and over all screening Through aluminium mylar tape Min 0.055 mm with min 25% overlap.
7.	Drain Wire	7 x 0.3 mm dia stranded tin coated copper drain wire laid under the contact with aluminium side of the tape.
8.	Inner Sheath	FRLS PVC type ST1 confirming to IS: 5831 Thickness shall be min. 0.3mm.
9.	Outer Sheath	FRLS PVC type ST2 confirming to IS: 5831 Thickness shall be min. 1.8mm.
10.	Armouring	Galvanised steel wire/strip to IS: 3975 (BS:5608 Part-II)
11.	Marking	Marking of length and pair no of the cable shall be at every meter interval on the outermost sheath of cables.
12.	**Electrical Properties at 20 Deg.C:**	
13.	Maximum Conductor loop resistance not greater than	73.4 Ohms/Km for 0.5 sq mm. Conductor
14.	Insulation resistance not less than	100 M Ohms / Km
15.	Mutual capacitance at 0.8 Khz not greater than	120 nF/Km
16.	Test Voltage: Conductor / conductor and conductor / shield	2000 Vrms for 1 minute

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
17.	Characteristic impedance at 0.8 KHz	370 Ohms
18.	Image attenuation at 0.8 KHz	0.11 dB/100 m
19.	Image attenuation at 10 KHz	0.29 dB/100 m
20.	Cross talk attenuation at 0.8 KHz greater than	70 dB/Km
21.	Coupling capacitance at 0.8 Khz not greater than	200 pF/100 m
22.	**High Voltage Test**	Duration
23.	Conductor to Conductor	2000 Vrms, 50 Hz for 1 min
24.	Conductor to Shield	2000 Vrms, 50 Hz for 1 min

4.8.0 CORE CABLES

S.No	SPECIFICATION	INFORMATION / REQUIREMENT / DATA
1.	Application	0.5 sq.mm shall be used for Binary signals
2.	Voltage Grade & Type	650V grade, multi-core cable
3.	Conductor type and Size	Nominal **0.5** sq.mm. area concentric lay annealed tinned high conductivity 7 x 0.307 mm. Dia copper conductor as per IS: 8130.
4.	Insulation type and size	Extruded HR PVC type C to IS: 5831, Colour coded. Nominal Insulation thickness shall be 0.3 mm.
5.	Screening and Shielding	Over all screening Through aluminium mylar tape Min 0.055 mm (0.075 mm) with min 25% overlap.
6.	Drain Wire	7 strands x 0.3 mm minimum size Annealed tinned copper drain wire, nominal size 0.5 sqmm, laid under the contact with aluminium side of the tape.
7.	Inner Sheath	FRLS PVC type ST1 confirming to IS: 5831 Thickness shall be min. 0.3mm.
8.	Outer Sheath	FRLS PVC type ST2 confirming to IS: 5831 Thickness shall be min. 1.8mm.
9.	Armouring	Galvanised steel wire/strip to IS: 3975 (BS:5608 Part-II)
10.	Marking	Marking of length and pair no of the cable shall be at every meter interval on the outermost sheath of cables.

4.9.0 TYPE TESTS:

Cables shall be of type tested quality. For each type and rating of cables reports on all type tests as per relevant standards, shall be submitted. In case the bidder is not able to submit report of the type test(s) conducted or in the case of type test report(s) are not found to be meeting the specification requirements, the bidder shall conduct all such tests on one drum out of every 10 drums or less for each size of cable in each lot in the presence of the Purchaser without cost implication and submit the reports for approval.

Sr. No.	Name of Test	Governing standard
1.	Annealing Test (for copper)	IS : 8130/84
2.	Conductor resistance test	As per spec
3.	Per sulphate test (Fo tinned copper wire)	IS : 8130/84
4.	Test for armours wires / strips	IS : 3975
5.	Test for measurement of DC resistance of armour	IS: 1554 (I)
6.	Test for measurement of thickness of insulation & sheath & other dimensions.	IS : 1554 (I)
7.	Measurement of volume resistivity of HRPVC insulation	IS : 5831-1984
8.	Tensile strength and elongation test for insulation & sheath.	IS:5831/1984
9.	Ageing test for insulation & sheath. Loss of mass test for PVC insulation & sheath.	IS:5831/1984
10.	Shrinkage test for PVC insulation & sheath.	IS:5831/1984
11.	Hot deformation test for PVC insulation & sheath	IS:5831/1984
12.	Cold bend test for PVC insulation.	IS:5831/1984
13.	Cold impact test for PVC sheath.	IS:5831/1984
14.	Heat shock test for PVC insulation & sheath.	IS:5831/1984
15.	Thermal stability test for PVC insulation and sheath.	IS:5831/1984
16.	Test for bleeding and blooming of pigments for PVC insulation of sheath.	IS:5831/1984
17.	Colour fastness to water.	IS:5831/1984
18.	Colour fastness to day light.	IS:5831/1984
19.	Water immersion test	IS:1554(I)
20.	Test for rodent & termite repulsion property of sheath.	Presence of lead shall be detected.

Sr. No.	Name of Test	Governing standard
21.	Oxygen index test on inner & outer sheath material.	ASTM:D-2863/77 : Min.29 Deg C
22.	Temp. index test on inner & outer sheath material	ASTM:D-2863/77 : Min.250 Deg C
23.	Acid gas emission test on inner & outer sheath material.	IEC-754-1 Acid gas generation shall be less than 20% by weight.
24.	Smoke Density test on inner & outer sheath material	ASTM-D-2843/77 Min. 40% light transmission during test.
25.	Flammability test on finished cable samples as per following methods: i. Swedish chimney test ii Vertical tray flame propagation test. iii. Single vertical cable fire resistance test.	SS-424-14-75 Cl. F-3 IEEE-383 IEC-332-1
26.	Tests for all electrical properties at 20Deg.C & maximum operating temp.	Asper spec

4.10.0 Routine Test:

Routine test shall be carried in presence of purchaser's representative for all types of cables.

1.	High voltage test	IS:1554 (I) 2 KV (RMS) for one Minute
2.	Conductor Resistance Test	IS:8130/84

4.11.0 Acceptance Tests:

Following tests shall be carried out on 1 drum out of every 10 drums or less for each size of cables in each lot, in presence of purchaser's representative.

1.	High voltage test	IS:1554 (I) 2 KV (RMS) for one Minute
2.	Conductor Resistance Test	IS:8130/84
3.	Volume Resistivity	IS:5831-1984
4.	Measurement of Mutual	100 NF/Km (max)

5.	Calculation & Verification of Characteristic impedance on the basis of value obtain for mutual capacitance at 0.8 KHZ	320 Ohms(nominal)
6.	Measurement of thickness of insulation and sheath & other dimensions	IS:1554 (I)
7.	Tensile strength and elongation at break of insulation & sheath	IS:5831/84
8.	Oxygen index test on inner & outer sheath at room temp.	ASTM-D-2863 Min.29 Deg.C
9.	Temp. index test on inner & outer sheath	ASTM-D-2863 Min.250 Deg.C
10.	Acid gas emission test on inner sheath & outer sheath.	TEC-754-1 : Max.20% by weight
11.	Smoke density test on inner sheath & outer sheath	ASTM-D-2843 : Min.40% light transmission during test.
12.	Flammability test	SS-424-14-75 Class F-3

4.12.0 ROUTINE TESTS (To be performed on every cable length)

RS-485 / CAN-Bus Cables

- High voltage test
- Conductor DC resistance
- Insulation resistance
- Characteristic impedance @ 100 kHz
- Mutual capacitance
- Attenuation @ 100 kHz

CAT-6 / CAT-6A Cables

- Wire map
- DC loop resistance
- DC resistance unbalance
- Continuity
- Propagation delay and delay skew

Fiber-Optic Cables

- OTDR trace
- Attenuation @ 1310/1550 nm
- Continuity

4.13.0 ACCEPTANCE TESTS (Sampling as per applicable standard)

RS-485 / CAN-Bus

- Dimensions & lay length
- Shield coverage/overlap
- Sheath & insulation thickness
- Conductor resistance
- Insulation resistance
- Impedance @ 100 kHz
- Attenuation
- Mutual capacitance
- Crosstalk

CAT-6

- NEXT / PS-NEXT
- FEXT / PS-FEXT
- Return loss
- TCL & ELTCTL
- Propagation delay & skew
- DC resistance unbalance

Fiber-Optic Cables

- Attenuation (cut-back/OTDR)
- Tensile test
- Crush test
- Impact test
- Bending test
- Temperature cycling
- Visual/dimensional checks

4.14.0 TYPE TESTS (Performed once per cable design)

RS-485 / CAN-Bus

- Impedance vs frequency
- Attenuation vs frequency
- Mutual capacitance
- Crosstalk
- Electrical resistance & insulation
- Flame (IEC 60332-1-2)
- Smoke (IEC 61034-2)
- Halogen acid gas (IEC 60754-1/2)

CAT-6 / CAT-6A

- NEXT / PS-NEXT
- FEXT / PS-FEXT
- Return loss
- TCL & ELTCTL
- Propagation delay & skew
- Coupling attenuation

- DC resistance unbalance
- Flame and bundle flame tests

Fiber-Optic

- Attenuation spectrum
- OTDR analysis
- Temperature cycling
- Crush, impact & tensile
- Water penetration
- Fiber geometry (MFD, concentricity, cladding dia.)

4.15.0 QUALITY ASSURANCE

Instrumentation Cables are to be tested for final test Routine and Acceptance test at shop prior to dispatch. The final Routine test to be carried out on completed cable in line with VDE-207 shall be as follows:

i. High voltage test
ii. Conductor Resistance measurement for core and drain wire
iii. Insulation Resistance

The final Acceptance test in line with applicable standard to be carried out on cable samples taken from end with sampling plan as specified in the standard or agreed under contract shall be as follows:

i. Overall dimension, conductor size, number of stands, lay length, direction of lay, thickness of insulation, core identification, shielding coverage/ overlap, inner sheath and outer sheath thickness.
ii. In case of armoring the no of armor wire/ strip, size and coverage to be measured. Armor wire sample to be checked for tensile, Elongation, wrapping/ torsion and adhesion test. Samples to be also checked for mass of zinc coating.
ii. Conductor Resistance measurement
iii. Annealing test (for reference)
iv. Insulation resistance (volume resistivity)
v. Characteristic impedance, Attenuation, Mutual Capacitance, Cross talk

Only one sample of any size from the offered lot of insulation and Sheath to tested for

i. Thermal stability test.
ii. Oxygen index on Outer sheath as per ASTM-D-2863
ii. Smoke density on outer sheath as per ASTM D-2843
iii. Acid gas generation test on outer sheath as per IEC-754
iv. Fire resistance test as per SS 4241475
v. One length of cable to checked for length measurement and while

vi. measurement of length visual defects if any, sequential marking,
vii. embossing are to be checked.
viii. Tensile and elongation test
ix. Volume resistivity test

One sample of any size from the complete order may be selected for:
i. Tensile and elongation of PVC insulation and outer sheath after ageing
ii. Flammability test as per IEC 332

The cable drums are to be provided in good conditions with proper identification suitable for transportation and storage / handling till lying of cable. In case of wooden drums necessary ant termite treatment to be provided. The cables are to be sealed at both ends prior to dispatch.

The manufacturing of Cables are to be carried out as per Quality program of manufacturer which shall atleast meet the following incoming and process checks:

Conductor material, resistivity, dimension, joints and lay length shall conform to requirements of International standard or IS-8130. The annealing process shall be controlled to meet the required strength and finish.

Insulation, inner and outer sheath material properties including FRLS for inner & outer sheath shall meet the requirement of International standard specified / as per IS-5831 and standards for FRLS specified in this specification.

Insulated core shall be checked for finish, color and to be tested for spark test preferably using on line testers with counter/ identification system. The insulation thickness to be controlled to give the required thickness and concentricity when measured under profile projector.

Shielding shall be checked for thickness, width and overlap.

Armor wire/ strip samples to be checked for size, tensile, elongation, wrapping/torsion and galvanization check as per applicable International standard / IS-3975. The coverage of armor and absence of overlap to be checked during armoring process.

The extruders used shall have temperature controllers to give smooth finish and free from defects. The outer sheathing color, finish, diameter needs to be controlled. The sequential marking shall be legible and be indented for longer retention.

Checks on wooden / steel drums shall be as per requirement of International standard / as per IS- 10419.

4.16.0 PACKAGING, IDENTIFICATION & DELIVERY

a. Cable drums shall be new, sturdy, and suitable for transport.
b. Both cable ends shall be sealed.
c. Drums shall carry:
   - Cable type
   - Size
   - Drum length
   - Batch number
   - Date of manufacture
   - Arrow for direction of rolling
   - Weight
d. Sequential length marking shall be provided at every 1 m as applicable.

4.17.0 DOCUMENTATION REQUIREMENTS

The following drawings/documents to be furnished during detailed engineering stage

- Detailed Bill of material with Quantity
- Data Sheet for each type of cables
- Construction / General arrangement drawings of all types of cables
- Quality Assurance Plan
- Type test procedures
- Type test reports
- FAT Procedure
- Compliance certificates
- Any other documents as required by the purchaser / Owner during detail engineering