4.1.6.1. ADSS Cable

1.1. Design Principles:

The proposed Fibre cable shall be single mode, 48 core all-dielectric self supporting cable (ADSS).

The cable shall be designed and manufactured in accordance with the following standards:

- Cable: IEEE 1222
- Fiber: IEC 60793, ITU-T G.65X series
- Color code: ANSI/EIA 359-A, IEC 60304

1.2. Route Survey:

Prior to design and installation, the contractor shall visit the route accompanied by KPLC staff to ascertain for themselves the requirements for the link. During this survey a pole count and a sketch for the cable installation shall be carried out. This sketch shall indicate the locations of splice boxes and the approximate distances between them. The poles shall also be assessed for their ability to support the ADSS cable. Any need for modification shall be determined at this stage.

Suitable drum lengths shall also be determined at this stage to reduce the number of joints preferably at section poles. KPLC shall assess the contractor’s report and carry out modifications where it is felt necessary.

1.3. Installation:

The cable installation shall be aerial on existing power lines. Majority of these lines are on wooden structures and the ADSS cable shall be installed below the power line. The installation shall be done under live line conditions except in some instances where safe working clearance cannot be maintained.

It is not the intention of the employer to recommend any specific installation method but whichever method applied should be in accordance with the international standards, manufacturer’s recommendation and within KPLC safety regulations.

1.4. Installation Materials & Fittings:

All bolts, nuts and clamps used during the construction shall confirm to IEEE standards that apply to testing and performance of Hardware for All-Dielectric Self Supporting cable (ADSS)

All fitting materials shall conform to the approve standards by IEEE1222. The bidder shall attach type test certificates from the certifying bodies.
1.5. **Approach Fiber Optic Cable:**

The ADSS aerial cable shall terminate at first structure after the bus bar at the substations. An underground fibre optic cable shall be run from this structure to the building. This approach cable shall be 48 core SM, armoured, loose tube cable, with a dielectric central member. The cable shall be Kevlar yarn reinforced, steel tape armour and a UV resistant HDPE outer layer. It is for outdoor applications, in ducts, for direct burial or latched installations.

1.6. **Splicing & Testing:**

All joints shall be fusion spliced. The splice loss shall be equal to or less than 0.1db. After all the terminations are done the cable shall be tested from ODF to ODF using the OTDR as well as power meter and the results tabulated.

1.7. **Optical Distribution Frames (ODFs):**

These ODFs shall be wall mounted and lockable supplied complete with patch panel, SM pig tails with SC connectors and splice tray cassettes.

1.8. **Fittings & Spare Capacity:**

Unless otherwise specified in this specification, all requirements for individual components and completed cable shall be mainly in accordance with the following standard specifications.


The Contractor shall include 10% spare cable capacity for future maintenance work on the link.

4.1.6.2. **Specifications for Underground Fibre Optic Cabling and associated hardware & fittings**

This section describes the functional requirements, major technical parameters and Type testing, Factory Acceptance Testing & Site Acceptance Testing requirements for underground fibre optic cables, HDPE pipes, Joint Box, Marking, packaging, and transportation installation requirements have also been described.

**Under Ground FO Cable**

**General**

The underground fibre optic cable shall be unarmoured and shall be suitable for underground installation in pipes. The cable should be of low weight, small volume and high flexibility.
The mechanical design and construction of each unit shall be inherently robust and rigid under all condition of operation, adjustment, replacement, storage and transport.

**Applicable Standards**

- The cable shall conform to the standards named below and the technical specifications described in the following sections.
- **ITU-T Recommendations G.652**
- **Bellcore GR-20**

**Fibre Type(s) and Counts**
The cable shall consist conform to G.652 D standards.

**General Cable Construction**
The optical cable shall consist of a central fibre optic unit protected by one or more layers of helically wound anti-hygroscopic tape or yarn. The central fibre optic unit shall be designed to house and protect the fibres from damage due to forces such as crushing, bending, twisting, tensile stress and moisture, wide temperature variations, hydrogen evolution etc. The fibre optic unit shall be of loose tube construction. The inner polyethylene jacket and outer sheath jackets shall be free from pinholes, joints, splits or any other defects. All fibre optic cable shall have a minimum service life span of 25 years. Documentary evidence in support of guaranteed life span of cable & fibre shall be submitted by the Contractor during detailed engineering.

**Colour Coding & Fibre Identification**
Individual optical fibres within a fibre unit/ fibre units shall be identifiable in accordance with EIA/TIA 598 or IEC 60304 or Bellcore GR-20 colour-coding scheme. The colour coding system shall be discernible throughout the design life of the cable. Colouring utilized for colour coding optical fibres shall be integrated into the fibre coating and shall be homogenous. The colour shall not bleed from one fibre to another and shall not fade during fibre preparation for termination or splicing. Each cable shall have traceability of each fibre back to the original fibre manufacturer’s fibre number and parameters of the fibre. If more than the specified numbers of fibres are included in any cable, the spare fibres shall be tested by the cable manufacturer and any defective fibre shall be suitably bundled, tagged, and identified at the factory. The colouring scheme shall be submitted along with the cable drawing for Employer’s approval.

**Strength Members**
The central fibre optic unit should include a central strength member of Fibre Reinforced Plastic (FRP) or other suitable material. Peripheral strength members and aramid yarns are also acceptable. The central FRP strength member may be slotted type with SZ lay (reverse oscillation lay) of fibre units or it may be cylindrical type with helical lay of fibre units.
Filling Compound
The interstices of the central fibre optic unit and cable shall be filled with a suitable compound to prohibit any moisture ingress or any longitudinal water migration within the fibre optic unit or along the fibre optic cable. The water tightness of the cable shall meet or exceed the test performance criteria as per IEC60794-1-2-F5. The filling compound used shall be a non-toxic homogenous waterproofing compound that is free of dirt and foreign matter, anti-hygroscopic, electrically nonconductive and non-nutritive to fungus. The compound shall also be fully compatible with all cable components it may come in contact with and shall inhibit the generation of hydrogen within the cable.

The Sheath / Inner jacket
The sheath shall be black, smooth, concentric, and shall be free from holes, splits, blisters and other surface flaws. The sheath shall be extruded directly over the central fibre optic unit and shall also be non-hygroscopic. The cable sheath design shall permit easy removal without damage to the optical fibres or fibre units. The sheath shall be made from good quality of weather resistant polyethylene compound (Black High Density Polyethylene- HDPE) and thickness shall be > 1.8mm.

The Outer Jacket/ Termite protection
A circular jacket of not less than 0.65mm Polymide-12 (Orange Nylone-12) material should be applied over the sheath as an outer jacket. The outer jacket shall have smooth finish and shall be termite resistant.

Rip Cords
Suitable rip cord(s) shall be provided to open the outer sheath of the cable. The rip cord(s) shall be properly waxed to prevent wicking action and shall not work as a water carrier.

Cable drums, Marking, Packaging and Transport
All optical fibre cable shall be supplied on strong wooden drums provided with lagging with adequate strength, constructed to protect the cabling against all damage and displacement during transit, storage and subsequent handling during installation. Both cable ends in the drum shall be sealed and shall be readily accessible. The drum shall be marked with arrows to indicate the direction of rotation. Both the ends of the cable shall be provided with pulling eye. The pulling eye and its coupling system should withstand the same tensile load as applicable to the cable. The following marking shall be done on each side of the cable drums.
   i. Drum number
   ii. Consignee’s name and address
   iii. Contractor’s name and address
   iv. Type of cable
   v. Number of fibres
   vi. Type of fibres
   vii. Year of manufacturing, month & batch no
   viii. Name of manufacturer
   ix. Total cable length Power Grid Corporation of India Ltd.
x. Inner end marking and Outer end marking

Packing list supplied with each drum shall have all the information provided on marking on the respective cable drum and following additional information: OTDR length measurement of each fibre and Ratio of fibre and cable length.

**Optical fibre cable marking**

A suitable marking shall be applied in order to identify this cable from other cables. Marking on the cable shall be indelible, of durable quality, shall last long and shall be applied at regular interval of one-meter length. Marking shall be imprinted and must clearly contrast with the surface and colours used must withstand the environmental influences experienced in the field. The accuracy of the sequential marking must be within + 0.5% of the actual measured length. The sequential length marking must not rub off during normal installation. In case laser printing is used the marking shall not exceed 0.15 mm depth. The optical fibre cable shall have the following markings in every meter:

i. Type of Cable
ii. Running meter length
iii. Number of fibres
iv. Type of fibre
v. Laser symbol & caution notice
vi. Year of manufacture and batch no.
vii. Employer’s Name

**PLB HDPE pipe and Accessories**

The following paragraphs describe the functional requirements, major technical parameters and Type and Factory Acceptance Testing requirements for Permanently Lubricant High Density Polyethylene (PLB HDPE) Pipe. PLB HDPE pipe shall be suitable for underground fibre optic cable installation by blowing as well as conventional pulling. The PLB HDPE pipe shall be suitable for laying in trenches by directly burying, laying through G.I/RCC hume pipe and laying through trench less digging. The expected service life of HDPE pipe and accessories shall not be less than 50 years. Documentary evidence in support of guaranteed life span shall be submitted by the Contractor during detailed engineering. The unit rates quoted in the price schedule shall be the composite price of PLB HDPE pipe along with all accessories.

**Construction of PLB HDPE pipe**

The PLB HDPE pipe shall have two concentric layers viz. outer layer and inner layer. The outer layer shall be made of HDPE material and the inner layer of solid permanent lubricant. These concentric layers shall be co-extruded and distinctively visible in cross-section under normal lighting conditions and generally conform to IS-9938. The colour of the PLB HDPE pipe shall be finalized during detail engineering. In the finished PLB HDPE pipe, the coextruded inner layer of solid permanent lubricant shall be continuous and integral part with HDPE outer layer and preferably be white in colour. The inner layer of solid permanent lubricant shall not come out during storage, usage and throughout the life of the pipe. The
finished pipe shall be of good workmanship such that the pipe is free from blisters, shrink holes, flaking, chips, scratches, roughness, break and other defects. The pipe shall be smooth, clean and in round shape, without eccentricity. The ends shall be cleanly cut and shall be square with axis of the pipe.

**General**
The HDPE pipe shall conform to the following standard and the technical specifications described in the following sections.

i. IS: 4984 / IS: 2530/IS:14151/(part1)/ IS:9938/IS:7328/IS12235(Part-9)/IS:5175


iii. TEC-spec no. GR/CDS-08/02/NOV-04(including all amendments)-HDPE pipe for use as duct for optical fibre cable.

**Material**
The raw material used for the PLB HDPE pipe shall meet the following requirements:

i. The anti-oxidant establishers, colour master batch and other additive used shall be physiologically harmless and shall be used only to minimum extent necessary to meet the specification.

ii. Usage of any additives used separately or together, should not impair the long-term physical and chemical properties of the PLB HDPE pipe.

iii. Suitable Ultra Violet stabilizers may be used for manufacture of the PLB HDPE pipe to protect against UV degradation when stored in open for a minimum period of 8 months.

iv. The ash content of the colour master batch shall not be more than 12% when tested as per method detailed below: Test Method for ash content: About one gram of the sample under test shall be taken and dried at 105°C for two hours in a platinum or glazed porcelain or silica or quartz crucible. The weight of the sample shall be noted. Subsequently, the sample with the crucible shall be transferred to a muffle furnace maintained at 600±50°C and allowed to remain there for three hours. The ash content may be calculated as a percentage of the weight of the original sample.

v. The base HDPE resin used for manufacturing outer layer of pipe shall conform to any grade of IS-7328 or to any equivalent standard meeting the following requirement when tested as per standards referred in this Section below.

   i) Density (outer and inner layer): 940 to 958kg/m3 at 27°C. The density of completed PLB HDPE shall not be differ by more than 0.003gms/cc by this value when tested as per IS:2530 or IS:7328.

   ii) Melt Flow Rate (MFR): 0.2 to 1.1 g/10 minutes at 190°C & 5 kg load: when tested as per IS:2530. The MFR of the outer layer of the completed PLB HDPE pipe shall not differ by more than 30% of this value.

   iii) Tensile Strength at Yield: 20 N/mm2 minimum
iv) Elongation at break: >600%, when tested as per ASTM D638, Type-IV specimens
v) Flexural Modulus at 1% strain: 690 N/mm2 minimum, when tested as per ASTM D 790.
vi) Hardness, Shore-D: Between 60 and 65 units, when tested as per ASTM D 2240
vii) Heat Deflection Temperature at 45 g/mm2: 65ºC minimum, when tested as per ASTM D 648.
viii) Environmental Stress Crack resistance, When tested with 10% Igepal, CO0630 Solution 50ºC: 96 hrs., when tested as per ASTM D 1693, No cracks.
ix) Weathering in artificial (UV) light (Specimens shall be as per ASTM D 638 Type-IV) and cut from compression moulded sheet. After exposure for 720 hrs., Tensile strength shall be tested. The variation shall not be greater than 20% compared to tensile strength obtained at above.
x) OIT (in Aluminium Pan): 30 minutes minimum, when tested as per Annexure I.
xi) UV Stabiliser Content: Hindered Amine Light Stabiliser minimum 0.15%, when analysed as per FT-IR method.

vi. In the inner layer of PLB HDPE pipe, the friction reducing, polymeric material to be used as the inner layer lubrication material shall be integral with HDPE layer. The lubricant materials shall have no toxic or dermatic hazards for safe handling.

Accessories of PLB HDPE pipe

The following accessories are required for jointing the pipe and shall be supplied along with the pipe. The manufacturers shall provide complete design details, procedure for method of installation and type of the material used for the accessories. No part of the accessories shall contain metal part and minimum pulling force of the coupler shall be 330kgf.

i) Plastic coupler: The coupler shall be used to join two PLB HDPE pipes. The coupling shall be able to provide a durable airtight and watertight joint between two pipes without deteriorating the strength of the pipes. The strength of coupler shall match the primary strength of the PLB HDPE pipe and threaded coupler is not acceptable. The jointing shall meet the air pressure test of 15 kg/cm2 for a minimum period of 2 hours without any leakage.

ii) End plug: This shall be used for sealing the ends of empty pipe, prior to installation of FO cable and shall be fitted immediately after laying of the PLB HDPE pipe, to prevent entry of any unwanted elements such as dirt, water, moisture, insects/rodents etc.

iii) Cable sealing plug: This is used to hold the cable and prevent entry of any unwanted elements, as specified above.

iv) End cap: This cap is made of hard rubber, shall be fitted with both ends of PLB HDPE pipe to prevent the entry of any unwanted elements such as dirt, water, moisture, insects/rodents during transportation and storage.
v) Set of installation/maintenance accessories comprising of C-Spanners for tightening plastic coupler (4 nos.), Rotary duct cutter (2 nos.), spare cutting wheel (4 nos. per Rotary Duct cutter), Chamfering tool for giving slight chamfer to the ends of PLB HDPE pipe shall be used during maintenance of the PLB HDPE pipes and these items (1set) shall be supplied along with the pipe.

4.1.6.3. Fibre Optic Ground Wire (OPGW)

The overhead earth wire shall be Fibre Optic Ground Wire (OPGW) with a minimum of 48 strands. The fibre optic earth wire supplied shall be suitable for installation on transmission line and shall be supplied complete with all necessary fittings and optical joint boxes. The earth wire fittings and optical joint boxes shall be type approved.

The fibre optic earth wire shall comprise an optical sub-unit containing optical fibres over which shall be laid aluminium, aluminium alloy or aluminium coated steel strands. The clad steel wire incorporated in fibre optic earth wire shall comply with the requirements of IEC 61232. Shaped aluminium or aluminium alloy wire sections shall conform to the requirements of the appropriate IEC standard.

The optical sub-unit shall withstand the temperature rise associated with the specified lightning fault current flowing in the earth wire without damage. The fibre optic earth wire (OPGW) shall be manufactured in continuous lengths of not less than 2,000 m.

The overall system design of the fibre optic system shall meet the following minimum requirements:

Single failure or degradation in any optical fibre not more than one year averaged over five years;

Failures or degradations affecting more than one optical fibre, not more than one in ten years;

Increase in optical system transmission attenuation due to accumulated ageing and other effects at the end of five years and not more than 0.05 dB/km.

Optical Fibres

Optical fibres shall be single mode fibre and shall conform to IEC 793-2-B1.

The fibre coating material shall be mechanically strippable. The optical fibres shall be capable of being jointed by fusion technique.

There shall be no measurable long term or short-term optical attenuation change due to the temperature rise associated with a fault current flowing in an earth wire, or a lightning strike on the earth wire.

OPGW Fittings
The fibre optic earth wire shall be with approved conductor fittings. The application of these fittings shall not damage the earth wire or fibres, either mechanically or optically. At each support, a bypass device shall be provided to guide the cable around the earth wire fittings associated with the support.

**Optical Joint Boxes**

Optical joint boxes shall be provided to protect the splice joint of optical fibres, either when individual lengths of the fibre optic OPGW, are jointed or between the fibre optic earth wire and the underground fibre optic cable.

The joint boxes shall consist of external steel or die cast aluminium housing providing protection to IEC 529 IP 44 and an internal die cast aluminium or high impact plastic ABS box to IEC 529 IP54.

The external housing shall be designed so that the rainwater is directed away from the door and there shall be no water ingress when the door is opened.

The joint boxes shall be supplied complete with all fittings to secure and seal the cable in the gland plates or blank the unused spigots. The cable cleats to secure the fibre optic OPGW or underground cable shall be fitted inside the box. The cleats shall not have a detrimental effect on the performance of the optical fibres when tightened to the recommended torque.

The top and bottom of the joint box shall be vented and the vents provided with the vermin shields.

The box shall be supplied complete with internal splice cassettes to accommodate the required number of splices. The glands shall be fitted to accommodate either the fibre optic OPGW or underground fibre optic cable.

**Fixing Clamps**

A bolted clamping system shall be used to attach the OPGW to the inside of the support, without drilling or modifications to the support steel work. The attachment clamps shall be capable of being attached and detached from the support, without affecting the OPGW. Fixing clamps shall be made from a suitable grade of aluminium alloy complying with the requirements of BS 1490 and / or BS EN 1676. Bolts shall be made from mild steel grade S275JR to BS EN 10 025. Bolts and nuts shall be ISO Metric Black Hexagon to BS 4190 and shall unless otherwise specified be threaded ISO Metric Coarse Pitch to BS 3643: Part 2, Tolerance Class 7h/8g.

**Non – Metallic Underground Fibre Optic Cable**

The fibre optic cable shall be circular in cross section and shall be designed so that any cable strain is so directly imported on the optical fibres. The cable shall not include any metallic components to prevent high-induced voltages when used in switching or substation compounds.

**Protective Treatment**

Fibre optic earth wire
Where two layers of wire strands are provided over the optical sub-unit, the external surface of the optical sub-unit and the inner strand layer shall be greased, using approved conductor grease.

**Ingress of Moisture**
The cable shall be capped before shipment to prevent the ingress of water.

**General**
The supplier of the OPGW shall be responsible for the supervision of installation by the Contractor; to ensure that system reliability requirements are met.

**Workmanship**
The Contractor shall ensure that the fibre optic cable are not strained or damaged either mechanically or optically during stringing and/ or jointing.

**Fibre optic joints**
Optical fibre joints in the OPGW, or between the OPGW and the non-metallic underground fibre optic cable, shall be housed in optical joint boxes. The joint boxes shall be located immediately above the anti-climbing device for convenient access by technical personnel. All joint boxes shall be earthed to the support steel work using approved multi-wire / multi-strand flexible aluminium earth bond.

### 4.1.6.4. OPTICAL DISTRIBUTION FRAMES (ODF)

Each Optical Line Terminal Equipment (OLTE) or SDH multiplexer shall include an optical distribution frame, installed in a own wall mounted fixed cubicle.

Assignment between station fibre cable and OLTE's shall be made by using patch cords between the termination box and the optic distribution frame. Capacity of the optic distribution frame shall allow free assignment between each individual fibre of the station fibre optic cables and the relevant optical I/O ports of the OLTE's.

The optic distribution frame shall be equipped with low loss optical connectors (< 0.3 dB including the loss in the bulk head, loss in the connector splice & the loss in the pig tail) of the screw-on type. Auxiliary connectors shall be provided to facilitate testing and maintenance of the fibres/equipment. All spare fibres shall be properly terminated and spliced on connectors of the same type within the frame.

### 4.1.6.5. FIBRE TERMINAL EQUIPMENT

**Specifications**
The terminal equipment shall be the type SDH STM-4 optical terminal equipment, equipped for SCADA Data, Ethernet capability.
SDH (STM-1) multiplexer shall be installed in racks that are EMC compatible and suitable to work in HV system environments.

The multiplexer shall be based on the SDH technology, working on the basic transmission Bit Rate of 155.520 Mbit/s (STM-1). It shall be in accordance with the latest ITU-T SDH recommendations such as: G.703, G.704, G774, G.783, G.784, G.785, G.811, G.812, G.813, G.823, G.825, G.826 and M.3010.

The equipment shall be able to perform both, multiplexing and line terminating functions. The SDH Equipment (Terminal Equipment, Add/Drop Multiplex, Synchronous Digital Cross-Connect) to be offered shall meet the following requirements:

- It shall have at least all the functions outlined in ITU-T G.783.
- The PDH electrical tributary interfaces to the SDH equipment shall conform to ITU-T G.703.
- The SDH electrical and optical interfaces shall conform to ITU-T G.703 and G.957.
- The cross-connect offered shall be capable of providing non-blocking connection between virtual containers.
- The Optical Power to be offered shall be such that under normal operating condition, the BER of the system at the receiver is better than $1 \times 10^{-10}$. Error performance versus the receive signal shall be verified during the factory acceptance tests.

The multiplex structure shall conform to ITU-T G.707. Details of the Multiplex structure for the offered equipment including the usage of the overhead bits shall be detailed with the offer.

The synchronous optical interface protection shall be achieved by having 1+1 protection. The laser shall automatically cut-off when the link is disturbed. Redundant cross connect, where failure on either one shall not cause link outage, and path protection on the traffic interface and the 2 Mbit/s levels shall also be provided.

Timing and synchronization shall conform to ITU-T G. 783, G.811, G.812 and G.813. Timing references, number of timing references available, switching time to a different timing reference, type and level of clocks shall be stated in the offer.

The equipment shall automatically switch to another clock if the reference timing is lost and automatically revert back upon restoration. The accuracy of the internal clock as well as the details of the clock signal distribution shall also be stated in the offer.

The equipment shall be capable of diverting timing references between the STM-1, 2 Mbit/s and a G.703 tributary interfaces.

The SDH equipment shall be wired for the full STM-1 capacity, however equipped under the scope of this specification to receive at least four (4) PCM tributaries as specified below. However, if higher PDH signals other than the 2 Mbit/s are required to be routed through, the same shall be possible just by adding the respective interface cards and no extra wiring needed. It shall have 2 Mbit/s outputs where it can directly be connected to digital telephone exchanges or teleprotection equipment.
The jitter and wander tolerance for PDH and SDH interfaces shall conform to ITU-T G.823 and G.825. Jitter and wander characteristics of SDH multiplex and line equipment shall conform to ITU-T G.783.

The Contractor shall submit the details of the power budget calculations stating the following (based on 0.25 dB/km optical fibre attenuation at 1550 nm):

- Transmitter Power
- Minimum receive Signal @ BER 1x10^-10
- Connector Loss
- Repair Splice Loss
- Power Penalty (Chromatic dispersion and LD reflection Loss)
- Maintenance Margin (> 2dB)
- Other Loss
- System Margin
- The SDH equipment to be offered shall provide the followings:
  - A data communication channel to the Telecommunication Management Network, in accordance with ITU-T G.773 for the purpose of integration of the new equipment into the Telecommunication Network Management System.
  - A Craft interface in accordance with ITU-T G.773 to allow a local terminal to access the network element.
  - An engineer order–wire which shall have conference and selective calling features.
  - Performance monitoring in accordance with ITU-T G.784 and G.826.
  - Optical safety as per ITU-T G.783.
  - The alarm functions shall include but not limited to:
    - Alarms classified as critical, major, minor, and information.
    - Indications of loss of incoming signal.
    - Visual and audible indication of alarms.
    - Test function of alarm indicators to ensure workability of alarm indicators.
  - Alarm functions shall be detailed by the Contractor, e.g. if implemented in Telecommunication Network Management System.