Technical Specifications for Phasor Measurement Unit (PMU)

SECTION 1: PHASOR MEASUREMENT UNIT (PMU) REQUIREMENTS 3

1.0 GENERAL REQUIREMENTS 3
1.1 PMU REQUIREMENTS 3
1.1.1 PMU Functional Requirements *3*
1.2 GPS BASED TIME FACILITY 6
1.3 INDUSTRIAL GRADE LAYER-3 LAN SWITCH 7
1.4 PMU TESTING 7

Section 1: Phasor Measurement Unit (PMU) Requirements

1.0 General requirements

The offered PMUs shall be complete in all respect including GPS receiver. The PMU shall be integrated with Phasor Data Concentrators (PDCs) installed at Control centers of SLDC/RLDC and NTAMC (National Transmission Asset Management Center) /NLDC as per IEEE C37.118.1-2011, IEEE C37.118.2-2011 & C37.118.1a-2014 standard. The scope of Integration shall be upto the supplied PMUs and associated substation switches only.

The supplied PMUs shall be mounted in the C&R/SAS panels being supplied by the Contractor for respective substation package and interface cabling requirements shall be as applicable for relay.

1.1 PMU Requirements

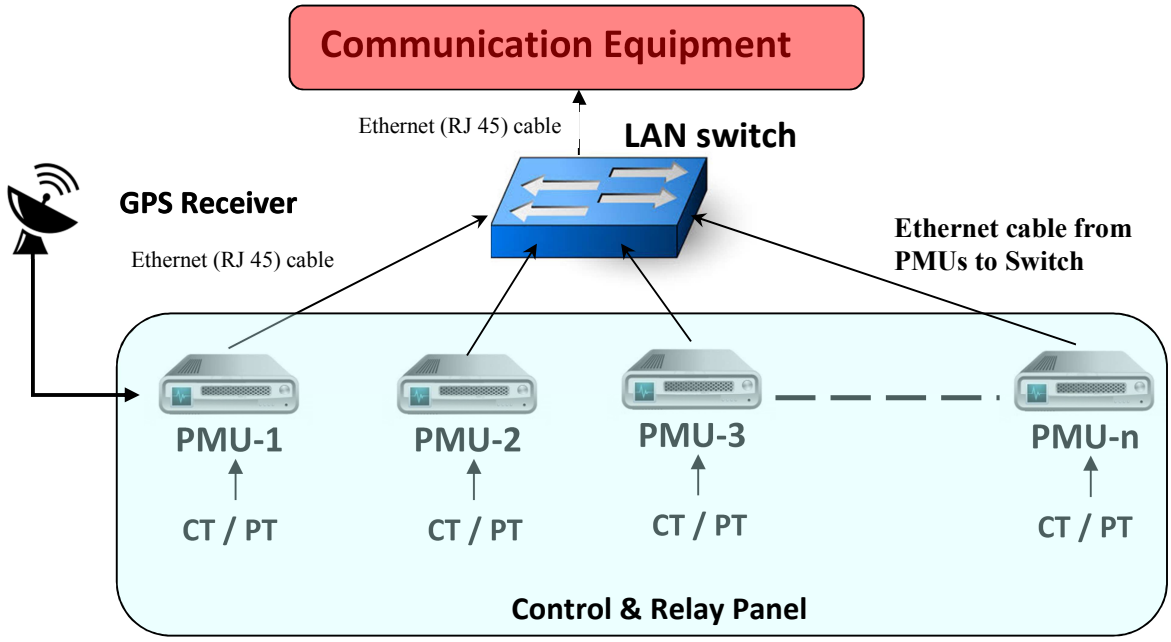
1.1.1 PMU Functional Requirements

The supplied PMUs shall be compliant to M class requirements of IEEE C37.118 Standards (latest version released in 2014).

The PMUs shall communicate with PDC at Control center over the communication link provided by the Employer. For this, PMU shall be provided with One Ethernet port of 10/100 Base Tx and one optical fiber port of 100 Mbps for streaming the data in UDP/IP multicast in IEEE C37.118 format. The supplied PMUs shall be suitable to operate on unearthed 220 V DC or 110V DC or 48V DC (+10%, -15%) power supply as available in the substation.

The PMU shall support data 'Reporting Rates' of 25, and 50 frames per seconds for 50 Hz System. The actual rate to be used shall be user selectable. All the PMU hardware and software shall be sized considering 50 frames per second. The typical network architecture of PMUs at substation is given at Fig 1.1 & Fig 1.2 below. The Data Requirement Sheets (DRS) of PMUs and associated items are mentioned at **Annexure-I**.

At Sub Station Control Room



PMU installed at Sub-Station Control Room
(with Centralized C&R Panels)

Fig 1.1: Typical Network Architecture at Sub Station Control Room

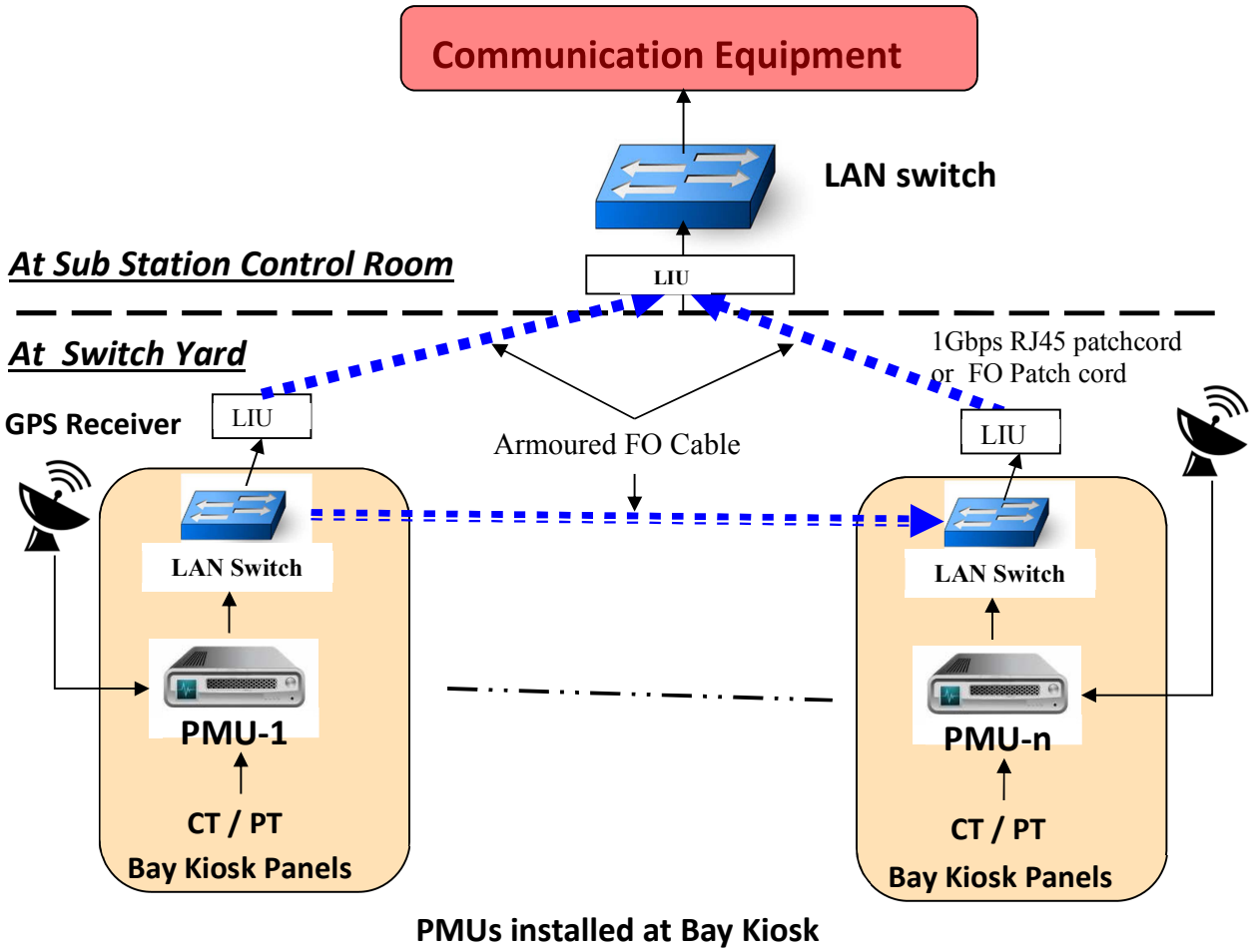


Fig 1.2: Typical Network Architecture at Sub Stations having Bay Kiosks at Switch Yard.

PMUs shall be provided to measure Voltage and Current Phasors of feeders and transformers specified in the BoQ. PMU shall also measure status of master protection and circuit breakers for units, feeders and transformers as per SLD. The PMUs shall be able to measure/calculate following:

- 3-phase voltage Phasors,
- 3-phase current Phasors,
- positive sequence voltage,
- positive sequence current,
- Breaker Status
- Main Protection Status
- Frequency,

- Rate of Change of Frequency (ROCOF) -df/dt,

Provision shall be made for user selection of measured value.

A time synchronization system (GPS receiver) shall be provided with PMU. The PMU shall have internal clock, which shall be synchronized with GPS clock. Upon loss of signal from the GPS source, the PMU shall detect a loss-of-signal and generate an alarm which will be transferred to PDC. Upon loss of signal, the PMU time facility shall revert to an internal time base. The internal clock shall have minimum stability of 1 ppm.

There shall be provision for HMI (Human Machine Interface) in PMU for configuration. The HMI shall also display the real time measured values. Alternatively Portable configuration device for PMUs can be provided for configuring the PMUs. Testing & configuration accessories such as test switch, connector, software, hardware etc., which are required for testing and configuration changes locally, shall be supplied.

The PMUs shall have continuous self-monitoring ,diagnostic feature and capable to identify & communicate problems and shall generate alarm in case of any abnormality which shall be displayed locally as well as shall be transferred to the PDC.

The Data Requirement Sheets (DRS) of PMU are mentioned at **Annexure-I**.

1.2 GPS based Time Facility

The PMU requires time reference to UTC. A GPS based time facility to synchronize PMU clock with Coordinated Universal Time (UTC), shall be provided except in case of in-built GPS in each PMU. The GPS receivers to be offered shall meet the supplied PMUs interface and accuracy requirements.

The time receiver shall include propagation delay compensation and shall also include an offset to permit correction to local time to achieve time accuracy of at least ± 0.2 microseconds (μs). Within one minutes of reacquisition of signal, the time shall return to within 0.2 micro-second of UTC. Proper correction of leap second shall be provided. The signal sent to PMU from the GPS receiver shall be UTC or provide information to the PMU to correct the time to UTC by using the IRIG-B time profile as per IEEE Standard C37.118. The supplied GPS shall be IEEE1588v2.0 (PTP) compliant.

The supplied GPS shall have “one IRIG-port plus 1 PPS port” and one Ethernet port as minimum.

In some of the locations, GPS shall be installed in switchyard along with PMU. GPS must be suitable to work in such Electrical environment.

1.3 Industrial Grade Layer-3 LAN Switch

The PMUs at Substations/Power Plants shall be connected to the communication equipment through an industrial grade Layer-3 LAN switch. The industrial grade LAN switch shall interface PMUs on one side and communication equipment on the other side. The LAN switch shall operate on 220V DC or 110 V DC or 48V (+10%, -15%) DC supply voltage of station.

1.4 Armoured Fibre Optic cables

Fibre optic cables within the control room shall be of armoured type for protection against rodents and physical stresses. Fibre optic cables, required to be laid in the switchyard shall also be of armored type. The characteristics of the fibre optic shall be as per the IEC 60870-5-103 standard. The fibre optic cables shall be run in GI conduit pipes while passing through cable trenches / cable racks outside the control room building. The fibre optic cables inside the panel shall be neatly laid and tied. Data Requirement Sheets (DRS) of armoured FO cables are given in **Annexure-I**.

1.5 Cabling & Interconnections

All cabling between component units of the PMU, PMU to GPS along with antenna and to the Employer control and relay panels (located in the substation control room) shall be supplied and installed by the Contractor and shall be shown on Contractor supplied drawings. Plug-type connectors with captive fasteners or compression type connectors shall be used for all internal interconnections. The connectors shall be polarized to prevent improper assembly. Each end of interconnection cables shall be identified by a marker which includes the cable number and the identifying number and location of each of the cable's terminations. This information shall match with the Contractor's drawings.

Adequate space and hardware shall be provided for routing of the field wiring within the enclosures. Contractor wiring within enclosures shall be neatly arranged and shall not be directly fastened to the enclosure frame. All internal interconnection wiring and cables shall be routed separately from field wiring to the PMU terminals & power wiring. All wiring shall use copper conductors and have flame retardant insulation. Conductors in multi-conductor cables shall be individually colour coded.

The use of non-flammable, self-extinguishing, plastic wire troughs is permissible. Metal clamps must have insulating inserts between the clamps and the wiring. Wiring between stationary and movable components, such as wiring across door hinges or to components mounted on extension slides, shall allow for full movement of the component without binding or chafing of the wiring.

The bidder shall be responsible for laying and termination of all cables required under the project which includes interconnections among bidder supplied equipment and their interconnection with employer’s panels. Testing and commissioning of these interconnections shall also be done by the bidder.

1.6 Wiring/Cabling requirements

Shielded (screened) cables shall be used for external Cabling from the PMU/ SIC panels. These external cables (except communication cables) shall have the following characteristics:

a) All cables shall have stranded copper conductor.

b) Minimum core cross-section of 2.5 sq.mm for PT cables, 4 sq.mm for CT cables and 2.5 sq.mm for Power & Control outputs and 1.5 sq.mm for Digital Status inputs, transducer mA current output

c) Rated voltage Uo/U of 0.6/1.1KV

d) External sheathing of cable shall have oxygen index not less than 29 & temperature index not less than 250. Cable sheath shall meet fire resistance test as per IS 1554 Part- I.

e) Shielding, longitudinally laid with overlap.

f) Dielectric withstand 2.5 kV at 50 Hz for 5 minutes

g) External marking with manufacture's name, type, core quantity, cross-section, and year of manufacture.

The Communication cable shall be of shielded, twisted pairs and of minimum 0.22sq mm size Copper cable or Fibre optic cable.

1.7 PMU TESTING

(a) Type Testing

The list of Type tests applicable on the PMU is mentioned in **Table-1**& type test requirements are mentioned in **Table-2**. The contractor may optionally submit type test reports for all the tests conducted at accredited laboratory for review & approval by Employer. However, in the event, the type test reports are not meeting the specification requirement, Employer may ask for the type testing above tests (EMI/EMC, Environmental & Functional tests) as required at no additional cost.

(b) Routine Testing

Each complete unit shall undergo routine testing. The list of Routine tests to be performed in the factory is mentioned in **Table-1**. Few samples of PMUs from each Package shall be tested at the PMU Test Lab being set up in India by POWERGRID before taking up mass production.

(c) Field Tests

The Contractor shall carry out the field-testing of PMUs after installation and integration with C&R panels. The list of field tests is mentioned in **Table-1**.

Table-1: List of Tests on PMU:

Test Nos.	DESCRIPTION OF THE TEST	Type test	Routine test	Field test
	FUNCTIONAL TESTS FOR PMU			
1.	Check for BOQ, Technical details, Construction & Wiring as per PMU drawings		√	√
2.	Check for PMU database & configuration settings		√	√
3.	Check the operation of all Analog inputs, Digital and Status input points of PMU		√	√
4.	Check operation of all communication ports of PMU	√	√	√
5.	Check for communication between PMU and PDC	√		√
6.	Test for PMU time synchronization from GPS	√		√
7.	Test Power Supply Voltage Margin, Ripple Levels and Short Circuit Protection	√		
8.	Test for PMU operation with DC power supply voltage variation	√		
9.	Check for auto restoration of PMU on DC power recovery after its failure	√	√	√
10.	Test for PMU diagnostic feature	√		
11.	Accuracy tests as per IEEE C37.118.1-2011, IEEE C37.118.2-2011 & C37.118.1a-2014 standard	√		
12.	Test for PMU internal Clock stability	√		
13.	End to end test (between PMU&PDC) for all I/O points			√
14.	Testing and Configuration of PMU from HMI or Portable Configuration tool	√	√	√
	EMI/EMC IMMUNITY TESTS FOR PMU			
15.	Surge Immunity Test as per IEC 61000-4-5& IEC 60255-22-5	√		
16.	Electrical Fast Transient Burst Test as per IEC 61000-4-4 & IEC 60255-22-4	√		
17.	Damped Oscillatory Wave Test as per IEC 61000-4-18 & IEC 60255-22-1	√		
18.	Electrostatic Discharge test as per IEC 61000-4-2 & IEC 60255-22-2	√		
19.	Radiated Electromagnetic Field Test as per IEC 61000-4-3 & IEC 60255-22-3	√		
20.	Damped Oscillatory magnetic Field Test as per IEC 61000-4-10	√		
21.	Power Frequency magnetic Field Test as per IEC 61000-4-8	√		
	INSULATION TEST FOR PMU			
22.	Power frequency voltage withstand Test as per IEC 60255-22-5	√		
23.	1.2/50 µs Impulse voltage withstand Test as per IEC 60255-22-5	√		

24.	Insulation resistance test	√		
	ENVIRONMENTAL TEST FOR PMU			
25.	Dry heat test as per IEC60068-2-2 / 2-3	√		
26.	Damp heat test as per IEC60068-2-78	√		
27.	Cold Test as per IEC60068-2-1	√		

Note: Test levels for above type tests are elaborated in Table 2

Table-2: PMU Type Test Requirements

Test Nos.	Test Name	EUT Status	Test Level	Power Supply Points		I/O Points	Passing Criteria
				CM	DM	CM	
1	Surge Immunity Test	ON	Level 3	2 kV	1 kV	2 kV	A
2	Electrical Fast Transient Burst Test	ON	Level 3	2 KV	-	1 kV	A
3	Damped Oscillatory Wave Test	ON	Level 3	2.5 kV	1 kV	2.5 kV	A
4	Electrostatic Discharge Test	ON	Level 3	+/- 6 kV in Contact discharge mode or +/- 8 kV in Air discharge mode			A
5	Radiated Electromagnetic Field Test	ON	Level 3	10 V/m electric field strength			A
6	Damped Oscillatory Magnetic Field Test	ON	Level 3	10 A/m at 1MHz of magnetic field strength			A
7	Power frequency magnetic field	ON	Level 3	30 A/m of magnetic field strength (Continuous duration sine wave)			A
8	Power frequency voltage withstand	OFF	-	1 kV rms for 1 minute			No break down or flashover shall occur
9	1.2/50µs impulse voltage withstand	OFF	-	2 kVp			No break down or flashover shall occur
10	DC Voltage Dips & Interruptions / Variation as per IEC 61000-4-29	ON	-	-			-

11	Insulation Resistance Test	OFF	-	Measure Insulation resistance using 500 VDC Megger before & after Power Freq& Impulse voltage withstand tests	As per manufacturer standard
12	Dry heat test	ON	-	Continuous operation at 55^0 C for 16 hrs	0
13	Damp heat test	ON	-	at 95% RH and 40^0 C for 16 hrs	0
14	Cold test	ON	-	Continuous operation at 0^0 C for 96 hrs	0

Note:-

1. EUT - Equipment Under Test
2. CM - Common Mode; DM - Differential mode
3. I/O points do not include Communication ports
4. Passing Criteria

   0 - no failure: normal performance within the specified limits

   A: minor failure: temporary degradation or loss of function or performance which is self- recoverable
5. Functional test as per the sl. nos. 1-14 of Table-1 shall also be done during type testing.

Annexure-I: BOQ for PMUs and associated items

BOQ for PMUs and associated Substation items			
S. No	Name of the item	Unit	Substation Name No of 400kV transmission lines – "x"
	Hardware		
1	PMU	No.	X
2	Time System (GPS Receiver)	Nos.	X
3	Substation Grade Layer-3 LAN Switches with minimum 4 x 10/100 Mbps Ethernet ports and 2 x 1 Gbps Ethernet ports	Nos.	X+1
4	Armoured Fibre Optic Cable and associated termination	Lot	1
	Services		
5	Integration - PMU with PDC at RLDC and SLDC	Lot	X

Note: 'X' is the no. of 400kV and above transmission lines of substations under the respective package.

In case of substations with conventional Control & relay panels.

- The no of PMUs shall be decided as per no of 400kV transmission line feeders under the scope of respective package.
- One GPS receiver shall be supplied for every 4 PMUs.
- No of LAN switches (no of ports in the LAN switch) shall be decided based on no of PMUs in a given Substation with C&R panels.

Annexure-II: Data Requirement Sheets (DRS) of PMU and associated items

1. Phasor Measurement Unit (PMU) :

The supplied Phasor Measurement Units (PMUs) shall be compliant to IEEE 37.118 Standard (latest version released in 2014):

S.No	Description of the Features	Minimum Quantity of the features	Offer by the Contractor
1.	Device	Phasor Measurement Unit (PMU)	
2.	Manufacturer		
3.	Model No.		
4.	Country of origin		
	Inputs		
5.	Minimum Analog Channel	6	
6.	Minimum Digital Channels	6	
7.	CT core	Capable for Metering Core	
8.	Auxiliary Power Supply Source	220 V DC or 110V DC or 48V DC (+10%, -15%) power supply source	
9.	Communication ports	One Ethernet port of 10/100 Base Tx and one optical fiber port of 100 Mbps	
10.	Interface ports for Time synchronization	IRIG-B interface port for either a standard or high-accuracy demodulated IRIG-B time-synchronization input signal or Ethernet port on IEEE 1588v2.0 (PTP)	
11.	Communication Protocols	Both Multicast and Unicast	
	Measurement Output		
12.	Performance Class	M class	
13.	Test Compliance as per IEEE 37.118	Bidder to fill the values as per test conducted in the lab for each individual values both in steady state and Dynamic State as per IEEE C37.118 Standard	
14.	Environmental Condition During testing	Bidder to fill the environmental condition during testing for each test.	

15.	Reporting rates (Frame per second)	25 and communication port wise	
	Environmental condition		
16.	Temperature	-10 to 50 degree Celsius	
17.	Humidity	10% to 95%	
18.	Configuration tool		
19.	HMI facility	Yes	
20.	Remote configuration Change	Yes	

2. GPS based time facility

S.No	Description of the Features	Minimum Quantity of the features	Offered by the Contractor
1.	Manufacturer		
2.	Model No.		
3.	Country of origin		
4.	Time stability of internal time base	Minimum 1 ppm	
5.	Propagation delay compensation	Yes	
6.	Include an offset to permit correction to local time	Yes	
7.	Reverting to internal time base upon loss of signal from UTC source	Yes	
8.	Resynchronization Delay	Not more than 5 minutes.	
9.	Accuracy of resynchronization	< 1.5 Micro Sec	
10.	Interfaces	**Minimum one Ethernet port and One IRIG-B port & 1 PPS port.**	

3. Industrial grade Layer-3 LAN Switch (Substation LAN Switch)

S.No	Description of the Features	Minimum Quantity of the features required	Offered by the Contractor
1.	Manufacturer		
2.	Model No.		

3.	Country of origin		
4.	Performance	Minimum 5 Gbps Switching Capacity	
5.	Functions	Data Exchange between PMU and PDC	
6.	Layer-2 & Layer-3 features required	Static Routing for IPv4 and IPv6	
		RIP for IPv4 (RIPv1/v2) and IPv6 (RIPng)	
		OSPF for IPv4 (OSPFv2) and IPv6 (OSPFv3)	
		Border Gateway Protocol 4 with support for IPv6 addressing wherever applicable.	
		Policy-based routing	
		IPv6 tunneling to allow IPv6 packets to traverse IPv4-only networks by encapsulating the IPv6 packet into a standard IPv4 packet.	
		Dynamic Host Configuration Protocol (DHCP) client, Relay and server.	
		Support for Multicast VLAN	
		Support for Jumbo frames	
		Should provide for 32K MAC Address Table	
		Should have facilities such as IPv6 to IPv4 tunneling, DHCPv6, ICMPv6	
7.	Features to support	Support IEEE 802.3u: Auto-negotiation on TP, IEEE 802.3x, 802.1p: flow control and prioritization, IEEE 802.1Q: VLANs, maximum 32 VLANs, IEEE 8021.1d, 802.1w: Spanning Tree, Rapid Spanning Tree including RSTP 2004 extensions providing sub-second hop on rings, IEEE 802.1p: DiffServ, traffic prioritization for routed IP flows/ports Shall support Multicast and Unicast. Shall be PTP enabled as per IEEE1588v2.0 (Power Profile)	
8.	Network management	• Console port for configuration of software features • Shall able to manage the switch through Command-line interface; Web browser; SNMP etc.,	
9.	Security	a. Access Control Lists for both IPv4 and IPv6 for filtering traffic to prevent unauthorized users from accessing the network	
		b. Port-based rate limiting and access control list (ACL) based rate limiting	
		c. IEEE 802.1x to provide port-based user authentication with multiple 802.1x authentication sessions per port	
		d. Media access control (MAC) authentication to provide simple authentication based on a user's MAC address	
		e. Dynamic Host Configuration Protocol (DHCP) snooping to prevent unauthorized DHCP servers	

		f. Port security and port isolation	
10.	Speed configurability at each port	WAN ports optional 64kbps to 2Mbps	
11.	Interface ports	As per BoQ The BOQ requirement is the minimum in every switch at Substations. The no. of ports in LAN switches at Substations shall be optimised as per the Phasors list given at Appendix-H of Part-B and additional 50% expansion ports shall also be provided in the LAN switch.	
12.	Mounting	Rack mountable	
13.	Environmental Compliance	IEC61850-3 and IEEE1613 (Electric Utility Substation),EMS-IEC61000, EMI: FCC part15 A	
14.	Operating temp	- 10 to 75°C, no fans	

4. Armored FO Cables

S. No	Description of the Features	Minimum requirements	Offered by the Bidder
1	Manufacturer	Powergrid Approved Vendor	
2	Application	Between kiosks & Control Room	
2	Cable Type	4F Multimode Cable 62.5/125 um	
3	Armoured/Un-Armoured	Armoured	
4	Wavelength	850nm/1300nm	
5	Attenuation	< 3.5 dB/km @850nm, <1.0 dB/km @1300nm	
6	Band Width	>= 200 MHz/km @850nm, >=500 MHz/km @1300nm	
7	No. of Fibers	24*	
8	Colour for Fiber	Blue , Orange, Green, White	
9	Cladding Diameter	125um ± 2	
10	Core Diameter	62.5 um ± 3	
11	Cable Diameter	Vendor Specific	

12	Numeric Aperture	0.275+/- 0.015	
13	Bending Radius	20xD where D is diameter of cable	
14	Armored Type	ECCS Tape (Electromagnetically Coated Corrugated Steel Tape)	
15	Operating Temperature	-20ºC to +70ºC	

Note: * 24 fibers to cater the need of PMU as well as for other substation applications