Schedule E

Standard Specification

Electrical Balance of Plant and Installation

2022-03-24	0	Approved for Use	V. Lalonde	S. Fortier	S. Fortier
Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**
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Schedule E

1. General

1.1.1.1 This document shall be read as part of a complete Specifications package including *St. Lucia Electricity Services Ltd. (LUCELEC)* documents and other technical appendices:

- *Energy Storage System* Request for Proposal (RFP)
- *Battery Energy Storage System* Specification
- *Power Conversion System* Specification
- Power Transformer Specification
- *Energy Management System* Specifications
- Electrical Balance of Plant and Installation Specifications
- Site Works and Civil Balance of Plant Specifications
- Containerized Building Specification
- Packaging and Shipping Requirements

1.1.1.2 Following definitions will be used for this Specification:

a.) ***Balance of Plant*** or ***BOP*** – electrical and site works for the entire facility, excluding the *ESS* equipment and *PPCS*

b.) ***Battery Energy Storage System*** or ***BESS*** – A lithium-ion electrochemical storage device capable of delivering or absorbing electrical energy at its *DC Bus*

c.) ***Battery Management System*** or ***BMS*** – the control and monitoring system for the *BESS* designed to manage all internal bank functions and internal protection. The *BMS* shall communicate with the *PCS* and *PPCS*

d.) ***Battery Module***- An assembly of rechargeable battery cells with a convenient mechanical arrangement and a degree of protection

e.) ***Battery Rack*** – a free standing assembly of battery modules, integrated as part of an overall *BESS*

f.) ***Calendar Life*** – The expected number of calendar years that the battery is expected to last independent of charge and discharge cycles

g.) ***Contract*** – The agreement resulting from this RFP process

h.) ***Contractor***– the successful *Proponent* with whom the *LUCELEC* may enter into a *Contract*

i.) ***LUCELEC –*** St. Lucia Electricity Services Ltd.

j.) ***LUCELEC's Representative*** – The person appointed by the *LUCELEC* who has responsibility for managing the *Contract* and, unless *Contractor* is expressly advised otherwise, *LUCELEC's Representative* (1) has full authority to act on behalf of and bind the *LUCELEC*, and (2) may, in writing, delegate any or all of his or her authority to any other person

k.) ***Current Transformer*** or ***CT*** - an instrument transformer used to step down a measured current for metering, control or protection purposes

l.) ***DC Bus*** – the direct current connection between the *PCS* and *BESS* capable of carrying rated system power

m.) ***Depth of Discharge*** or ***DOD*** – the ratio of the amount of energy discharged from the *BESS* to the maximum dischargeable energy capacity of the *BESS*

n.) ***End of Life*** or ***EOL*** – the defined remaining *BESS* capacity as a percentage of the amount of initial *BESS* capacity at which the *BESS* system becomes not functional as initially designed

o.) ***Energy Storage System*** or *ESS* – - consists of a *Battery Energy Storage System (BESS)* and a *Power Conversion System (PCS)*

p.) ***Factory Acceptance Testing*** or *FAT* – performance testing of all equipment at the factory to ensure it meets the specifications and requirements prior to shipment to site

q.) ***Factory Integration Testing*** or ***FIT*** - performance testing at the factory of an integrated system, consisting of the *ESS, PCS* and *PPCS* to ensure interface between components is functional prior to shipment to site

r.) ***Input/Output*** or ***I/O –*** refers to the input or output signals associated with a control system or component of the control system such as a programmable logic controller.

s.) ***Inspection and Test Plan*** or ***ITP*** – the plan for managing the quality control and assurance of a particular the construction work providing information on the requirements, overview of the method(s) to be used, responsibilities of relevant parties, and documentary evidence to be provided to verify compliance

t.) ***Human Machine Interface*** or ***HMI*** – A user interface that serves as the main point of interaction between an operator of the battery plant and the settings, functions and commands associated with the plant

u.) ***Low Voltage Bus*** – the alternating current connection between the *PCS* inverter and the step-up transformer

v.) ***Power Conversion System*** or *PCS* – The Battery *PCS* is the power interface from the battery system to the AC electrical grid

w.) ***Proponent*** or ***Tenderer*** – Each company receiving this *Request for Proposal*

x.) ***Proposal*** – Documents submitted by *Proponents* in response to this *RFP*

y.) ***Potential Transformer*** or ***PT*** - also known as a Voltage Transformer, an instrument transformer used to step down the main connection voltage for metering, control or protection purposes

z.) ***Programmable Logic Controller*** or ***PLC*** – A ruggedized industrial computer on which the core logic of the control system resides

aa.) ***Power Plant Control System*** or *PPCS* – the *Contractor* supplied power plant control system that communicates to the *PCS*

bb.) ***Primary Frequency Response*** or ***PFR –*** The first stage of frequency control in response to a disturbance on the power system frequency. Traditionally provided by fast acting governor systems.

cc.) ***Request for Proposal*** or ***RFP*** – This Request for Proposal including all attached and referenced documents and subsequent addenda

dd.) ***Remote terminal unit*** or ***RTU -*** A controller that interfaces with a physical system or sub-system of the plant and transmits information to the SCADA network.

ee.) ***Supervisory Control and Data Acquisition System*** or ***SCADA*** – the plant Supervisory Control and Data Acquisition system supplied by *LUCELEC*

ff.) ***SCADA Network*** – the communications network that facilitates the communication between *PLCs* and other networked components within the *BESS*

gg.) ***Site Acceptance Testing*** or ***SAT*** – performance testing of all installed equipment at site to ensure it meets the specifications and requirements and that there was no damage during shipment or installation

hh.) ***State of Charge*** or *SOC* – the ratio of present dischargeable energy storage capacity to maximum dischargeable energy storage capacity expressed either in percentage or MWh

ii.) ***Subcontractor –*** Any firm/individual that the *Contractor* may contract with to perform a portion or all of the *Work* and for which the *Contractor* assumes liability

jj.) ***Uninterruptible Power Supply*** or ***UPS*** - an electrical apparatus that provides emergency power to a load when the input power source or mains power fails.

kk.) ***Work*** or ***Supply –*** All or any part of the services and obligations required to be performed under the *Contract*.

1.1.1.3 This Specification is for the supply of all labour, materials, and services required for the design, engineering, installation, testing, delivery and commissioning of equipment related to the *ESS*.

1.1.1.4 The work called for is subject to the purchase order documents. They include the Specification, the general conditions of contract, any specific conditions, and any other attachments, all of which form an integral part of the contract. The *Contractor* shall be responsible for and be governed by all requirements therein. **Any exceptions to this Specification shall be stated in writing by the *Contractor* and a suitable alternative can be priced as an option.**

1.1.1.5 The supplied equipment shall be designed for continuous operation, and all components shall be of a robust, industrially proven design.

1.1.1.6 The *Contractor* supply shall include all components and accessories as required for the proper and safe operation of the complete system.

1.1.1.7 Compliance with this Specification does not relieve the *Contractor* of the responsibility to provide safe and reliable equipment. The *Contractor* shall have overall responsibility for the safety of the *ESS* design. Any areas of the *ESS* that pose a risk to the environment, personnel, or *LUCELEC*'s assets are to be clearly communicated to *LUCELEC* and its representative.

1.1.1.8 The equipment shall be complete in every aspect and ready to operate after installation and connection.

2. Codes and Regulations

2.1.1.1 The Electrical Balance of Plant Design shall comply with all applicable local regulations and codes for the local jurisdiction in which the *Energy Storage System (ESS)* is to be installed.

2.1.1.2 All electrical components shall meet all OECS Building Code requirements and bear a recognized certification mark such as one of CE, IEC, FM, etc., All electrical assemblies or sub-assemblies shall also bear such certification. All Electrical Balance of Plant subsystems shall either be listed or be field evaluated for installation in the St. Lucia by an approved agency.

2.1.1.3 *Proponents* shall clearly indicate in their *Proposals* the standards which the requested equipment meets. *Proponents* shall clearly indicate if field certification is required for any necessary standards.

2.1.1.4 Certification of equipment shall be at the *Contractor*'s expense.

2.1.1.5 In case of conflict between these standards and this Specification, the *Contractor* shall notify *LUCELEC* and its representative in writing of such conflicts as soon as they become known.

2.2 Standards

2.2.1.1 The supplied equipment shall be designed, manufactured, and tested in accordance with the most current revision of the following applicable standards, codes, and regulations:

- International Electrotechnical Commission (IEC).
- UK Electrical Industry British Standards (BS).
- *LUCELEC* General Design Criteria
- IEC 62271-100: high-voltage switchgear and control gear – Part 100 – alternating-current Circuit breakers
- IEC 61537: Cable management – Cable tray systems and cable ladder systems

- IEC 61386-1: Conduit systems for cable management – Part 1 – general requirements.
- IEC 61386-21: Conduit systems for cable management – Part 21 – Particular requirements – Rigid conduit systems
- IEC 61386-22: Conduit systems for cable management – Part 22 – Particular requirements – Flexible conduit systems
- IEC 61386-24: Conduit systems for cable management – Part 24 – Particular requirements – Conduit systems buried underground
- IEC 60331: Fire-Resisting Characteristics of Electric Cables
- IEC 60364: Electrical installations of buildings
- IEC 60364-4-42: Low-voltage electrical installations – Protection for safety – Protection against thermal effects
- IEC 60364-4-41: Low-voltage electrical installations – Protection for safety – Protection against electric shock
- BS 7671: Requirements for Electrical Installations. IET Wiring Regulations
- IEC 60502-2: 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) – Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
- IEC 60502-4: 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) Part 4: Test requirements on accessories for cables with rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
- IEC 60445: Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors
- IEC 62305: Protection against lightning
- National Environmental Policy and National Environmental Management Strategy for Saint Lucia
- Saint Lucia Employees (Occupational Health and Safety) Act
- Saint Lucia Labour Act
- Workmen's Compensation Ordinance Act
- OECS Building Code Grenada, St. Vincent & the Grenadines, St. Lucia, Montserrat, latest version (National Building Code)

2.2.1.2 The *Contractor* is responsible for any on-site certification or other inspection requirements, if required.

2.2.1.3 Compliance of the equipment and all its associated parts with the above-mentioned codes, standards and regulations does not release the *Contractor* from the responsibility of

supplying the equipment and accessories of proper design, electrically and mechanically suited to meet the guaranteed values at the specified service conditions.

2.2.1.4 All electrical equipment and components shall be CE approved and shall carry the CE labels. In the event of equipment not bearing the CE standard certification, the *Contractor* must validate the possibility of installing the equipment on *LUCELEC*'s site, even if it is not accredited by CE standard certification.

2.2.1.5 Where there is a discrepancy in requirements between the codes, standards and regulations, the references, or this document, the *Contractor* shall apply the most stringent requirements of the conflicting documents so that the design, manufacture and testing of the equipment are carried out to the highest degree of quality set forth by this group of documents.

2.2.1.6 If any of the requirements in this Specification are in conflict with the standards, the *Contractor* shall notify *LUCELEC*. Equipment that does not comply with this specification will be rejected and shall be credited, replaced, or brought into full compliance at the *Contractor*'s expense.

3. Ratings and Functional Requirements

3.1 All equipment shall be rated for a grounded system with a frequency of 50 Hz.

3.2 All outdoor apparatus shall be capable of continuous operation over the full ambient air temperature range from +15°C to +40°C.

3.3 All indoor apparatus shall be capable of continuous operation over the full ambient air temperature range from +15°C to +40°C with 66% to 85% humidity.

4. Materials, installation and testing

4.1 General

4.1.1.1 The equipment shall be robust, heavy-duty design. The design shall have been proven effective and reliable under similar operating conditions. No new or unproven design is acceptable.

4.1.1.2 All material shall be new, CE approved and not previously rebuilt or used.

4.1.1.3 Not all parts and materials are specified in this Specification. For those that are not specified, the *Contractor* shall use their standard parts and materials, which will be subjected to the approval of *LUCELEC* and their representative. All parts and materials shall suit the specified duty.

4.1.1.4 *LUCELEC*'s standard design and material requirements are included in *Schedule H – LUCELEC Design Criteria and Standards*. *Proponents* are expected to comply with any applicable *LUCELEC* requirements. *Proponents* to note any exceptions.

4.1.1.5 All outdoor equipment should have receptacles in their control cabinets or should have receptacles nearby for maintenance.

4.1.2 Equipment Supports

4.1.2.1 Except where otherwise indicated, the *Contractor* is responsible to supply any support or concrete base required for each equipment within its scope of supply.

4.1.2.2 The *Contractor* shall submit its support and anchorage design for approval by *LUCELEC* or its *Representative.*

4.1.3 Noise and Vibrations

4.1.3.1 The *Contractor* shall eliminate or reduce any noise or vibration to a minimum as per Health and Safety protocol and local regulation.

4.1.4 Spare Parts

4.1.4.1 The *Contractor* shall supply every spare part required in this contract.

4.1.4.2 The *Contractor* shall supply a spare part list for all equipment supplied under this *Contract*.

4.1.5 Disposal and Management of Any Waste Material

4.1.5.1 The *Contractor* shall dispose and manage any waste material generated as part of the construction process according to the site procedure.

4.1.6 Finish

4.1.6.1 The *Contractor* shall finish all metal surface, remove the rust and crust, clean the surface, apply primer and finishing paint.

4.1.7 Equipment Identification

4.1.7.1 The *Contractor* shall identify all electric equipment (switchgear, motor control center, panel, disconnect, etc.) by using the following nameplate characteristics. More information on the nameplate requirements can be found in *Schedule H – LUCELEC Design Criteria and Standards.*

- Except where otherwise specified, use mechanically fixed plastic lamicoid nameplate with a thickness of 3 mm.
- Except where otherwise specified, the nameplate lettering shall be black on white background for normal powered equipment.
- The tagging used on the nameplate shall be submitted for approval before installation.

4.1.7.2 Nameplate format:

Format	Label Size (mm)	Lettering (mm)
A	125 x 50	21 x 1.5
B	70 x 30	12 x 1.5
C	35 x 15	5 x 1
D	60 x 20	5 x 1

4.1.7.3 List of formats to be used except where otherwise specified:

Equipment	Format
Main labels on panels, cubicles, kiosks, junction and control boxes and similar items	A
Control and changeover switches and similar items	B
Fuses and links	C
Relays and contactors	D

4.1.8 Bolting

4.1.8.1 The *Contractor* shall supply all bolts and nuts required for the delivery of this project, including all *Contractor* supplied equipment or any equipment supplied by others.

4.1.8.2 All bolts and nuts shall be new.

4.1.8.3 The *Contractor* shall use an electrical connection plate washer on both side and a Belleville washer on the nuts side.

4.1.8.4 The *Contractor* shall tighten all bolts with a torque wrench as per manufacturer requirements.

4.1.8.5 The *Contractor* shall mark each bolt after he has tightened them.

4.1.9 Manufacturer Rating Nameplate and CE Mark

4.1.9.1 The manufacturer rating nameplate and CE mark shall be visible once the equipment is installed at its final location.

4.1.10 Warning Signs

4.1.10.1 The *Contractor* shall supply and install any warning sign as specified in this *Contract.*

4.1.11 Mounting Height

4.1.11.1 Except where otherwise specified all the mounting height shall be measured form the finish floor up to the center of the equipment.

4.1.11.2 Except where otherwise specified the electrical equipment shall be installed according to the following indications:

- Lighting switch: 1,400 mm.
- Receptacles:
  - General: 450 mm.
  - Above counter: 175 mm.
  - In electrical and mechanical room: 1,066 mm.
- Distribution panel: in such a way that the highest circuit breaker is not at more then 1,700 mm from finish floor.
- Phone and telecommunication outlets (offices and control room): 450 mm.
- Phone outlets in electrical and mechanical room: 1,500 mm.

4.1.12 Protection of equipment during work

4.1.12.1 During the work, the *Contractor* shall protect and identify the powered equipment to ensure worker safety.

4.1.12.2 Close and identify any room where electrical equipment is powered.

4.1.12.3 The *Contractor* shall supply and install temporary doors to close rooms which contain electrical equipment. These doors shall be locked during off time.

4.1.13 Opening, sleeve, conduit and penetration

4.1.13.1 The *Contractor* is responsible for making opening wherever necessary to pass the cables.

4.1.13.2 The *Contractor* shall seal any partition penetration as per appropriate details supplied with this package.

4.1.14 Cleaning

4.1.14.1 The *Contractor* shall clean its workplace everyday.

4.1.14.2 The *Contractor* shall clean any room or equipment before performing Commissioning.

4.1.14.3 While dismantling florescent lamp containing mercury a disposal certificate shall be supplied.

4.2 Wire and Cable Systems

4.2.1.1 All cabling and wiring shall follow the IEC 60364 and other applicable standards.

4.2.1.2 All equipment wires shall be SIS 600V, XLPE insulated, FT2 rated, stranded copper. Wiring to panel doors shall be extra flexible fine stranded conductor.

4.2.1.3 For lighting and 230 Vac receptacle circuits in conduit, single conductor, 600 V rated, type RW90, XLPE insulated, stranded copper wires, of appropriate ratings.

4.2.1.4 Minimum wire sizes:

- *Current Transformer* circuits: 4.0 mm^2 SIS yellow.
- *Potential Transformer*circuits: 2.5 mm^2 SIS red.
- Control and alarm wiring circuits: 2.5 mm^2 SIS grey.
- Neutral wire: 4.0 mm^2 white stranded wire. Green 4.0 mm^2 shall be used for connections to panel ground.
- AC power circuits: 2.5 mm^2 SIS red/black/blue/white.
- DC power circuits: 2.5 mm^2 SIS red/black.
- Analog signals: 0.75 mm^2 shielded twisted pair (or triad) with overall jacket.
- HVAC control wiring shall be, at a minimum, 2.5 mm^2 at 50 V or greater and 0.75 mm^2 for lower voltages.

4.2.1.5 Cables to be installed in cable trays shall be tray-rated.

4.2.1.6 All cables shall be rated for operation over an ambient temperature range of +15°C and +40°C.

4.3 Power Cables

4.3.1 Material

4.3.1.1 Medium voltage power cables shall be single or multi-conductor shielded, with 133% insulation design and shall be rated for a continuous operating temperature of 90ºC.

4.3.1.2 Medium voltage power cables shall be of stranded copper with a spiral lay.

4.3.1.3 1,000 V and 600 V cables shall be single or multi-conductor and shall be rated for a continuous operating temperature of 90ºC.

4.3.1.4 1,000 V and 600 V conductors shall be stranded copper, un-coated, un-tinned.

4.3.1.5 Minimum size LV AC and DC power circuit conductor shall be 4.0 mm^2.

4.3.1.6 Wire and cable shall have RW90 rated insulation. Thermoplastic insulated wire and cable are not acceptable.

4.3.1.7 Multi-conductor power cables shall contain an un-insulated copper-grounding conductor unless otherwise shielded in an enclosure.

4.3.1.8 Cable outer jackets shall be flame-retardant Low-Acid-Gas Evolution rated PVC.

4.3.1.9 When 1,000 V power cable is confined to tray and enclosures only, with no exposed field runs, non-armoured, tray-rated cable with RW90, XLPE-insulated copper conductors, copper shields and flame retardant Low-Acid-Gas Evolution rated PVC outer jacket shall be acceptable.

4.3.1.10 Cable Conductor Identification - Conductors shall be identified by coloured tape: red (Phase A), black (Phase B) and blue (Phase C).

4.3.2 Installation

4.3.2.1 Prior to cutting each drum of cable, voltage grade 600-volts or above is to be tested to verify the continuity of each conductor; also, the insulation resistance between phases, and from phase to ground. Any faults found are to be reported immediately to *LUCELEC* or its *Representative*.

4.3.2.2 Cables shall be installed in cable trays and conduits in accordance with the requirements of the applicable IEC standard.

4.3.2.3 Cables shall not be installed in conduits and cable tray until the cable support system has been satisfactorily completed and cleaned.

4.3.2.4 Where no conduits or cable trays are installed, adequate support shall be provided, and the installation shall be approved by *LUCELEC* or its *Representative*.

4.3.2.5 The *Contractor* shall pull cable into conduits and trays with sufficient length provided at the ends to conveniently form, terminate and make connections to all equipment and devices without stress on the cable or connection.

4.3.2.6 Where HV and LV cable have to be installed in the same cable tray due to space restrictions, a barrier shall be provided to separate the HV from the LV cable.

4.3.2.7 At one end of the cables, the length of each conductor phase shall be sufficient to allow phase interchangeability.

4.3.2.8 If a cable or wire is damaged during installation, it shall be replaced in its entirety at no extra cost.

4.3.2.9 Cables shall be lifted into place on the tray rather than pulled wherever possible.

4.3.2.10 No crossing of cables is acceptable.

4.3.2.11 Vertical runs of cable shall not exceed the manufacturer’s recommendations.

4.3.2.12 All MV cables shall be laid in one (1) layer and with one cable diameter space separation between each cable.

4.3.2.13 End bells shall be used where cables enter or leave the duct bank as required.

4.3.3 Installation of tray cable

4.3.3.1 When the cable tray is below 2,000 mm from the finish floor a tray cover shall be installed to protect the cables.

4.3.3.2 Tray cable outside cable tray shall be installed in conduit.

4.3.4 Installation of non armored cable or not categorized as tray cable

4.3.4.1 Install the wires and cables in conduit of appropriate dimensions in conformance with the applicable IEC standard.

4.3.4.2 Ground the cable shield.

4.3.4.3 For instrumentation cable used for analog signal the shield shall be grounded at one end only, at the source, and shall be of a complete continuity from one end to the other.

4.3.5 Cables pulling

4.3.5.1 When cable pulling using a winch is required the *Contractor* shall supply a complete pulling plan for approval. The plan shall be stamped by a Professional Engineer from St. Lucia.

4.3.5.2 Cables shall be pulled with equipment designed for this purpose, including power-driven winch, cable-feeding flexible tube guide, cable grips, and lubricants.

4.3.5.3 A sufficient number of trained personnel and equipment shall be employed to ensure the careful and proper installation of the cable.

4.3.5.4 Pulling force shall not exceed manufacturer's recommendation and a dynamometer shall be used in the pulling line to ensure that the pulling force is not exceeded. The dynamometer shall be calibrated, and calibration shall be up to date.

4.3.5.5 Suitable, purpose-designed rollers shall be used where pulling is necessary.

4.3.5.6 A non-conducting lubricant or cable-pulling compound, non-injurious to the insulation or sheath, shall be used as a lubricant to aid in pulling wire or non-metallic sheathed cable, where required. Oil or grease shall not be used for lubrication and excessive pulling stresses shall not be permitted.

4.3.5.7 Woven-wire cable grips shall be used to grip cable ends when pulling small cables and short straight lengths of heavier cables.

4.3.5.8 Pulling eyes shall be attached to the cable conductors to prevent damage to the cable structure.

4.3.5.9 Pulling eyes and cable grips shall be used together for non-metallic armor cables to prevent damage to the cable structure.

4.3.6 Bending radius

4.3.6.1 The manufacturer's bend radius specification shall be respected.

4.3.6.2 If the information is not available, the *Contractor*, with the approval of *LUCELEC* or its *Representative*, can use twelve (12) times the outer radius of the cable.

4.3.7 Cables fastening

4.3.7.1 For horizontal cable trays, all cables shall be fixed with heavy duty cable ties ETFE- type. A distance of 1000 mm maximum between cable ties shall be respected.

4.3.7.2 For vertical cables trays, all cables shall be fixed with heavy duty P clamps. Spacing shall not exceed 600 mm.

4.3.7.3 For single conductor or multiconductor cables in parallel heavy-duty Aluminium or Stainless-Steel P clamps shall be used for either horizontal or vertical installation.

4.3.8 Cables fittings or glands

4.3.8.1 A fitting or gland shall be installed at each end of a cable.

4.3.8.2 Particular care shall be taken to ensure that the cable armour is properly secured by the conical armour clamp within the gland, on which the gland plate grounding conductor is properly connected.

4.3.8.3 The *Contractor* shall verify wherever single-core cables are used, that the gland-plates supplied is made from non-magnetic material.

4.3.9 Lugs

4.3.9.1 Lugs are to be crimped onto the conductors with proper crimping tools.

4.3.10 Termination and splice

4.3.10.1 Joints and splices in cable runs are not allowed unless written approval is received from *LUCELEC* or its *Representative*.

4.3.10.2 All medium voltage cable terminations and splice shall be done by an approved third-party company, subcontracted by the *Contractor*, unless the *Contractor* can provide suitable credentials and experience to prove that they are capable of performing the terminations and testing themselves.

4.3.11 Multiconductor cables grounding

4.3.11.1 The armor, shield and sheath shall be grounded at both end of the cable.

4.3.11.2 Armouring is to be bonded to ground at each end of each cable via the cable gland and the gland plate conductor.

4.3.11.3 Under no circumstance whatsoever, may the armoring of any cable be used as the sole conductor for grounding or bonding purposes.

4.3.12 Single conductor cables grounding

4.3.12.1 The armor, shield and sheath shall be grounded at supply end only up to a maximum length of 150 m. For longer runs of the cables, the shield shall be grounded at 150 m intervals.

4.3.13 Testing

4.3.13.1 Medium voltage cables and termination shall be tested with a VLF (Very Low Frequency) test.

4.3.13.2 Site installation checks and test for all wires and cables and their terminations shall include:

- Checks for any cuts or abrasions in the insulation or protective covering, or kinks in the insulation, jacket or amour.
- Connection tightness and termination security checks - visual and physical.
- Circuit continuity test using an accurate ohmmeter.
- Insulation resistance test, using 1,000 V megger for all equipment rated 600 V and above and 500 V megger for equipment rated less than 600 V, - recording each minute until three equal and consecutive readings, with acceptance being a minimum of 50 megohms between phase conductors and between phase conductors and ground in a 3-phase 600 V circuit and 25 megohms in a 300 V circuit.
- Armor and shielding continuity and grounding checks, using an accurate ohmmeter.
- In addition, for MV cables and their terminations, high-potential dielectric withstand test in accordance with the manufacturers recommended test procedures.

4.3.13.3 Site installation checks and tests for all fibre optic cables and their terminations shall include:

- *LUCELEC* will provide detailed testing requirements.
- Armor and shielding continuity and grounding checks, using DC bell or buzzer, etc. and/or accurate ohmmeter.

All test data and checks shall be recorded and shall include the location and identification of equipment's and megohm readings versus time for insulation tests.

4.4 Medium Voltage and Low Voltage Termination Kits

4.4.1.1 Termination kits shall be of heat shrink design, and shall contain:

- Internal insulation tubing.
- Stress control tubing.
- Anti-track tubing, moisture sealant.
- Compression lugs, ground strap.

- Constant tension clip to connect ground strap to shield.
- Insulation boots.
- Cable breakout for the cables.

4.4.1.2 Termination kits shall be suitable for the cable type and size, shall have compatible voltage and insulation class, and shall meet the IEEE 48 design and test requirements.

4.4.2 Medium Voltage Installation

4.4.2.1 For indoor, MV cables shall be terminated with stress relief cones or special termination fitting, which shall be installed strictly in accordance with the instructions of the cable or termination manufacturer.

4.4.2.2 Care shall be taken in constructing stress cones to install the cone to the specified dimensions and to properly terminate and ground the outer shield conductor with the shield wire connected to the ground grid at only one end of the cable.

4.4.2.3 If the MV cable ends are not to be terminated on the same working day that they are cut, the *Contractor* shall immediately protect cable ends from damage or moisture by sealing with cable caps and silicone sealant, provide stress relief at all terminations, provide correct phasing of the conductors of each circuit at all terminations, and provide proper connections of tape shield or tape shield and drain wire to ground.

4.4.2.4 The completed MV cable terminations shall have voltage ratings of not less than 15,000 V (ungrounded neutral) and shall be subjected to standard withstand test voltage conforming to IEC standard 60502-4.

4.4.3 Low Voltage Installation

4.4.3.1 Terminal blocks shall be identified as per *Schedule H – LUCELEC Design Criteria and Standards.*

4.4.3.2 Not more than two wires or multi-conductors shall be connected at any device terminal or terminal block point.

4.4.3.3 All multi-core cables with metal armour shall have the armour bonded to ground at both ends.

4.4.3.4 Individual wires shall be terminated with compression-type terminals with NEMA standard hole sizes.

4.4.3.5 Individual wires shall be terminated to stud-type terminals on relays, meters, terminal strips, etc., using ring type lugs with only one wire in each lug.

4.4.3.6 All crimp-on compression lugs shall be installed according to manufacturer's specifications using approved tools.

4.4.3.7 The use of twist wire nuts (Marettes) for terminations or joints is not acceptable.

4.4.3.8 The *Contractor* shall ensure that DC and AC circuits are not terminated on the same terminal strip and instrumentation circuits shall be grouped and shall not be located beside control or power circuits.

4.4.3.9 When preparing a cable termination, the copper shield may be cut back to the edge of the outer cable jacket. The inner PVC bedding jacket may be cut back as required, either at the cable termination point or used as wire management for the cable conductors continuing to the point of wire termination. Both drain wires are to be terminated in accordance with the *LUCELEC*'s standard grounding practices. The bare copper drain conductors are to be insulated with clear plastic tubing of sufficient diameter for either individual or for both drain wires.

4.5 Control Cables

4.5.1.1 Control cables shall comprise of 600 V rated, armoured, multi-conductor with stranded annealed, soft bare copper conductors, XLPE insulation, fire retardant, low-acid-gas-emitting PVC inner jacket and overall spiral-wound copper shield, interlocked armour and fire retardant, low-acid-gas-emitting PVC outer jacket.

4.5.1.2 Control cables confined to tray and enclosures only, with no exposed field runs, non-armoured, tray-rated, multi-conductor cable with RW90, XLPE-insulated copper conductors, copper shield and flame-retardant Low-Acid-Gas Evolution PVC outer jacket, shall be acceptable.

4.5.1.3 Shielded cables shall have (2) helically applied 1.5 mm^2 - 19 strand bare copper drain wires. These are required to be in contact with the copper tape shield at all points throughout the cable length.

4.5.1.4 Conductors of a multi-conductor power shall be number coded.

4.6 Instrument Transformer Cable

4.6.1.1 Cables used in instrument transformer secondary circuits shall be stranded copper conductors in overall amour, with colour-coded conductors, as follows. Conductors shall have an overall copper tape shield with 50% overlap between turns.

4.7 Instrument Cable

4.7.1.1 Instrument cables shall be comprised of minimum 600 V, armoured, multi-conductor cable with stranded annealed, soft bare copper with XLPE insulation, twisted-pair or twisted-triad conductors.

4.7.1.2 Instrument cables shall include either spirally shielded copper, or aluminum mylar tape, with a tinned and stranded copper drain wire shields for each twisted pair or triad of conductors and for overall assembly of conductors, interlocked aluminum armour and fire retardant, low-acid-gas-emitting PVC outer jacket rated 90°C.

4.7.1.3 Cables shall have two helically applied 1.5 mm^2 - 19 strand bare copper drain wires that are in contact with the overall shield, at all points throughout the cable length. One 1.5 mm^2-19 strand drain wire within each individual pair or triad shall be provided.

4.8 Fire Alarm Cable

4.8.1.1 Cables shall be heavy duty 105°C and shielded.

4.8.1.2 Cables shall be rated for 300 V.

4.8.1.3 Outer jacket shall be of red colour and FT4 rated for cable tray installation and FT6 for plenum installations.

4.8.1.4 Minimum size conductor for fire alarm signalling circuits shall be 1.5 m^2.

4.9 Communications Cable – General

4.9.1 Material

4.9.1.1 Network cables shall be color-coded to distinguish between industrial and IT networks.

LAN	Color
SCADA	Blue
Corporate	Yellow
Video Surveillance (CCTV)	Purple

4.9.1.2 Fibre Optic Cables shall be coded as follows:

Type	Color
Single Mode OS2	Yellow
Multimode OM1 and OM2 (62.5 µm)	Orange
Multimode OM3 & + (50 µm)	Blue (Aqua)

4.9.1.3 These color cables shall not be terminated in the same equipment unless that equipment contains a gateway to control the data interchange.

4.9.2 Installation

4.9.2.1 *Contractor* shall install all components in accordance with the contract drawings and the manufacturer's recommendations.

4.9.2.2 Minimum bend radius shall be a minimum of four times the cable outside diameter and shall observe any additional vendor recommendations.

4.9.2.3 A minimum spare length of 5 meter on each side of the cabinet is required.

4.9.2.4 Communication cables shall not be routed near lighting ballasts, power cables, or motors. Communication cable distances from various equipment, shall be:

• Transformers up to 5 kVA	1,000 mm
• Power Lines (230 VAC power systems)	300 mm
• Fluorescent Lighting Ballasts	300 mm
• Power Lines (400 VAC power systems)	1,000 mm
• Power Lines (>400 VAC power systems)	1,500 mm
• Electrical Motors	1,000 mm
• Mechanical equipment (coils, dampers, VAR boxes etc.)	300 mm
• Transformers >5 kVA	3,000 mm

4.9.2.5 *Contractor* shall clearly identify and tag all communication cables with cable number markers at both ends as indicated on the Drawings or the shop drawings of the designer.

4.9.2.6 All wiring closets, patch panels, switches, devices, individual room ports, wall jacks are to be identified.

4.9.2.7 All CAT 6 wiring shall be installed by cabling system manufacturer trained technicians

4.9.2.8 Supply and install conduits and pull boxes as required.

4.9.2.9 Conduit shall be used for all surface mounted communication outlet boxes.

4.9.2.10 Where conduit is used, there shall be no greater than 180 degrees of offset between pull boxes.

4.9.2.11 No power cables are allowed in communication cable tray or conduit.

4.9.2.12 Install the panels and racks as shown on the issued for construction package and supply hardware and anchors required for installations.

4.9.2.13 The panels and racks shall be bonded to the facility ground grid in accordance with the Drawings.

4.9.2.14 Terminate communication cables in accordance with the approved connection diagram and supply all glands for cable entry into the panel, heat shrinks, and terminal lugs.

4.9.2.15 Twenty-five pair CAT 6 riser cable shall be installed in conduit.

4.9.2.16 Category 6 cables to be installed using strain relief bars or cable support bars, wire management panels and Velcro tie wraps for neatness.

4.9.2.17 After being placed in a tray, cable shall be neatly straightened and positioned to present an orderly appearance and to aid in tracing cable circuits.

4.9.2.18 All cables shall be supported in cable trays or approved cable raceways. Cable drops (except fibre optic cables) outside of the cable tray are not to exceed 10 m and must be supported at 2 m intervals by 'P' clamps or on Unistrut or similar support hardware and/or secured to cable ladders or instrument trays.

4.9.2.19 Anchoring and securing of wires and cables shall be with secure mechanical fasteners. Adhesive fasteners are not acceptable.

4.9.2.20 Multi-core cables with an overall outside diameter greater than 40 mm shall be individually clamped. Hold-down clamps and straps shall be of non-corrosive material and be compatible with the cable sheath and the support material. Single core cable shall be secured and supported individually or in trefoil-configuration with suitable non-magnetic clamps, straps or saddles, regardless of the diameter.

4.9.2.21 Spare wires in the multi-core cables shall be neatly tied back with sufficient length to reach any point in the enclosure. Spare wires shall be either grounded at both ends or the ends shall be taped.

4.9.3 Testing and Inspection

4.9.3.1 Each communication cable shall be test with an approved testing equipment type OTDR to confirm the data is transiting correctly.

4.9.3.2 In addition, fibre optic cable shall be tested to measure the attenuation value. The obtained value shall be then written down in the test report.

4.9.3.3 On the single mode fibre optic cable, the test shall cover the following wavelength:

- 1310 nm;
- 1550 nm.

4.9.3.4 The *Contractor* shall submit a complete test report.

4.9.3.5 Upon completion and verification of performance of installation, remove surplus materials, excess materials, rubbish, tools and equipment.

4.10 Communications Cable – Non-Fibre

4.10.1 Material

4.10.1.1 Non-fibre twisted-pair communication and control cables shall be CAT6, UTP, AMP Type 219560-8 or *LUCELEC*'s approved equivalent.

- Jackets shall be colored Blue, for *ESS* LAN, Yellow for Corporate LAN and phone, purple for Security LAN.

- Cable installed in cable trays shall have minimum FT4-rated outer jackets, otherwise they shall be installed in protective conduit tubing providing minimum FT4 rating.
- CCTV cables shall be CAT6 F/UTP shielded twisted pair.

4.10.2 Installation

4.10.2.1 The *Contractor* shall provide service loops of 3 m for cable ends in the communications room and 305 mm for cable ends at devices external to the communications room, on each end of each cable run.

4.10.2.2 The maximum allowable pulling tension for CAT6 four pair copper shall be 110 N.

4.10.2.3 The minimum allowable bending radius for CAT6 four pair copper cable shall be four times the cable diameter.

4.10.2.4 CAT6 cables shall not be spliced.

4.10.2.5 CAT6 communications cable shall not be terminated on screw terminals except where specifically indicated.

4.10.2.6 An approved insulation displacement connection (IDC) tool kit for copper cable terminations shall be used for all CAT6 cable terminations.

4.10.2.7 CAT6 cables shall not be untwisted for more than 12 mm from the point of termination to maintain cable geometry.

4.10.2.8 All elements of CAT6 cables shall be terminated and no cable shall contain un-terminated elements.

4.11 Communications Cable - Fibre Optic

4.11.1 Material

4.11.1.1 All Fibre shall be made of glass only.

4.11.1.2 Fibre cable installations must comply with manufacturer's recommendations and with information provided within this Technical Specification document.

4.11.1.3 All multimode cable installed as part of this contract shall contain multimode fibres with a 125-micron cladding and 62.5-micron core. Hybrid fibre shall contain a combination of multi-mode and a single mode cable.

4.11.1.4 Single mode fibre optic cables shall be used for CCTV and security system with 125-micron cladding and shall be compatible with the equipment provided.

4.11.1.5 All fibre cables shall be capable of supporting a short-term tensile load of 273 kg, without stretching, and shall be capable of bend radii of 15x times outside diameter under tensile load and 10x outside diameter under no tensile load. Minimum crush resistance of the cable shall be 150 kg/cm.

4.11.1.6 Cable installation inside the containerized buildings must meet a minimum of FT4 requirements. This can be accomplished through use of cable that has FT4 rated jacket or placing the cable inside of FT4 rated conduit (either PVC or EMT).

4.11.1.7 The Fibre optic cable shall be suitable for direct burial and/or underground conduit installation.

4.11.1.8 The Fibre optic cable shall be two sheath-slitting cords (a.k.a. ripcords) under each jacket at 180° apart.

4.11.1.9 The fibre and buffer tube shall be loose tube type.

4.11.1.10 The cable outer jacket sleeve marked to indicate, as a minimum, fire test rating, core/cladding size, strand count, sequential length in metres manufacturer and part number.

4.11.1.11 Cable construction shall prevent moisture from entering the interstitial spaces between fibres and buffer tubes using Dry block technology

4.11.2 Installation

Fibre optic cable can be easily damaged if due care is not used during the installation process therefore the following guidelines and techniques are to be adhered to the following:

4.11.2.1 Any unused strands shall be coiled at termination panels for future use.

4.11.2.2 Where redundant fibres are installed, primary and secondary fibres shall not run in the same cable tray to increase the reliability of the network.

4.11.2.3 No splice shall be acceptable between device and fibre optic termination panels.

4.11.2.4 The maximum allowable attenuation for any splice or termination is 0.3 dB.

4.11.2.5 The minimum static bend radius (i.e., long term while the cable is stored or in place after installation) is 10 x or 15x the cable's outer diameter (OD) - to be confirmed by the manufacturer. If information not provided, assume 15 times OD.

4.11.2.6 Fibre optic cable shall not be sharply bent or kinked as glass fibres cannot be straightened. It can also damage the fibre permanently, resulting in expensive repair work.

4.11.2.7 Pull the cable by hand or use a breakaway swivel to prevent cable damage. The *Contractor* shall ensure that the pulling tension does not exceed the manufacturer's recommendations to prevent glass fibres from stretching, fracturing or breaking.

4.11.2.8 When pulling a long length of fibre cable through a conduit, re-reel or "figure-eight" the excess to prevent cable damage due to kinks or sharp bends.

4.11.2.9 Do not install other cables or conductors in the same conduit or duct designated for fibre optic cable.

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4.11.2.10 Do not attach extra hardware or unrelated attachments to the fibre optic cable conduit or duct.

4.11.2.11 Seal any unused or spare fibre optic dedicated conduit at both ends.

4.11.2.12 Cap or seal all outside ducts with “duct seal” or a duct plug where the duct enters a building. If the duct is an empty spare, install a plastic cap. If the duct contains a cable, seal around the cable with duct seal or use a duct plug around the cable. Duct seal material shall be of a type which shall not degrade cable jackets.

4.11.2.13 Non-armoured fibre optic cables shall be installed either in dedicated fibre guard trays or, when installed in the same tray with control cables, fibre optic cable can also be installed in either 2 in. PVC or EMT conduit. Where conduit is used for installation, the following paragraphs apply:

- Junction boxes are not acceptable for bends or changes in direction of installed conduit or duct because they do not provide bend radius control.
- LB type conduit fittings are not allowed for fibre duct installations because they do not provide bend radius control.
- Pullboxes shall be at least 1.2 m (48") long with minimum cross-sectional dimensions of 0.1 m x 0.1 m (4" x 4") and used after every two 90º bends and/or every 30 m (100'). Metal pullboxes must be bonded to ground.

4.11.2.14 Fibre optic cables to be installed in cable trays shall have FT4-rated cable jackets.

4.11.2.15 At no time shall more than 2,700 N of tension be placed on any fibre cable while it is being pulled through tray or conduit.

4.11.2.16 It is preferred that all fibre cable be pulled with hand power only. If power winches or mechanical advantage devices are used to pull cable, a tensionometer shall be used to ensure that maximum tension is not exceeded. Alternatively, a “mechanical fuse” composed of a swivel and breakaway combination rated at 2,500 N may be included in the linkage.

4.11.2.17 Torsion forces on the fibre optic cable during installation shall be avoided by the use of a swivel at the cable end.

4.11.2.18 While under pulling tension, the minimum allowable bend radius shall be 15x the outside cable diameter, which shall be ensured through the use of suitable pulleys and sheaves where required.

4.11.2.19 After pulling, the minimum allowable bending radius at rest shall be 10x the outside cable diameter - subject to confirmation by cable manufacturer.

4.11.2.20 Fibre optic cables shall be pulled only from tops of reels in long smooth bends. As the cables are un-reeled, they shall be carefully inspected for sheath defects. If defects are found during the pulling operation or if the cable on the reel binds, twists, or does not roll off freely, the

pulling operation shall be stopped immediately and *LUCELEC* and its *Representative* shall be notified.

4.11.2.21 The *Contractor* shall use pulling compound or lubricant where necessary. Lubricants shall be compatible with the cable jacket material and shall be used in accordance with manufacturer's recommendations.

4.11.2.22 The *Contractor* shall ensure that the clamps used during cable pulling do not over-cinch or crush the cables. Cables are intended to be pulled from one end only and not gripped midway. Appropriately sized travelers must be used for pulling around corners or above equipment. The *Contractor* shall follow manufacturer's recommendations regarding size of the travelers.

4.11.2.23 Lengths of fibre in the order of 5 m - 10 m of cable must be provided at either end of a fibre run. These storage loops can be of open formation in the case of aluminum interlocked armour or within a Hoffman box for non-armoured cable. Said storage must be incorporated when planning routing of the cable from termination location to termination location.

4.11.2.24 Sheaths of armoured fibre cable are to be grounded at one end only to reduce the potential for circulating currents. Cable sheath at the ungrounded end must be shrink wrapped appropriately to prevent inadvertent ground or personnel contact. Labelling in the vicinity of the ungrounded end of the cable shall clearly indicate that the far end of the cable is grounded.

4.11.2.25 All fibre-optic cables will be terminated by the *Contractor* in accordance with the specifications.

4.11.2.26 Unless otherwise advised by *LUCELEC* or its *Representative*, all fibre optic terminations shall use SC type connectors with zirconium ferrule inserts.

4.12 Conductor Identification

4.12.1.1 The *Contractor* shall identify in a permanent manner all conductors.

4.12.1.2 The *Contractor* shall identify all power conductors by using the color code from IEC 60445 - Annex A.

4.12.2 Method of Conductor Identification

4.12.2.1 Cable identification shall be done using a combination of colours and alphanumeric tags.

4.12.2.2 Wire identification shall be done using a combination of colours and alphanumeric ferrules.

4.12.2.3 For intra-panel wiring, the terminal strip or device label shall be prefixed to the terminal number, separated by a colon (e.g., TB1:5).

4.12.2.4 For inter-panel wiring, the number of the primary panel or equipment involved shall be prefixed to the conductor identification described for intra-panel wiring, separated by a hyphen (e.g., CP1-TB1:5).

4.12.3 Location of Conductor Identification

4.12.3.1 Each conductor shall carry the same identification at each end of the conductor.

4.12.3.2 Tags shall be securely attached to each cable, in clearly visible locations.

4.12.3.3 Tags shall be attached to each end of each conductor and cable, at each junction box, in intermediate pulling boxes and at points of entering or exiting cable trays or conduits.

4.13 Cable Tray

4.13.1 Material

4.13.1.1 All metal cable trays shall comply to the IEC 61537 standard.

4.13.1.2 Cable trays shall be aluminum ladder type with 300 mm rung spacing and side rail height of 125 mm.

4.13.1.3 The designed vertical grouping of the cable tray runs is generally in accordance with the voltage level of the supported cables, with highest voltage at the top, as follows:

- MV power distribution.
- 230-400 V power distribution.
- DC power distribution.
- AC control systems.
- DC control systems.
- Communication and computer network systems.

4.13.2 Installation

4.13.2.1 All cable trays shall be run parallel to or perpendicular to building lines.

4.13.2.2 All cable trays shall be installed to ensure that cable bends are equal to or greater than the manufacturer’s specified minimum bending. The minimum radius for horizontal elbows, vertical riser, tee and cross trays shall be 305 mm.

4.13.2.3 Cable trays shall not be run on roofs or exposed exterior surfaces unless approved by *LUCELEC*.

4.13.2.4 In areas where cables may be exposed to physical damage, cable tray installations shall include solid covers. Cable trays extending vertically through floors shall be totally enclosed for 2 m above the floor to provide mechanical protection.

4.13.2.5 A minimum 150 mm vertical clearance shall be maintained between cable trays in tiers, except for trays with cables 50 mm or more in diameter for which 300 mm clearance shall be maintained. This measurement shall be made between the closest part of each tray, not the rungs.

4.13.2.6 A minimum clearance of 300 mm shall be maintained between the top of the tray to all ceilings, heating ducts and heating equipment, with 150 mm clearance allowed for short obstructions and 600 mm horizontal clearance shall be maintained on at least one side of cable trays to adjacent trays or other structures.

4.13.2.7 Cable tray runs with expansion joints shall be installed per the manufacturer's recommendations. Expansion joint splice plates shall be used to allow 30 mm of free movement between trays wherever the trays cross a structural expansion joint.

4.13.2.8 All cable trays shall be supported from building structural members. Drilling or welding of structural members shall only be permitted where necessary and shall be evaluated for the effect on the structure and approved by the *LUCELEC* or its *Representative* before work starts. Embedded heavy-duty channel supports will be supplied in concrete walls and ceilings, to accept threaded rod or other types of hangers and brackets. Where there is no embedded channel, the *Contractor* shall provide surface channels.

4.13.2.9 Cable trays shall be secured using specific-purpose clamping hardware provided by the tray manufacturer. Support fasteners shall be wood screws to wood, toggle bolts on hollow masonry units and concrete inserts or expansion bolts on concrete or brick. Load applied to fasteners shall not exceed one-fourth proof test load. Holes cut to depth of more than 40 mm in reinforced concrete beams or to depth of more than 20 mm in concrete joints shall not cut main reinforcing bars.

4.13.2.10 Cable trays shall be supported at intervals not greater than 3 m, and so that the tray deflection under maximum load shall not cause permanent deformation or weakening of the cable tray. The maximum mid-span deflection of the tray shall not exceed 10 mm.

4.13.2.11 Brackets for attaching trays to walls shall be standard tray fittings. Brackets for support from ceilings shall be either tree-type or trapeze-type.

4.13.2.12 Tree-type brackets shall consist of one vertical double-channel center section fastened to inserts in the ceiling and carrying adjustable tray supports on each side.

4.13.2.13 Trapeze-type brackets shall consist of two 12 mm (1/2" nominal) threaded rods suspended from inserts in the ceiling, to which are attached one or more horizontal steel channel sections upon which the tray shall be clamped.

4.13.2.14 Supports shall adequately support the cable tray per the manufacturer's recommendations. Only one tray joint shall be allowed between a set of supports.

4.13.2.15 In passages, walkways, and other access areas, supports shall be installed so that protruding ends are kept to a minimum length.

4.13.2.16 Excess ends of supports and hanger rods shall be cut-off and field cuts shall be smoothed and painted with a suitable corrosion inhibiting coating. Touch-up paint shall be an organic, cold galvanizing compound having a minimum of 65% zinc dust in the dried film.

4.13.2.17 Alternative method is to cut off and terminate with acorn nuts (of material similar to nuts/rods).

4.13.2.18 The *Contractor* shall, where necessary, modify the installation position of the cable trays in coordination with the on-Site mechanical ductwork, piping, structural members, fireproofing and sprinkler system piping to ensure the cable trays remain accessible after installation and do not interfere with the Work of other trades.

4.13.2.19 The *Contractor* shall coat all field-cut ends of galvanized steel with a Galvafroid coating or approved equivalent.

4.13.2.20 A continuous ground conductor, minimum size 35 mm^2, shall be provided throughout the length of the cable tray run. The ground conductor shall be bonded to the cable tray.

4.13.2.21 Only the manufacturer's fittings shall be used and no field modifications to tray sections or fittings, to create custom elevation or directional changes, will be permitted unless authorized by *LUCELEC* or its *Representative*.

4.13.2.22 Holes shall not be cut in cable tray for the purpose of allowing cables to exit unless shown on the *LUCELEC*'s Drawings or specifically authorized by *LUCELEC* or its *Representative*. Where such holes are approved, they shall be provided with dropout fittings or grommets to provide protection to the cable jacket.

4.13.2.23 Where specified, power cables shall be laid in cable trays with 100% spacing maintained between circuits, with the cables held in position by means of specific design cable clamps, spaced at no greater than 1,500 mm intervals. Typically, power circuits comprising of single-conductor cables, 70 mm^2 or larger shall be installed in a flat arrangement with the arrangement and spacing maintained. Where specified, 100% spacing for 3-phase cables shall be maintained by means of metal single-cable clamps. In tray runs where one horizontal spaced layer of cables is possible. *Contractor* may propose the use of alternate spacing means to ensure cable spacing is maintained at not less than one cable diameter so as to retain the ampacity rating of the cables.

4.13.2.24 Where non-spaced cables are specified, the cables shall be laid neatly, in layers, with a flat arrangement.

4.13.2.25 Control cables shall be laid neatly, in layers, with a flat arrangement. Barrier strips shall be installed in mixed use cable trays for separation of power and control cabling and in specified sections of power circuit cable trays for separation between controlled-spacing cable installation and random fill cable installation.

4.13.2.26 Cable trays carrying high voltage cables shall be marked "Danger "voltage level" V" by self-adhesive signs at a minimum interval of 30 m and in every room or enclosed area through which the trays pass.

4.14 Cable Trench

4.14.1.1 Routing outside the containerized buildings shall be done by Cable Trench System.

4.14.1.2 The designed vertical grouping of the cable trench runs is generally in accordance with the voltage level of the supported cables, with highest voltage at the top, as follows:

- MV power distribution.
- 230-400 V power distribution.
- DC power distribution.
- AC control systems.
- DC control systems.
- Communication and computer network systems.

4.14.1.3 A plank, 38 m x 140 mm, pressure-treated with a waterproof preservation product shall be used for cable protection.

4.14.1.4 A red plastic ribbon shall be used as cable protection.

4.14.1.5 A 600 x 600 x 100 mm concrete protection and bearing the words: “cable”, “splice”, “conduit”, or “piping” printed on the upper surface shall be used when specified.

4.14.1.6 The concrete protection shall also have an arrow indicating changes in cable routing printed on it.

4.15 Firestop

4.15.1.1 Firestop materials shall be provided with a minimum fire resistance rating of 2 hours for the wall, floor or ceiling penetration.

4.15.1.2 Firestop materials shall be asbestos-free, capable of maintaining an effective barrier against flame, smoke and gases and rated not to exceed the opening sizes for which they are intended.

4.15.1.3 Firestop materials for cable bundles shall comprise of non-curing, re-penetrable, intumescent materials.

4.15.1.4 Accepted manufacturers of firestop materials are:

- Hilti.
- A/D Fire Protection Systems.

4.15.1.5 Wherever cables or conduits pass trough a fire rated partition, the *Contractor* shall fill the opening with compound in compliance with FM Global.

4.16 Conduit

4.16.1.1 Surface mounted and embedded conduits, fittings and accessories shall comply with the applicable IEC standards.

4.16.2 Material

4.16.2.1 All rigid metal conduits (RMC) shall be full weight and size, rigid, hot-dip galvanized steel. All conduit fittings, accessories, caps, bushings, and pennies shall be hot-dip galvanized for rigid metal conduits. Wooden plugs or makeshift caps for the embedded conduits will not be permitted.

4.16.2.2 Rigid conduits made of threaded galvanized steel shall be used for power conductor of 400 V and more.

4.16.2.3 Electrical Metallic Tubing (EMT) shall be used for power conductor of less than 400 V and low voltage signal.

4.16.2.4 Flexible Metal Conduit and Liquid-Tight Flexible Metal Conduit shall be used to connect any motor or any vibrating equipment.

4.16.2.5 Rigid PVC Conduit shall be used for underground installation and wherever required on the drawing.

4.16.3 Conduit Supports

4.16.3.1 For apparent conduit with a diameter equal to or lesser than 50 mm the support shall be a one (1) hole clamp made of the same material as the conduit.

4.16.3.2 For apparent conduit with a diameter greater than 50 mm the support shall be a two (2) hole clamp made of the same material as the conduit.

4.16.3.3 When installing apparent conduit on steel structure a Beam clamp shall be used.

4.16.3.4 To support more than two (2) conduit a U shape steel strut shall be used.

4.16.3.5 To support the steel strut from the ceiling treaded rod of adequate diameter shall be used.

4.16.4 Expansion Joint

4.16.4.1 For any outdoor installation expansion joint shall be used at every box connection as per code requirement.

4.16.4.2 A ground jumper shall be installed at each expansion joint.

4.16.5 Installation

4.16.5.1 Install apparent conduits in such a way to reduce, as much as possible, the clearance height of the room, and by using as little space as possible.

4.16.5.2 The minimum acceptable bending radius shall be six (6) times the interior diameter for conduits measuring 50 mm or less and ten (10) times the interior diameter for all conduits measuring 60 mm and above.

4.16.5.3 An expansion joints shall be installed at each building crossing.

4.16.5.4 In humid or hazardous locations sealing gaskets shall be installed.

4.16.5.5 All conduits crossing areas where temperature variations may be greater than 20°C shall be isolated over a 3-meter distance and a drainage fitting shall be installed.

4.16.5.6 Conduit shall be dried before pulling the cables.

4.16.5.7 Conduit shall be installed at a minimum of 1,500 mm of any heating apparatus.

4.16.5.8 Unless indicated otherwise, conduits shall not cross structural elements.

4.16.6 Concealed Conduits Installation

4.16.6.1 It is forbidden to install conduits horizontally in masonry walls.

4.16.6.2 All connections shall be done from the top of masonry walls.

4.16.6.3 Embedding conduits in terrazzo or in concrete screeds is forbidden.

4.16.7 Embedded Conduits Installation

4.16.7.1 Installation of the embedded conduit system shall consist of cutting to the correct length, bending, threading except for PVC conduits, and reaming ends, installation of expansion joints and general assembly of the conduit and fittings.

4.16.7.2 Bending shall be done in an approved manner and there shall be no flattening of the section or cracking of the conduit.

4.16.7.3 The ends of cut conduit shall be carefully reamed to provide a smooth interior surface when assembled.

4.16.7.4 All joints of the RMC conduits shall be threaded.

4.16.7.5 Welding of the RMC conduit will not be permitted.

4.16.7.6 The ends of the RMC conduit shall be protected and closed off by threaded caps or bushings and steel or fibre pennies. The end of the PVC conduits shall be protected and closed off by end caps.

4.16.7.7 Conduit and fittings shall be placed accurately in the forms and shall be securely fastened in place to prevent displacement either at the terminals or along the run.

4.16.7.8 All RMC conduit and fittings shall form a continuous metallic path, all joints or connections shall be watertight.

4.16.7.9 Where embedded conduit crosses a contraction or expansion joint, expansion fittings with integral bonding system shall be supplied and installed.

4.16.8 Embedded Conduits in Cast-in-Place Concrete Installation

4.16.8.1 Conduit shall be installed in the central third of the slab while taking into consideration the location of the frame.

4.16.8.2 The conduits exit point of the concrete structure shall be protected.

4.16.8.3 Couplings shall be installed at locations where the conduits go through a slab or a wall.

4.16.8.4 Prior to installing the waterproof membrane, install oversized couplings where conduits go through the membrane as well as cold-applied mastic between the coupling and the conduit.

4.16.8.5 Embed the conduits in concrete and cover the conduits with at least 25-mm of concrete.

4.16.9 Surface mounted conduits Installation

4.16.9.1 Conduits shall be run parallel or perpendicular to building lines. Conduits shall be grouped whenever possible.

4.16.9.2 Conduits shall be run on the flanged surface of structural steel and shall not pass-through structural members.

4.16.9.3 Conduits less than or equal to 53 mm trade size shall be supported by one-hole clamps. Conduits larger than 53 mm trade size shall be supported by 2-hole clamps.

4.16.9.4 Conduit support fasteners shall be wood screws to wood; toggle bolts on hollow masonry units; concrete inserts or expansion bolts on concrete or brick; and beam clamps, or spring-tension clamps on steel work. Conduits or conduit supports shall not be welded to steel structures.

4.16.9.5 Load applied to fasteners shall not exceed one-fourth proof test load.

4.16.9.6 Fastener holes drilled to a depth of more than 40 mm in reinforced concrete beams or to a depth of more than 20 mm in concrete joints shall not cut main reinforcing bars. Any unused holes shall be properly filled and finished.

4.16.9.7 Parallel conduit runs shall be supported on ‘U’ channels (trapezes) mounted at 1.5 m intervals. Horizontal channels (trapezes) shall be supported with threaded rod with a minimum diameter of 6 mm.

4.16.9.8 Supports or equipment installed for other trades shall not be used for conduit support unless specifically authorized by *LUCELEC* or its *Representative.* Conduits shall not be supported

by false ceiling support system. Conduit and box systems shall be supported independently of either tie wires supporting ceiling grid systems or ceiling grid systems into which ceiling panels are placed.

4.16.9.9 Pull boxes shall be installed at a minimum spacing of 30 m of conduit run. Conduit runs between outlet and outlet, between fitting and fitting, or between outlet and fitting must not contain more than the equivalent of three 90° bends, including those bends located immediately at the outlet or fitting.

4.16.9.10 Conduits and outlet bodies shall not be used as junction boxes.

4.16.9.11 Where conduit crosses building contraction or expansion joints, the *Contractor* shall install an approved expansion fitting, with internal bonding conductor, and shall provide bends or offset in conduit adjacent to building joint where conduit is installed above suspended ceilings.

4.16.9.12 Conduits installed outside or inside against a wall with condensation shall have spacing blocks.

4.16.9.13 Conduits shall be cut square, properly reamed, have cut threads and shall have threads brushed clean, and joints must be brought butt-to-butt in the couplings. All conduits shall be deburred and cleaned of all debris and moisture throughout its length before pulling any wires.

4.16.9.14 Where conduit is threaded in the field, each threaded end must consist of at least five full threads. Corrosion-inhibitive compound must be used on conduit threads in exterior areas.

4.16.9.15 The *Contractor* shall install polypropylene fish cord in empty conduits. The fish cord shall have a minimum 5 kN force tensile strength. A minimum 915 mm of slack length shall be provided at each end of cord.

4.16.9.16 The *Contractor* shall cap open conduit ends to prevent entry of dirt and moisture.

4.16.9.17 Field bending of conduit shall be carried out with approved hickey or conduit bending machines designed for the purpose, so as not to distort nor vary the internal diameter of the conduit. If the diameter of the bent conduit is less than 90% of the original diameter, the conduit must be discarded. Conduit elbows larger than 65 mm trade size shall be long radius, manufactured elbows.

4.16.9.18 The use of dissimilar metals throughout the conduit system shall be avoided to eliminate the possibility of galvanic corrosion. Place appropriate insulators between the two contact faces where dissimilar metals are in contact.

4.16.9.19 Conduit terminations in sheet metal enclosures shall be fastened with two locknuts and terminate with a bushing. The interior area immediately around the opening shall be cleaned free of paint to ensure a good bond between the conduit and enclosure. Install locknuts inside and outside enclosures.

4.16.9.20 Boxes shall be plumb with the surrounding structures, and shall be securely fastened in place, independent of the conduits or wires entering them.

4.16.9.21 A separate insulated ground conductor independent of the conduit shall be run in all conduits to every light fixture, receptacle and switch and shall be connected to the ground terminal in each conduit fitting and device. This ground conductor shall be continuous. It shall be the same size and type as the power wiring to the devices and shall have a green jacket.

4.16.9.22 Electric Metallic Tubing (EMT) conduit, where used, shall not be encased in concrete, mortar, grout or other cementitious material.

4.16.9.23 The *Contractor* shall install rigid steel conduit to extend conduit stubs through concrete floors for connection to free-standing or wall-mounted equipment. Above 150 mm over floor, flexible metal conduit may be used where permitted by the applicable standards.

4.16.9.24 Flexible metallic conduit shall be used to connect recessed fixtures from outlet boxes in ceilings, metallic transformers, and other approved assemblies. Runs of flexible steel conduit shall not be more than 1,800 mm in length and shall be installed only in exposed or accessible locations. Interior cut surfaces of flexible conduit shall be smoothed to be free from burrs and sharp edges which might cause abrasion of wire coverings. The ends of flexible steel conduit shall be provided with grounding bushings and approved fittings.

4.16.10 Underground Conduits Installation

4.16.10.1 Conduits shall be installed with a slope to ensure water evacuation.

4.17 Grounding and Bonding

4.17.1.1 The grounding/bonding system shall be electrically continuous throughout the ESS and tied back to the ESS Ground Grid.

4.17.1.2 More information on the *LUCELEC* Grounding and Bonding requirements can be found in *Schedule H – LUCELEC Design Criteria and Standards.*

4.17.1.3 Ground rod and ground grid design shall be based on soil resistivity testing, touch and step calculations, and all applicable standards.

4.17.1.4 The maximum width of the trenches shall be 200 mm.

4.17.1.5 The 2/0 perimeter ground wire and ground rods shall be at a depth of 500 mm.

4.17.1.6 All grounding grid connections below ground shall be made by CADWELD. There are three types of connections that will be completed by CADWELD

4.17.1.7 Copper conductor to copper conductor.

4.17.1.8 Copper conductor to ground rod.

4.17.1.9 Copper conductor to Copper Coated Steel CAMO conductor.

4.17.1.10 Potential Transformers, Current Transformers, lightning arrestors, breakers and any similar apparatus that is bolted to a structure, which is separately grounded to the main ground grid, shall be grounded to that structure. The apparatus shall be connected to the structure with a 24" flexible tin-plated copper strap or a suitable length of CAMO Copper Clad Steel 40%, 120 mm^2, 19 Strand cable with a lug at each end. Whichever is appropriate for the particular application.

4.17.1.11 Power and station transformers and any similar apparatus which is installed as a unit directly on a foundation, shall be connected to the main ground grid by means of CAMO Copper Clad Steel 40%, 120 mm^2, 19 Strand. One end of the cable shall be hand formed neatly around the foundation and transformer tank and bolted to the appropriate terminations (i.e., tank and lightning arrestor grounding pads, and neutral bushing, etc.)

4.17.1.12 Large pieces of electrical equipment such as switchgear, transformer shall have two (2) bonds.

4.17.1.13 All structural steel, metal enclosures, panels and equipment shall be bonded to the ESS grounding grid as per IEC 60364 requirements.

4.17.1.14 70 mm^2 conductor shall be run throughout the complete cable tray arrangement such that each individual cable tray piece can be connected to the 70 mm^2 copper conductor via a Burndy GB 26, or equivalent, type ground connector. The final length of the 70 mm^2 conductor shall be ran down one of the less cluttered panels, secured with tie wraps and terminate to the ground bus bar with an appropriate connector and hardware.

4.18 Lighting

4.18.1.1 Outdoor substation lighting materials and mounting accessories shall be supplied and installed.

4.18.1.2 Outdoor luminaires shall be connected to Hammond Manufacturing C3R884SC junction boxes.

4.19 Fibre Panel

4.19.1.1 *Contractor* shall supply a Corning CCH-02H rack-mount fibre panel for fibre distribution.

4.19.1.2 Fibre panel shall include two (2) single mode Corning CCH-CS12-59-P00RE and two (2) multi-mode Corning CCH-CS12-G7-P00BE spice cassettes.

4.19.1.3 Optical connectors shall be ST style for multi-mode and LC style for single mode.

4.20 Toxic Materials

4.20.1.1 Polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) shall not be used.

4.20.1.2 If a significant amount of toxic substance can be emitted from the equipment during a failure, fire or emergency/protective operation, an alarm system to alert personnel shall be included in the equipment. Description of the toxic nature of the substances as well as treatment for exposure to it shall be included in the O&M manual.

4.20.1.3 Where applicable, *Contractor* shall identify any spill risks that are credible for the types of cells used. The *Contractor* shall mitigate against any spills that are credible for the types of cells used. The design shall include features that contain any spills and prevent discharge to the surrounding environment.

4.21 Site Acceptance Testing

4.21.1.1 The *Contractor* shall supply all required materials, equipment and manpower to perform testing of electrical systems installed within the scope of work.

4.21.1.2 The *Contractor* is responsible for post-installation testing of electrical equipment such as transformers, breakers, switchgear, cables, relays etc. This equipment shall be tested using the latest edition of the applicable testing standards. All reports, as-builts and documentation shall be turned over to *LUCELEC*.

4.21.1.3 The *Contractor* shall develop turnover packages in accordance with the ESS work package documents.

5. Site Work

5.1 Equipment Installation

5.1.1.1 The *Contractor* is responsible of offloading all equipment supplied by the *ESS* scope.

5.1.1.2 *Contractor* shall install all equipment identified in the scope of work, in locations shown on the applicable layout drawings.

5.1.1.3 The *Contractor* shall prepare an installation and test plan for all equipment installed, which shall be submitted to *LUCELEC* as part of the construction package.

6. Performance, Asset Management, and Maintenance

6.1.1.1 All enclosures, auxiliaries, and controls are expected to last for the project life.

6.1.1.2 The *Contractor* shall assist *LUCELEC* with asset criticality ranking for Asset Management Planning.

6.1.1.3 The *Contractor* shall provide any requested information to be entered into *LUCELEC*'s Enterprise Asset Management System (completion of *LUCELEC* data sheets).

6.2 The *Contractor* shall provide a compiled list of all maintenance tasks and activities, and their frequency for the entire system to *LUCELEC.*

Schedule E

END OF SECTION