**Annex V: Relays and Communication Network for Protection System**

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# General Requirements

The scope of delivery shall include design, supply, install and commission of the protection relays and corresponding communication interfaces supporting the relay tele protection, remote control of the substation breakers and data exchange with monitoring and automation controller (PMAC).

At high-level through this project the following shall be provided:

* Protection settings calculation for the new relays
* A protection scheme with modern communication protocols for fast, reliable and selective protection schemes and other protection functions that can be added relatively easily in the future.
* Onboard metering of the protection relays for metering of main electrical parameters, such as current, voltage, power, frequency and energy thus negating the need for the installation of a replacement measuring devices at the VCBs.
* Protection relays with PMU capabilities providing synchrophasor measurement function that complies with IEEE C37.118 Standard.
* Data and messages from the protection relays to be acquired in the process monitoring and automation controller (PMAC) located in the power plant operator’s premises.
* GPS clocks with demodulated IRIG-B output connected to the protection relays
* Ethernet switches to communicate with the protection relays and PMAC for communication-assisted protection schemes or for data exchange purposes.
* New CTs and VTs for Isolating Transformers and the new switchgear.

Protection relays shall be provided for the substation feeders and two incoming lines, as well as for two isolating transformers, a battery storage system, synchronous condenser and other equipment installed in the new substation.

# Protection Relays Basic Technical Requirements

The relay protection system must continuously monitor the condition and operation mode of the power system elements, which are within the scope of this Project. Relay protection devices must respond to all kinds of faults, act on the circuit elements of the 13.8/4.16 kV grid to automatically trip the faulty section and allow the operator to restore the damaged/faulty section and return to normal operation. The protection system must be able to operate reliably with minimum generation and unilateral power supply action.

Each protection relay must include the functionality of indicating the approximate location of damage/fault on the power line.

The scope of supply shall be based on state-of-the-art multifunctional protection terminals and communication devices. It shall include:

* Interfaces for local and remote communication equipment.
* Wired and/or fibre optic connections to PMAC, auxiliary supply, measuring transformers and the circuit breaker.
* Time tagging systems.
* Engineering, factory testing, installation and site testing.
* Training on the job.
* Configuration and setting software, manuals, special tools at each protection supply location.

The relays shall be delivered as a lose equipment for housing in the new switchgear installed in the substation. They shall provide a combination of functions including protection, monitoring, control, and automation. Relay self-checking functions shall be included.

General requirements to the relay hardware are as follows:

* Operating temperature range of -10°C to +75°C
* Power supply input operating voltage range of 85-300 Vdc, 85-250 Vac.
* Demodulated IRIG-B time-synchronization input capability.
* 5A or 1 A, AC current inputs, and optional neutral current input.
* 300 V maximum, 3 AC voltage inputs.
* Flexible, configurable I/O, including digital I/O and analogue I/O
* High-speed outputs for tripping
* High-current interrupting output contacts
* Selectable current (up to ±20 mA range) or voltage (up to ±10 V range) analogue inputs.
* Relay front panel shall meet the requirements of NEMA Type 1/IP54.
* Type tests shall comply to IEC standards.
* Relay suitable for harsh environments.
* UL certified for hazardous locations.
* Service and support.

**Reliability.** The manufacturer shall supply the actual mean time between failures (MTBF) for the device upon request.

**Conformal Coating.** The device shall have optional conformal coating to protect the circuit boards from harsh environments.

**Service.** Technical support for five years within the price quoted for this project.

**Warranty.** Five-year warranty for all material and workmanship defects.

## Feeder Protection Relay Functional Requirements

These are the relays installed in the substation feeders

Specific requirements are provided below.

* Phase, residual, and negative-sequence overcurrent elements (50P/50G/50Q) with optional directional control
* Phase, residual, and negative-sequence inverse-time overcurrent elements (51P/51G/51Q) with optional directional control
* Nondirectional sensitive earth fault (SEF) protection and directional ground protection on low-impedance grounded or high-impedance grounded.
* Neutral overcurrent and inverse-time overcurrent elements (50N/51N)
* Breaker/contactor failure (BF)
* Auto reclosing control (79)
* Vector shift elements (78VS) for islanding detection
* Line/cable thermal elements (49T) per IEC 60255-149
* Over- and undervoltage (59/59G/59Q/27)
* Inverse-time over- and undervoltage elements (59I, 27I)
* Directional power elements (32)
* Power factor (55)
* Over- and underfrequency (81)
* Rate-of-change of frequency (81R)
* Fast rate-of-change of frequency (81RF) for vulnerability mitigation
* Loss-of-potential (60)
* Synchronism check (25)
* Second- and fifth-harmonic blocking (HBL)
* Incipient cable fault (50INC)
* Phase discontinuity detection (PDD)
* Broken conductor detection (BCD)
* Cold-load pickup element (CLPU)
* Disturbance Recorder (95DR)
* Event Recorder (95ER)
* Fault locator. The relay shall include a fault-locating algorithm to calculate fault location without communications channels, special instrument transformers, or pre-fault information.
* Synchrophasors. The relay shall include operation as a phasor measurement unit (PMU) following IEEE C37.118, IEEE Standard for Synchrophasors for Power Systems.
* Adaptive phase overcurrent elements. The relay shall incorporate adaptive phase overcurrent elements that perform reliably in the presence of current transformer saturation, DC offset, and off-frequency harmonics.

The relay shall provide the following logic and control functions:

* 32 local control logic points, 64 remote control logic points, 64 latching logic points, 64 counters, 64 math variables, 64 timers, and 128 remote analogs.
* Logic control equations with Boolean and math equations capability for logic and control.

The relay shall provide the following communications options:

* Modbus RTU/TCP, Simple Network Time Protocol (SNTP), Ethernet/IP, IEEE 1588 firmware-based Precision Time Protocol (PTP), Telnet, FTP, DNP3 or IEC 104 serial and LAN/WAN, IEEE C37.118 (synchrophasor data), IEC 61850, IEEE 802.1Q-2014 Rapid Spanning Tree Protocol (RSTP)
* Parallel Redundancy Protocol (PRP) and fast failover switching for dual Ethernet models.
* Copper and fiber-optic Ethernet port(s).
* Windows-based PC software for settings, report retrieval, metering, HMI, and control must be included in the scope.
* Built-in web server in Ethernet-equipped relays to access relay data and to perform firmware upgrades.
* IEC 61850 Test Mode support with standard operating modes On, Blocked, Test, Test/Blocked, and Off for easy commissioning.

Synchrophasor capabilities of the relay:

* The relay shall have embedded PMU functions complying with C37.118 IEEE Standard.

The relay shall provide the following time synchronization capabilities:

* The relay shall provide high-accuracy (±10 µs or better) phasor measurements for voltages and currents.
* The relay shall provide a selectable synchrophasor data update rate of 50 or 60 messages per second (depending on nominal frequency).
* The Relay shall be capable of being time synchronized with the Global Positioning System (GPS) using either an internal or external GPS Clock.

The relay shall provide the following visualization capabilities:

* The front panel shall be capable of displaying measured values, calculated values, I/O status, device status, and configuration parameters on a front-panel LCD display.
* The display shall have a rotating capability to display custom messages and data.
* The front panel shall also have user-programmable LEDs and user-programmable pushbutton controls with programmable LEDs.
* The feeder protection relay shall be ordered with front-panel touchscreen display.

The relay shall provide the following Touchscreen Display functionalities:

* The front panel shall be capable of enabling the rotating display and control of a breaker and as many as eight two-position and two three-position disconnects from the Bay Screens application. The front panel shall be capable of displaying bay screens, metering and monitoring data, targets, event summary and SER information, relay status and configuration, controllable relay operations, and editable settings.
* The front panel shall have a minimum of 6 user-programmable tricolor LEDs, a TARGET RESET and HOME pushbutton, and 4 or 8 user-programmable pushbutton controls with 8 or 16 programmable tricolor LEDs, respectively.

The relay shall have the following programming and reporting capabilities:

* **Load-Profile Monitoring.** Provides periodic snapshot (selectable rate from every 5 to 60 minutes) of minimum 15 selectable analogue quantities.
* **Metering.** The relay shall include metering capabilities for real-time current, voltage, power, energy quantities, and differential quantities, as well as phase demand and peak demand current values. Harmonic content from the fundamental to the fifth harmonic for all AC current and voltage inputs shall be included. Minimum/maximum metering shall also be included.
* **Through-Fault Event Monitor.** The relay shall provide for the capability of reporting fault current level, duration, and date/time for overcurrent events. A settable I2t alarm indicates an excess of accumulated through-fault energy.
* **Event Summaries.** Fault type and trip data, including time of tripping.
* **Event Reports.** 15-cycle length (as many as 100 reports) or 64-cycle length (as many as 25 reports) with 4 or 16 samples/cycle resolution
* **Disturbance/Sequential Events Recorder (95DR/95ER).** As many as 1000 time-tagged, most recent input, output, and element transitions.
* **Settings, Event Report, and SER Data.** Stored in non-volatile, Flash memory.
* **COMTRADE:** Exporting data in COMTRADE file format for external analysis.

## Transformer Protection Relay Functional Requirements

These are the relays installed in the isolating transformers

Specific requirements are provided below.

* **Percentage Differential Protection (87).** The relay shall incorporate restrained differential protection for two windings with fixed or variable percentage, using one or two settable slopes with adjustable intersection point and minimum pickup values.
* **CT Phase Angle Compensation.** The relay shall incorporate full “round-the-clock” current compensation, in 30-degree increments, to accommodate virtually any type of transformer and CT winding connection.
* **Harmonic Elements.** The relay shall incorporate second-, fourth-, and fifth-harmonic elements, with the choice of either harmonic blocking or harmonic restraint to prevent restrained differential element operation during inrush or overexcitation conditions; an independent fifth-harmonic alarm element shall be included to warn of an overexcitation condition.
* **Unrestrained Differential Protection (87U).** The relay shall include unrestrained differential protection to produce rapid tripping for severe internal faults.
* **Restricted Earth Fault Protection (87G).** The relay shall incorporate restricted earth fault protection for the detection of ground faults in wye-connected windings.
* **Overcurrent Fault Protection (50P, 50G, 50Q, 50N, 51P, 51G, 51Q,51N).** The relay shall incorporate two groups of three-phase current inputs that can be independently enabled for overcurrent protection. Overcurrent elements per group shall be included to provide phase, neutral, negative-sequence, and residual protection.
* **Overexcitation Volts/Hertz Protection (24).** The relay shall incorporate volts/hertz protection as an ordering option to detect and provide an output when user-settable volts/hertz thresholds are exceeded.
* **Breaker Failure Protection (50BF).** The relay shall provide breaker failure detection for two breakers. Breaker failure detection shall provide subsidence current detection to minimize system coordination times.
* **Directional Power Protection (32).** The relay shall provide three-phase directional power protection elements with real (watts) and reactive (VARs) input selection.
* **Loss-of-Potential Detection (LOP).** The relay shall provide loss-of-potential detection elements for detecting open voltage transformer fuses or other conditions that cause a loss of relay secondary voltage input.
* **Temperature Inputs (49).** The relay shall have the following features when equipped with internal or external RTD inputs: Optical fibre transmission of RTD temperatures to relay, separately field selected RTD types: PT100, NI100, NI120, or CU10.

The relay shall provide the following logic and control functions:

* 32 local control logic points, 64 remote control logic points, 64 latching logic points, 64 counters, 64 math variables, 64 timers, and 128 remote analogs
* Logic control equations with Boolean and math equations capability for logic and control.

The relay shall provide the following communications options:

* Modbus RTU/TCP, Simple Network Time Protocol (SNTP), Ethernet/IP, IEEE 1588 firmware-based Precision Time Protocol (PTP), Telnet, FTP, DNP3 or IEC 104 serial and LAN/WAN, IEEE C37.118 (synchrophasor data), IEC 61850, IEEE 802.1Q-2014 Rapid Spanning Tree Protocol (RSTP)
* Parallel Redundancy Protocol (PRP) and fast failover switching for dual Ethernet models.
* One EIA-232 or EIA-485 port, optional single or dual, copper or fiber-optic Ethernet port(s).
* Windows-based PC software for settings, report retrieval, metering, HMI, and control
* Built-in web server in Ethernet-equipped relays to access relay data and to perform firmware upgrades.
* IEC 61850 Test Mode support with standard operating modes On, Blocked, Test, Test/Blocked, and Off for easy commissioning.

The relay shall have embedded PMU functions complying with IEEE Standard Synchrophasor Measurements for Power Systems C37.118.1-2011 and IEEE Standard Synchrophasor Measurements for Power Systems, Amendment 1: Modification of Selected Performance Requirements C37.118.1a-2014.

* The relay shall provide high-accuracy (±10 µs or better) phasor measurements for voltages and currents.
* The relay shall provide a selectable synchrophasor data update rate of 50 or 60 messages per second (depending on nominal frequency).
* Be capable of being time synchronized with the Global Positioning System (GPS) using either an internal or external GPS Clock.
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The display shall have a rotating capability to display custom messages and data.

The front panel shall also have user-programmable LEDs and user-programmable pushbutton controls with programmable LEDs.

The Feeder Protection Relay can be supplied with the touchscreen display.

**Touchscreen Display**

The front panel shall be capable of enabling the rotating display and control of a breaker and as many as eight two-position and two three-position disconnects from the Bay Screens application. The front panel shall be capable of displaying bay screens, metering and monitoring data, targets, event summary and SER information, relay status and configuration, controllable relay operations, and editable settings.

The front panel shall have a minimum of 6 user-programmable tricolor LEDs, a TARGET RESET and HOME pushbutton, and 4 or 8 user-programmable pushbutton controls with 8 or 16 programmable tricolor LEDs, respectively.

The relay shall have the following programming and reporting capabilities:

* **Load-Profile Monitoring.** Provides periodic snapshot (selectable rate from every 5 to 60 minutes) of minimum 15 selectable analogue quantities.
* **Metering.** The relay shall include metering capabilities for real-time current, voltage, power, energy quantities, and differential quantities, as well as phase demand and peak demand current values. Harmonic content from the fundamental to the fifth harmonic for all AC current and voltage inputs shall be included. Minimum/maximum metering shall also be included.
* **Through-Fault Event Monitor.** The relay shall provide for the capability of reporting fault current level, duration, and date/time for overcurrent events through the differential protection zone. A settable I2t alarm indicates an excess of accumulated through-fault energy.
* **Event Summaries.** Fault type and trip data, including time of tripping.
* **Event Reports.** 15-cycle length (as many as 100 reports) or 64-cycle length (as many as 25 reports) with 4 or 16 samples/cycle resolution
* **Disturbance/Sequential Events Recorder (95DR/95ER).** As many as 1000 time-tagged, most recent input, output, and element transitions.
* **Settings, Event Report, and SER Data.** Stored in non-volatile, Flash memory.
* **COMTRADE:** Exporting data in COMTRADE file format for external analysis.

# Communication Network and Interfaces

Local Area Network (LAN) for protection system shall be based on ethernet switches installed in the new switchgear.

The switches should be selected in such a way that 50% of the ports are free or 50% expandability is possible for their use in the future.

The switches must be powered from the same source as the relay.

The switches must be suitable for harsh environments and UL certified for hazardous locations.

## Managed Ethernet Switch Requirements

The Managed Ethernet Switch shall meet the following specifications:

* **Ethernet Ports (with minimum 50% spare).** 10/100BASE-T copper ports, 100BASE-FX or 100BASE-LX fibre-optic ports.
* **Copper Interfaces.** Data rate: 100 Mbps, Connector: RJ45,
* Compatible cable: Category 5 shielded, twisted pair, Maximum distance: 100 m, Autoconfiguration: Crossover cable, speed, and half- or full-duplex operation.
* **Fibre Interfaces.** Data rate: 100 Mbps, Multimode (100BASE-FX), Maximum distance: 2 km, Wavelength: 1,300 nm.
* Single-mode (100BASE-LX), Maximum distance: 15 km, Wavelength: 1,310-1550 nm.
* **Virtual Local Area Networks (VLANs).** The device shall support IEEE 802.1Q-2005 VLANs.
* **Rapid Spanning Tree Protocol (RSTP).** The device shall support IEEE 802.1D-2004 RSTP.
* **Bridge Protocol Data Unit (BPDU) Guard.** The device shall be capable of automatically disabling a port receiving unexpected BPDUs.
* **MAC-Based Port Security.** The device shall support MAC-based port security.
* **Port Rate Limiting.** The device shall support setting maximum ingress and egress rates on device ports.
* **Multicast MAC Filtering.** The device shall support filtering multicast MAC addresses.
* **Layer 2 Traffic Prioritization.** The device shall support IEEE 802.1Q-2005 VLAN and Priority Tagging CoS traffic prioritization.
* **Layer 3 Traffic Prioritization.** The device shall support DiffServ DSCP traffic prioritization.
* **Port Mirroring.** The device shall support mirroring ingress and egress frames to a target port.
* **Simple Network Management Protocol (SNMP).** The device shall support SNMP v1, v2c, and v3.
* **Link Layer Discovery Protocol (LLDP).** The device shall support IEEE 802.1AB-2009.
* **Graphical User Interface (GUI)-Based Secure Management.** It is preferable but not mandatory the device provides a secure GUI-based management interface.
* **Automated Diagnostics and Reporting.** The device shall monitor health and functions and report state changes.
* **Settings Import/Export.** The device shall support importing and exporting device settings.
* **Secure Firmware Upgrades.** The device shall support authentication of firmware through digital signatures.
* **NTP Time Synchronization and Distribution.** The device shall be capable of performing as an NTP Customer.
* **Nonintrusive Monitoring and Setting.** The device shall provide an Ethernet interface to the HTTPS management port. The management port will be used for configuration settings and monitoring and will be protected with encryption and authentication algorithms.
* **Lightweight Directory Access Protocol (LDAP).** The device shall support centralized authentication through LDAP.
* **Remote Authentication Dial-In User Service (RADIUS).** The device shall support multifactor centralized authentication through RADIUS.
* **Configurable PCP to Priority Queue.** The device shall support configuring mappings of PCP to priority queue.
* **Configurable DSCP to Priority Queue.** The device shall support configuring mappings of DSCP to priority queue.
* **User-Based Accounts.** The device shall authenticate and authorize users using user-based accounts.
* **Logging.** The device shall log locally and forward event messages across an Ethernet network.
* **Configurable Alarm Contact.** The device shall support configuring the alarm contact behaviour for each event category.
* **Far End Fault Indication (FEFI).** The 100BASE-FX ports shall support FEFI.
* **Dual Power Supplies.** The device shall have a redundant power supply option.
* **Mounting.** The device shall be standard DIN rail mounted in the substation switchboard.
* **Suitable for Harsh Environments.** The device shall meet IEEE 1613 Class 1, IEC 61850-3, and IEC 60255 standards.
* **Reliability.** The manufacturer shall supply the actual measured mean time between failures (MTBF) for the device upon request.
* **Service.** A higher evaluation point will be awarded if the device shall include no-cost technical support for the life of the product.
* **Conformal Coating.** The device shall have conformal coating to protect the circuit boards from harsh environments.
* **Warranty.** The device shall include a five-year warranty for all material and workmanship defects.

# Time Synchronization

GPS satellite-synchronized clock clocks for synchronization with a time accuracy of up to a maximum of 0.1 ms, including modulated and demodulated IRIG-B ports shall be provided.

Relays must be time synchronised with a Global Positioning System (GPS), Coordinated Universal Time (UTC) reference using a GPS Clock. The GPS satellite-synchronized clock must be:

* Either an integral part of the relay or a separately manufactured product.
* Installed at each site to synchronise the relays.
* Supplied with all required accessories such as antennas, antenna cables and surge protection.
* Able to compensate for propagation delay in the antenna cable.

GPS clocks shall be installed in the cabinets for VCBs and shall be provided as a loose equipment for installation in the feeders and incomers switchboard.

Installation of antenna and corresponding coaxial cable is included.

GPS clock with synchronization over network functionality (NTP) shall be considered for the substation switchgear, other locations can be equipped with simple clocks.

The Process Monitoring and Automation Controller must have the facility to be time synchronised via a GPS or NTP clock, to allow for the accurate time synchronisation of alarms and events.

The GPS Clocks must be powered from the same source the relay and switch.The Clocks must be suitable for harsh environments and UL certified for hazardous locations.

## Satellite-Synchronized Clock Requirements

The satellite-synchronized clock shall provide high-accuracy time in multiple formats. Self-checking functions shall be included. Specific requirements are as follows:

* **High Accuracy**. IRIG-B demodulated outputs shall be within ±100 nanoseconds (average) and ±500 nanoseconds (maximum) of UTC time. Modulated output and serial port IRIG-B outputs shall be ±1 microsecond of UTC time.
* **Holdover Accuracy**. The clock shall have an accuracy of ±0.08 ppm for 20 minutes (over the entire operating temperature range) while the clock is not locked to the GPS satellite reference.
* **Time Outputs**. The clock shall have a minimum of one modulated IRIG-B output and demodulated IRIG-B outputs programmable to IRIG-B, 1 PPS, or 1k PPS. Any of the demodulated time outputs can be programmed for UTC or local time. The clock shall provide IRIG-B connection capability as well as ASCII time output at one serial port. An optional fibre optic serial port shall also be available.
* **IEEE Extended Control Functions**. IRIG-B outputs shall be capable of adding the extended control functions specified by IEEE 1344 and IEEE C37.118.
* **Daylight Time**. The clock shall have automatic daylight-saving time advance/return with presets for North America and Europe, or custom DST setting capability.
* **Alarm Contact**. The alarm contact shall be programmable to include loss-of-satellite lock, loss of power supply, and processor self-test failure. Alternately, the clock shall provide an output pulse per programmable period for testing or time synchronization.
* **Display**. Front-panel LEDs shall display UTC or local day and time as well as clock operational status.
* **Settings**. Settings shall be accomplished easily, e. g. using accessible control (DIP) switches.
* **Software**. No proprietary software shall be required to communicate with the clock. Standard PC-compatible terminal emulation programs shall be sufficient to establish communication, provide commands and settings, and download data.
* **Computer Clock Setting Software**. The clock shall support the capability to provide date and time to a PC or computer via a communications link using accessory software.
* **Security**. Password security shall be provided to control clock access. Security features shall include a complex password, requiring old password entry before changing to a new password, never showing the password on communications ports, and providing a lockout for failed password-entry attempts.
* **Power Supply**. The clock shall use the same DC power supply source as other substation equipment 110–250 Vdc.
* **Mounting.** The device shall be standard DIN rail mounted in the substation switchboard.
* **Operating Temperature**. The clock shall have an operating range of –10° to +75°C with rated accuracy.
* **Robust Hardware**. The clock shall meet and be tested for EMI, RFI, shock, vibration, and environmental compliance per the IEEE C37.90, IEC 60255, IEC 61000, and IEC 60068 standards.
* **Safety**. The clock shall be CE-compliance marked, meeting the IEC 61010 standard, and shall be UL listed.
* **Reliability.** The vendor shall supply the actual measured mean time between failures (MTBF) for the device upon request.
* **Robust Hardware.** The clock shall meet and be tested for EMI, RFI, shock, vibration, and environmental compliance per the IEEE C37.90, IEC 60255, IEC 61000, and IEC 60068 standards.
* **Conformal Coating.** The device shall have optional conformal coating to protect the circuit boards from harsh environments.
* **Service.** A higher evaluation point will be awarded if the device shall include no-cost technical support for the life of the product.
* **Warranty.** The device shall include a five-year warranty for all material and workmanship defects. In addition, the warranty shall cover accidental customer-induced damage.

# Fiber Optic cables and Patch cords

The scope includes the supply and installation of

* Multi-mode fiber optic cables from the new substation switchgear to the relay and PMAC rooms in the Power Station
* Multi-mode fiber optic cables from substation to Isolating transformers premises
* Multi-mode fiber optic patch cords between the substation relays and communication switches

Relay protection units shall be incorporated into the fiber LAN and shall communicate with the substation LAN switches.

All necessary auxiliary equipment and materials, such as connectors, fiber optic patch cords, fiber terminating frames and other accessories required for a complete working fiber links should be part of the supply.

## Requirements to the Fiber Optic Cables Installed in Channels

Fibre optic ducted cable shall be non-metallic with 12 multi-mode fibres.

Non-metallic cables must be reinforced and reinforced to protect against rodents and be suitable for laying in ducts and pipes.

Mechanical characteristics

The fibre optic ducted cables shall have the following mechanical characteristics:

* The tensile strength of the cable shall be such that a nominal pulling tension of 1000 N shall cause no temporary or permanent optical degradation or mechanical cable damage for optical cables for blowing in and 3000-5000 N for optical cables for mechanical pulling in.
* The permissible bending radius of the cable shall be recommended.
* The strength member of the fibre optic cable shall provide protection against buckling, kinking and strain. The material to be used shall be fibre reinforced plastic.
* The outer jacket shall be made of Polyethylene. Nominal thickness of the outer jacket shall be 1.5 mm. Contractor may propose a thicker jacket, if necessary.
* The anti-termite protection shall be made of rigid plastics over the outer cable jacket.
* The jackets for all the cables shall be durably marked at intervals not exceeding one meter.

## Optical Distribution Frame

The optical Distribution Frames with connectors for fibre optic ducted cables shall have the following characteristics:

The fibre optic cable gland shall accept metal free optical cable with min 12 fibres and loose buffered construction.

* The optical distribution frame (patch-panel) shall accept 12 metal free optical patch cords with single mode fibre and connected pigtails.
* The housing of the box shall be standing type, tamper-proof sealed and of rugged construction
* The type of optical connectors shall be proposed.
* Maximum insertion loss shall be < 0.1 dB per connection.

## Fibre-Optic Patch Cords

Equipment cables and cross connecting cables shall be single fibre installation cables consisting of one tightly secondary coated fibre (tight buffer), strength element and PVC-sheath in accordance with IEC 189-1 and IEC 304.

The maximum outer diameter of the cable should be 3.0 mm and the nominal thickness of the sheath shall be not less than 1.4 mm. The sheath of the cable shall be durable PVC-plastic and in accordance with IEC 189-1.

The cables shall withstand following installation properties:

* tensile strength 100 N
* minimum allowed bending radius 40 mm.

The fibres shall have tight secondary coating (tight buffer).