BIDDING DOCUMENT
FOR

"Supply Installation and Commissioning of PMUs for upcoming 400 kV and 220 kV Grid Substations and associated Transmission lines under AIIB"

FUND: "AIIB State Share"

(E-Tender)
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Section1

Introduction & General Information

This Part of technical specifications for Phasor Measurement Unit (PMU) describe functional and performance requirements of Phasor Measurement Unit (PMU), associated accessories etc.

This Part of Technical Specification describes Network Configuration requirement of Communication equipment, EMI/EMC requirement and testing requirement of Communication equipments.

Besides these, a detailed BoQ is described in price schedules of Vol. I.

Section 2

Technical Specifications

2.1 Phasor Measurement Unit

Substations and generating stations are generally equipped with Current Transformers (CTs) for each bay in the switchyard, along with Capacitive Voltage Transformers/Potential Transformers (CVTs/PTs) provided in each transmission line bay and on each bus. Typically, CTs are designed with one metering core and four protection cores, while CVTs are provided with three cores for metering and protection purposes.

The Phasor Measurement Units (PMUs) offered shall be connected to the available CT and CVT cores, and they shall be suitable for measurement from both metering and protection cores. The specific cores to be utilized for PMU connections shall be finalized during the detailed engineering stage.

The Phasor Measurement Units (PMUs) to be supplied under this specification shall be installed at designated Substations and Power Stations. Each PMU shall communicate with the Phasor Data Concentrator (PDC) at State Load Dispatch Centre (SLDC) and Regional Load Dispatch Centre (NERLDC) respectively, in compliance with the IEEE C37.118.1-2011, IEEE C37.118.2-2011, IEEE C37.118.1a-2014, or IEC/IEEE 60255-118-1:2018 standards (including all subsequent amendments). Preference shall be given to PMUs conforming to IEC/IEEE 60255-118-1:2018.

The Integration of the supplied PMUs with PDCs at SLDC and NERLDC shall be under the scope of the successful Bidder. The Bidder shall also extend technical support at Local end for seamless integration of the PMU with PDC at SLDC & NERLDC end.

The supplied PMUs shall be mounted within the panels provided by the bidder. All associated hardware, including panels, accessories, and cabling required for proper installation and operation, shall also be provided by the bidder.

The PMUs shall be compatible with secure IEC 60870-5-104 and IEC 61850 communication protocols. The CCU/PDC shall be capable of issuing islanding commands to the PMUs using IEC 61850 R-GOOSE or secure IEC 60870-5-104, and shall also report the required data points to the SLDC/NERLDC SCADA over secure IEC 60870-5-104. The successful demonstration of this functionality shall be carried out by the bidder during Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT).

The PMUs shall be designed for continuous operation in utility-grade environments and shall comply with the standards, protocols, and performance criteria specified herein.

2.1.1 General Requirements

The offered PMUs shall be supplied as complete systems suitable for installation at substations or power plants. They shall be capable of seamless communication with the

CCU/PDC located at the SLDC/NERLDC. All required cables, connectors, and installation hardware shall be provided by the bidder. As a general practice, the PMUs shall be installed near the control and relay panels, with CT/PT and CVT connections extended from these panels.

2.1.2 Communication Interfaces

For integration with the PDC/CCU, each PMU shall be equipped with at least two (02) Ethernet port of 10/100 Base-Tx and two (02)optical fibre port of 100 Mbps. These ports shall support streaming of data in UDP/IP multicast or unicast and TCP/IP modes in compliance with IEEE C37.118. The Ethernet port shall allow direct connection to the substation communication equipment, and the PMU shall also be capable of reporting data over TCP/IP also.

2.1.3 Data Reporting Capability

The PMU shall be capable of synchro-phasor reporting to a minimum of four (04) clients over TCP and/or at least four (04) clients over UDP in multicast or unicast mode. The device shall be capable of transmitting data both in multicast and unicast configurations as required by the system operator.

2.1.4 Power Supply

The PMUs shall be suitable for operation on unearthed DC supplies of 220 V, 110 V, or 48 V with an operating tolerance of +10% and –15%. In addition, the PMUs shall also be capable of operating on an AC auxiliary supply of 230 V, 50 Hz (±10%). The bidder shall ensure that the supplied units can operate reliably with any of the available supply voltages at the substation.

2.1.5 Reporting Rate

The PMUs shall support user-selectable synchro-phasor reporting rates of 50 frames per second, or higher, for a 50 Hz system. PMUs with higher reporting rates shall be given preference. All hardware and software supplied shall be adequately sized to support the maximum reporting rate offered by the device.

2.1.6 Protocol Support

The PMUs shall support multiple protocols to ensure interoperability with CCU and SCADA systems. These shall include:

- Routable GOOSE (R-GOOSE) and IEC 61850-90-5,
- IEEE C37.118.2-2011 (Communication), IEEE C37.118.1-2011 with Amendment IEEE C37.118.1a-2014 (Measurement), or IEC/IEEE 60255-118-1:2018 (preferred),
- IEC 61850 Editions 1 and 2,

- IEC 60870-5-104 Client and Server protocols with secure implementation in compliance with IEC 62351-5 and IEC 62351-3 to ensure authentication, encryption, and integrity of communications.
- IEEE 1588 PTP or IRIG-B for precise time synchronization.

2.1.7 Measurement Capabilities

Each PMU shall be capable of measuring and reporting three (03)-phase voltage phasors (magnitude and angle), three (03)-phase current phasors (magnitude and angle), positive sequence voltage and current (magnitude and angle), breaker status, main protection status, frequency, rate of change of frequency (ROCOF), and analog quantities such as MW and MVAr. Measurement coverage shall be provided for a minimum of two (2) bays per PMU as specified in the Bill of Quantities.

2.1.8 Time Synchronization

The PMU shall be supplied with a GNSS & NaVIC receiver for accurate time synchronization. The internal PMU clock shall be synchronized with the GNSS &NaVIC clock and revert to an internal oscillator with stability of at least 1 ppm upon loss of GNSS &NaVIC signal. The PMU shall generate an alarm in the event of GNSS signal loss, and the alarm shall be transmitted to the PDC. The PMU shall maintain TVE, frequency error, and ROCOF within the limits specified in IEEE C37.118 and its amendments. The PMU shall also time synchronise with control centre's clockover NTP for time synchronization, in case of failure of GNSS &NaVIC.

2.1.9 Protection and Monitoring Functions

The PMU shall include continuous self-monitoring and diagnostic features capable of detecting and reporting internal faults or abnormal conditions. All alarms shall be displayed locally and reported to the PDC, with status indications provided on the PMU front panel.

2.1.10 Configuration and display

The PMU shall support Configuration Frames 2 and 3. A local display, embedded in PMU, shall be provided to display measured voltages, currents, frequency, active, reactive, and apparent power, power factor, primary and secondary phasors, positive, negative, and zero-sequence values, and breaker and protection status. Remote configuration via PDC/CCU over the same communication channel used for reporting shall be supported and the necessary software for Remote Configuration shall be supplied by the Bidder.

Alternatively portable configuration device for configuring the PMUs can be provided. Testing & configuration accessories such as test switches, connectors, hardware and software shall be also supplied.

2.1.11 Cybersecurity and NMS compatibility

The PMU shall incorporate robust cybersecurity features. Access shall be role-based and password-protected, with logs maintained for all access attempts. Configuration changes shall require authorized access, and all such changes shall be logged and reported to the PDC/CCU. The PMU shall be protected from external threats including malware and spam. Compliance with IEC 62351 or equivalent cybersecurity standards shall be ensured, and secure firmware upgrades shall be supported.

The PMUs shall support network monitoring by the NMS for device availability and health supervision. The PMU shall expose parameters such as device status, communication port status, CPU and memory utilization, and internal alarms via standard protocols including ICMP, SNMP, and Syslog. This information shall be used exclusively for device monitoring in the NMS.

2.1.12 Data Streaming

The PMU shall support multiple independent data streams. Each stream shall be individually configurable with respect to contents, reporting rate, class of service (P or M), communication mode (TCP/UDP), and destination IDCODE.

2.1.13 Performance Classes

The PMUs shall meet the requirements of both P-Class and M-Class performance as specified in IEEE C37.118.1-2011, IEEE C37.118.1a-2014, or IEC/IEEE 60255-118-1:2018. The reporting class shall be user-selectable. Certified test reports demonstrating compliance with both classes shall be submitted by the bidder.

2.1.14 Accuracy and Frequency Range

The PMUs shall measure electrical parameters with specified accuracy in the frequency range of 48 Hz to 52 Hz, in accordance with IEEE C37.118.1 standards. Data shall remain available outside this band, and the PMU shall ensure that the effect of frequency deviations on measurement accuracy remains within the permissible limits of the applicable standards.

2.1.15 Power Quality Functions

Each PMU shall incorporate an embedded Power Quality Analyzer conforming to IEC 61000-4-30 Edition 3, Class A. The PMU shall generate statistical PQ reports in accordance with EN 50160 and shall detect, store, and alarm events such as frequency deviations, voltage dips, interruptions, temporary and transient over-voltages, voltage unbalance, harmonics, inter-harmonics, and Total Harmonic Distortion (THD).

2.1.16 Environmental and Reliability Requirements

The PMU shall be suitable for continuous operation in utility environments with an ambient temperature range of –10 °C to +60 °C and relative humidity up to 95% non-condensing. The design shall comply with IEC 60068 standards for temperature, humidity, and vibration

testing, as well as IEC 61000 for EMC/EMI compliance. The PMU shall withstand seismic conditions in line with IEEE 693 or equivalent. The design shall target a minimum MTBF of 100,000 hours, and hot-swappable modules or redundant designs shall be preferred.

2.1.17 Redundancy and Latency

The PMU shall support redundant communication paths over Ethernet and fiber. Dual redundant AC/DC power supply inputs shall be provided. End-to-end latency shall not exceed 20 ms for P-Class operation at 50 fps, in compliance with IEEE C37.118.

2.1.18 Interoperability and Testing

The PMUs shall be interoperable with PDCs and SCADA systems of multiple vendors. The bidder shall demonstrate interoperability and compliance with all functional requirements during Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT). All features specified in this document shall be successfully validated during FAT and SAT.

2.1.19 Documentation

The bidder shall provide comprehensive documentation to establish compliance with IEEE and IEC standards. This shall include details of supported performance classes, measurement functions, certified test results, equipment settings used in testing, and environmental conditions during testing.

2.2 NaVIC& GNSS based Time Synchronization Equipment

The PMUs and CCU/PDC require precise time synchronization with Coordinated Universal Time (UTC). For this purpose, GNSS &NaVIC-based time synchronization receivers shall be supplied, installed, and commissioned at control rooms and substations as specified in the BoQ.

2.2.1 General Requirements

The time synchronization receiver shall provide UTC reference signals with sufficient accuracy to ensure that the Total Vector Error (TVE) of associated PMUs remains within the limits specified by applicable standards. The receiver shall clearly indicate synchronization status, including loss of signal, reacquisition progress, and current accuracy. It shall include propagation delay compensation and provide offset correction to local time, thereby achieving an overall time accuracy of at least ±0.2 microseconds with respect to UTC. Following loss of signal and subsequent reacquisition, the receiver shall return to within ±0.2 μs of UTC within one minute. The unit shall also support proper leap-second correction.

2.2.2 Standards Compliance

The time synchronization receiver shall support IRIG-B time profile as defined in IEEE C37.118.1-2011, IEEE C37.118.1a-2014, and IEEE C37.242-2013. It shall comply with IEC/IEEE 60255-118-1:2018 standard for synchro-phasor measurement requirements and shall also be fully compliant with IEEE 1588v2 Precision Time Protocol (PTP). These

provisions will ensure interoperability with PMUs, CCUs/PDCs, and other compliant equipment.

The bidder shall submit all relevant certificates demonstrating NaVIC and GNSS functionality testing, accuracy validation, and interoperability compliance with the above standards. In addition, the bidder shall provide documented evidence of compliance with applicable cybersecurity norms, including protection of management interfaces, secure firmware/software design, and adherence to IEC 62351 or equivalent security frameworks.

2.2.3 NaVIC/GNSS Operation

The receiver shall be capable of operating with either NaVIC or GNSS satellite signals. The primary source of synchronization (NaVIC or GNSS) shall be user-selectable and finalized at the time of implementation. In the event of a failure or loss of the selected primary source, the receiver shall provide automatic fallback to the alternate source while maintaining the required time accuracy. The switchover between NaVIC and GNSS shall be seamless and shall not interrupt synchronization of the PMUs.

2.2.4 Interfaces

The receiver shall be provided with multiple interfaces to ensure compatibility with PMUs and CCUs/PDCs. At a minimum, it shall provide one IRIG-B output port, one PPS output port, and one Ethernet port supporting IEEE 1588 PTP. All interfaces shall be capable of supporting synchronization of multiple PMUs and CCU/PDC equipment at the respective substation or control centre.

2.2.5 Hardware and Accessories

The bidder shall supply all hardware and accessories necessary for complete installation and reliable operation. This shall include a GNSS &NaVIC antenna with a suitable mounting kit, low-loss RF coaxial cable of sufficient length to connect the antenna to the receiver (minimum 30 m, extendable as per site requirements), and IRIG-B cables of appropriate length for connecting the receiver to PMUs or CCU/PDC. In addition, PPS distribution cables, connectors, power supply adapters, signal splitters, or converters as required for integration shall also be supplied.

2.2.6 Capacity and Coverage

A single GNSS &NaVIC receiver unit shall be capable of providing synchronized time to all PMUs and associated devices installed at the respective substation or control centre, as specified in the BoQ. The receiver shall be designed for 24x7 continuous operation under utility-grade environmental conditions, ensuring reliability and long-term performance.

2.2.7 Environmental Conditions

The supplied GNSS &NaVIC receivers shall be suitable for continuous operation in substation environments that may not be fully air-conditioned. The equipment shall be designed to operate within a temperature range of -10 °C to +55 °C and a relative humidity range of 5% to 95% non-condensing. The receiver shall be housed in an enclosure providing at least IP-52 protection for indoor installation, while the outdoor antenna shall meet minimum IP-65 protection. The equipment shall comply with IEC 61000 series EMC standards and IEC 60068-2 environmental standards for vibration, shock, and transport.

Power supply options shall be compatible with typical substation DC (48/110/220 VDC) and AC (230 VAC ±15%) sources.

2.2.8 Documentation

The bidder shall provide full documentation for the GNSS &NaVIC time synchronization system. Manuals shall include installation instructions, antenna placement guidelines, configuration procedures for UTC, NaVIC, and GNSS modes, interface details for IRIG-B, PPS, and IEEE 1588 PTP, and procedures for handling alarms and loss-of-signal scenarios. Documentation shall also include cybersecurity compliance guidelines, future reconfiguration procedures, and test certificates for NaVIC/GNSS accuracy, leap-second handling, and interoperability with PMUs and PDCs.

2.3 Gigabit Ethernet Switch (Layer-3, Industrial Grade)

In substations and power plants, the Layer-3 industrial grade Gigabit Ethernet switch shall provide reliable connectivity between PMUs and the upstream communication equipment. In the control centre, the Layer-3 switch shall be used to interconnect various devices including CCU/PDC, NMS servers, GNSS receivers, routers, firewalls, and workstations, thereby forming the core of the local area network.

2.3.1 General Requirements General Requirements

The switch shall be an industrial-grade device, designed for continuous operation in substation and control centre environments. It shall provide interfaces for PMUs on one side and communication equipment on the other side in substations, and for multiple servers, routers, VoIP and IT/OT equipment in control centres.

The switch shall support dual power options depending on location:

- Substations: DC supply of 220 V DC, 110 V DC, or 48 V DC (+10%, -15%) or AC supply of 220 V AC, 50 Hz..
- Control centres: AC supply of 220 V AC, 50 Hz.

The bidder shall supply all required accessories, including mounting hardware, cables, connectors, and software licenses, for complete installation and commissioning.

2.3.2 Port Requirements

The number of ports required in each switch shall be worked out by the bidder based on the devices to be integrated at the respective location. Each switch shall include a minimum of 50% spare ports for future expansion.

However, minimum 08 number of Gigabit Ethernet (10/100/1000 Mbps auto-sensing) port and minimum two ports of fiber (1 Gbps SFP/SFP+) shall be provided for reliable backbone connectivity.

2.3.3 Hardware and Software Features

The switch shall support the following minimum features:

- Layer-2 and Layer-3 switching capabilities.
- Support for VLANS (IEEE 802.1Q) and inter-VLAN routing.
- Support for IPv4/IPv6 dual stack.
- Support for Spanning Tree Protocol (STP, RSTP, MSTP).
- Link aggregation (IEEE 802.3ad LACP).

- Quality of Service (QoS) with traffic prioritization for SCADA, PMU, and VoIP applications.
- IGMP Snooping for multicast traffic optimization.

Port mirroring for diagnostics.

Redundant power supply support preferred.

2.3.4 Cybersecurity and Management

The switch shall support secure access and management using SSH, HTTPS, SNMPv3, and Syslog. Role-Based Access Control (RBAC) shall be provided. The device shall comply with IEC 62351 cybersecurity guidelines and shall include protection against unauthorized access.

The switch shall integrate with the Network Management System (NMS) supplied under this project, exposing status, alarms, and performance data. It shall support centralized monitoring of port health, link utilization, and error statistics.

2.3.5 Environmental Conditions

The switch shall be suitable for substation-hardened operation and designed for 24×7 use. It shall support an operating temperature range of -10 °C to +60 °C and relative humidity tolerance of 5% to 95%. The enclosure shall provide a minimum protection rating of IP-30 or better.

2.3.6 Compliance and Reliability

The switch shall comply with relevant international standards, including:

- IEEE 802.3 (Ethernet standards).
- IEEE 802.1D/802.1Q/802.1s/802.1w (bridging, VLAN, STP, MSTP, RSTP).
- IEC 61850-3 and IEEE 1613 for substation-hardened equipment.
- IEC 61000 series for EMC compliance.

The device shall have a high Mean Time Between Failures (MTBF) suitable for critical utility installations.

2.3.7 Documentation

The bidder shall provide comprehensive documentation, including installation manuals, configuration and administration guides, user operation manuals, and troubleshooting references. Manuals shall cover VLAN and QoS configuration, integration with NMS, and procedures for future expansion. Compliance certificates for environmental, EMC, and cybersecurity standards shall be submitted along with the documentation.

2.4 Next Generation Firewall (NGFW)

The Next Generation Firewall (NGFW) shall provide advanced perimeter and internal security for Control Centre networks. The firewall shall protect SCADA, PMU, NMS, GNSS, routers, switches, and other mission-critical applications against cyber threats, while complying with utility-grade cybersecurity standards. The bidder shall be responsible for maintaining the cybersecurity posture of the supplied system, including patching, firmware upgrades, and software updates during the AMC/Guarantee period, at no additional cost to the owner. All software shall be supplied with valid licenses up to the end of the AMC period. Outdated or end-of-life software shall be replaced or upgraded by

the bidder free of cost during AMC.

2.4.1 Security and Functional Features

The NGFW shall include, but not be limited to, the following features:

- Encryption & VPN: IPSec VPN (AES-128/256 with MD5/SHA1/SHA2), SSL VPN, and client-based VPN for Windows, Linux, and Mac platforms. Must support at least 100 VPN tunnels with redundant operation and minimum throughput of 5 gbps.
- Deep Packet Inspection (DPI) and application control for known and unknown TCP/UDP applications, with configurable allow/block policies.
- **Threat Protection:** The NGFW shall include Intrusion Detection and Prevention (IDS/IPS) capabilities, Anti-Virus, Anti-Spyware, DoS/DDoS prevention, IP/MAC spoofing protection, Man-in-the-Middle (MITM) prevention, and automatic signature updates (online/offline).
- **Zero-Day Protection:** Advanced malware detection/sandboxing for zero-day threats, with automatic updates.
- **Traffic Shaping:** Integrated bandwidth allocation, prioritisation, and QoS enforcement.
- **High Availability:** Active/Passive and Active/Active modes with stateful session failover and load balancing.
- **SSL/TLS Inspection:** Capability to inspect encrypted SSL/TLS traffic, including TLS 1.3.
- **Web & Application Filtering:** Category-based filtering (malware, social media, P2P, etc.) with customizable policies.
- **Logging & Retention:** Storage and export of logs/events for minimum 180 days, supporting CSV and SIEM formats. Logs shall be exportable to a centralized log management system (e.g., syslog, SIEM).

2.4.2 Power Supply

The NGFW shall support dual redundant hot-swappable AC power supplies, operating on 220 V AC, 50 Hz input. The design shall ensure uninterrupted firewall operation in case of failure of one power supply module. Power modules shall be replaceable without interrupting traffic (hot-swap capability).

2.4.3 Network and Protocol Support

The NGFW shall support:

- **Utility Protocols:** IEC-60870-5-104, ICCP/TASE.2, PMU (IEEE C37.118), IEC 61850, and Ethernet.
- **IP Support:** Simultaneous operation of IPv4 and IPv6.
- **Segmentation:** Configurable VLANs and VRF for traffic separation.
- **Sessions:** Minimum **500,000 concurrent sessions** and at least **20,000 new sessions per second.**
- **Management:** Secure remote configuration, centralized authentication with RADIUS/LDAP/TACACS+, RBAC, and SNMPv3 with encrypted authentication. The NGFW shall be accessible for secure configuration and management via an **HTTPS**

web portal, in addition to CLI (SSH) and APIs (REST/JSON). The web portal shall provide role-based dashboards, real-time monitoring of sessions/traffic, and policy management.

- **Time Synchronisation:** NTP/SNTP support with mandatory sync to official Indian Timekeeping Agency (time.nplindia.org).

2.4.4 Performance Requirements

The firewall shall meet the following minimum benchmarks:

- Firewall throughput (1518-byte packets): ≥ 5 Gbps
- NGFW throughput with IPS/AV/DPI enabled: ≥ 1.5 Gbps
- IPSec VPN throughput: ≥ 500 Mbps
- Concurrent sessions: ≥ 500,000
- New sessions per second: ≥ 20,000
- Minimum interfaces: 8 × GE RJ-45, 2 x SFP (fiber)
- Expansion capability for higher throughput shall be available.

2.4.5 Compliance and Deployment Requirements

- The NGFW shall be rack-mountable in standard 19-inch equipment cabinets.
- The firewall shall support firmware checksum validation before upgrades and provide a documented process for patching and updates.
- All updates, patches, and signature definitions shall be provided free of cost for a minimum of 36 months from shipping.
- The product shall not be declared End-of-Sale or End-of-Support or End-of-life for at least 5 years from supply date.
- Must comply with NCIIPC guidelines, CERT-In advisories, and provide a hardening
- checklist aligned to IEC 62443.
- Integration with centralized SIEM/NMS using syslog, CEF/LEEF, or equivalent format.
- Support for REST/JSON APIs for integration with orchestration platforms.

2.4.6 Documentation

The bidder shall provide comprehensive documentation, including installation manuals, configuration and administration guides, cybersecurity hardening guidelines, and troubleshooting references. Documentation shall cover VPN setup, VLAN/VRF configuration, RBAC, log management, firmware upgrade, and integration with SCADA/PMU/VoIP/NMS environments. Manuals shall also provide procedures for future configuration changes, patch management, and AMC support. Compliance certificates for performance, cybersecurity, and regulatory standards shall be included.

2.5 Light Interface Unit (LIU) for FO cable termination:

Fibre optic cables to be laid within the control room and in the switchyard between bay kiosks, shall be terminated in a Light Interface Unit (LIU) having minimum 12 ports (6-in and 6-out). The LIU shall also have adapter plates for connector mounting to support all

types of FO connectors such as ST, SC, LC, and FC etc. The LIU shall support managing splicing and termination of FO cables. The LIU shall be 19-inch rack mountable. The specification of LIU is given at Annexure-l (DRS of PMU and associated items).

2.6 Cabling and Interconnections

1. All cabling between component units of the PMU, PMU to GNSS (including antenna), PMU to Layer-3 Switch, PMU to the substation/power station control and relay panels, and Layer-3 Switch to Wide Band Communication Equipment shall be supplied, laid, terminated, and commissioned by the bidder.
2. Interconnections shall be shown in bidder-supplied drawings. Any additional equipment, hardware, or software required for integration shall also be supplied by the bidder. Final requirements shall be confirmed during the site survey.
3. Plug-type connectors with captive fasteners or compression-type connectors shall be used for all internal interconnections. Connectors shall be polarized to prevent incorrect assembly.
4. Each end of every interconnection cable shall be identified with a durable marker showing the cable number, termination number, and location. This information shall match the bidder's approved drawings.
5. Adequate space and hardware shall be provided for routing of field wiring within enclosures. Internal wiring shall be neatly arranged and supported, and shall not be fastened directly to the panel frame.
6. Internal interconnection wiring shall be routed separately from power wiring to avoid interference.
7. All wiring shall use copper conductors with flame-retardant, low-smoke, halogen-free insulation. Conductors in multi-core cables shall be individually colour coded.
8. Non-flammable, self-extinguishing plastic wire troughs may be used. Metal clamps, if used, shall have insulating inserts between clamp and cable.
9. Wiring across moving parts such as door hinges or sliding components shall allow full movement without binding or chafing.
10. All cables shall comply with relevant |S/IEC standards.
11. Power cables shall be copper conductor, XLPE insulated, armoured, flame retardant, and low smoke halogen-free.
12. Control and communication cables shall be copper conductor, multi-core, twisted pair where applicable, shielded, and FRLSH insulated.
13. Ethernet cables shall be Category-6A or higher, shielded (STP/FTP).
14. Fibre optic cables, where required, shall be single-mode, armoured, minimum 12 fibres, conforming to ITU-T G.652D or equivalent.
15. Signal and communication cables shall be individually or overall shielded for EMI/RFI protection. Shields shall be earthed at one end only.
16. Power supply cables shall have a minimum cross-section of 2.5 sq.mm copper for single-phase loads and 4 sq.mm copper for DC supply runs. Voltage drop shall not exceed 3% at rated load.
17. Power, signal, and communication cables shall be segregated by routing in separate

trays or conduits, with adequate spacing between high- and low-voltage circuits.

18. Cable identification shall be ensured by printed ferrules on each conductor at both ends. Cable tags of stainless steel or UV-resistant material shall be fixed at regular intervals along the route.
19. At least 20% spare cores shall be provided in each control and communication cable. Spare cores shall be terminated on spare terminals and properly identified.
20. Cables shall be laid on trays, ducts, or conduits with proper clamping and dressing. Minimum bending radius shall not be less than 12 times the overall cable diameter.
21. Entry and exit into panels shall use compression type cable glands with neoprene seals.
22. All terminations shall be made with crimped tinned copper lugs with insulating sleeves.
23. The bidder shall carry out laying, termination, testing, and commissioning of all cables, including interconnections among bidder-supplied equipment and with employer's panels. Power, signal, and communication cables shall be segregated by routing in separate trays or conduits, with adequate spacing between high- and low-voltage circuits.
24. Testing shall include insulation resistance measurement, continuity check, high voltage withstand test where applicable, and loop resistance measurement. Test results shall be submitted for approval.
25. Any other type of cable or interconnection necessary for proper functioning of the system, as identified during site survey or commissioning, shall be supplied and installed by the bidder.

2.7 Wiring Requirements

Shielded (screened) cables shall be used for external cabling from the PMU/SIC panels. These external cables (except communication cables) shall meet the following requirements:

1. All cables shall have stranded copper conductors complying with IEC 60228.
2. Minimum core cross-section shall be 2.5 sq.mm for PT cables, 4 sq.mm for CT cables, 2.5 sq.mm for power and control outputs, and 1.5 sq.mm for digital status inputs and transducer mA current outputs.
3. Rated voltage shall be Uo/U = 0.6/1.1 kV.
4. Cable insulation and sheathing shall be flame retardant, low smoke, halogen-free (FRLS/FRLSH) type. External sheathing shall have oxygen index not less than 29 and temperature index not less than 250. The sheath shall meet fire resistance requirements as per IS 1554 Part-I/IEC 60332, and smoke density requirements as per IEC 61034.
5. Cables shall have shielded, longitudinally laid with overlap, with an aluminium/polyester tape and tinned copper drain wire of minimum 0.5 sq.mm cross-section.
6. Dielectric withstand capability shall be minimum 2.5 kV at 50 Hz for 5 minutes.
7. Cables shall be marked externally with manufacturer's name, type, number of cores, cross-section, and year of manufacture at regular intervals.
8. Communication cables shall be of shielded twisted pair copper cable of minimum 0.22 sq.mm or fibre optic cable (single mode, armoured, conforming to ITU-T G.652D or equivalent).
9. Shields shall be earthed at one end only, preferably at the panel side, to prevent ground loops.

10. Colour coding of conductors shall conform to relevant IS/IEC standards. Each conductor shall be identified at both ends by printed ferrules, and cables shall be tagged with stainless steel or UV-resistant tags at regular intervals.
11. Power, control, and communication cables shall be segregated and laid in separate trays/conduits with adequate spacing. Minimum bending radius shall not be less than 12 times the overall diameter.

Section–03

Inspection, Test and Availability

All materials furnished and all work performed under this Contract shall be inspected and tested**.** Deliverables shall not be shipped until all required inspections and tests have been completed, and all deficiencies have been corrected to comply with this Specification and approved for shipment by the Employer.

Except where otherwise specified, the Contractor shall provide all manpower and materials for tests, including testing facilities, logistics, power and instrumentation, and replacement of damaged parts. The costs shall be borne by the Contractor and shall be deemed to be included in the contract price.

The entire cost of testing for factory & site acceptance, routine tests, production tests and other test during manufacture & site activities specified herein shall be treated as included in the quoted unit price of materials, except for the expenses of Inspector/Employer's representative.

Acceptance or waiver of tests shall not relieve the Contractor from the responsibility to furnish material in accordance with the specifications.

All tests shall be witnessed by the Employer and/or its authorized representative (hereinafter referred to as the Employer) unless the Employer authorizes testing to proceed without witness. The Employer representative shall sign the test form indicating approval of successful tests.

Should any inspections or tests indicate that specific item does not meet Specification requirements, the appropriate items shall be replaced, upgraded, or added by the Contractor as necessary to correct the noted deficiencies at no cost to the Employer. After correction of a deficiency, all necessary retests shall be performed to verify the effectiveness of the corrective action.

The Employer reserves the right to require the Contractor to perform, at the Employer's expense, any other reasonable test(s) at the Contractor's premises, onsite, or elsewhere in addition to the specified Type, Acceptance, Routine, or Manufacturing tests to assure the Employer of specification compliance.

All security related features shall be demonstrated during FAT/SAT as required by the Employer.

3.1 Inspection and Testing

3.1.1 Type Testing

The reports for all type tests as per this technical specification shall be furnished by the Contractor along with equipment / material drawings. However, type test reports of equipment/material already accepted in POWERGRID can be accepted for all projects with similar requirement. The type tests conducted earlier should have either been conducted in a NABL accredited laboratory, or accredited based on ISO / IEC Guide 25/17025 or EN 45001 by the national accreditation body of the country where laboratory is located or witnessed by POWERGRID/representative authorized by POWERGRID/representative of Utility /representative of accredited test lab/representative of the National Accreditation Board for Certification Bodies (NABCB) certified agency shall also be acceptable.

Unless otherwise specified elsewhere, the type test reports submitted shall be of the tests conducted within the last Seven (7) years from the date of NOA. In case the test reports are of the test conducted earlier than seven (7) years from the date of NOA, the contractor shall repeat these test(s) at no extra cost to the Employer.

The type testing requirements are described below:
The list of Type tests applicable on the PMU is mentioned in Table-1 and 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 repeat type testing of above tests (EMI/EMC, Environmental & Functional tests) as required. at no additional cost. The supplied Phasor Measurement Units (PMUs) shall comply with type test requirement as per below mentioned standards:
i) **For Functional Type Tests:** As per the latest versions of IS/IEC/IEEE 60255-118-1 and IEEE C37.118.2 standards with all amendments.
ii) **For EMI/EMC Immunity & Environmental Tests:** As specified in below **Table-1 & Table-2.**

3.1.2 Routine Testing (Factory Acceptance Testing)

Each complete unit shall undergo routine testing as part of factory acceptance testing. The list of Routine tests to be performed in the factory is mentioned in Table-1.

3.1.3 Field Tests (Site Acceptance Testing)

The Contractor shall carry out the field-testing (Site Acceptance Testing) of PMUs after installation, commissioning, and integration with upstream PDC. 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 (FAT)	Field test (SAT)
	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 the latest versions of IEEE C37.118.2 and IS/IEC/IEEE 60255-118-1 standards with all amendments	√		
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 with Severity Level 3	√		
16	Electrical Fast Transient Burst Test as per IEC 61000-4-4 Level-4 or IEC 60255-22-4 with Severity Level 3	√		
17	Damped Oscillatory Wave Test as per IEC 61000-4- 18 & IEC 60255-22-1 with Severity Level 3	√		
18	Electrostatic Discharge test as per IEC 61000-4-2 Level-4 or IEC 60255-22-2 with Severity Level 3	√		
19	Radiated Electromagnetic Field Test as per IEC 61000-	√		

	4-3 or IEC 60255-22-3 Severity Level 3			
20	Damped Oscillatory magnetic Field Test as per IEC 61000-4-10 with Severity Level 3	√		
21	Power Frequency magnetic Field Test as per IEC 61000-4-8 with Severity Level 3	√		
	INSULATION TEST FOR PMU			
22	Power frequency voltage withstand Test as per IEC 60255-5 for 1kV	√		
23	1.2/50 µs Impulse voltage withstand Test as per IEC 60255-5	√		
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	√		

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	-	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 or IEC 60255-11	ON	-	-	-
11	Insulation Resistance Test	OFF	-	Measure Insulation resistance using 500 VDC Megger before & after Power Freq& Impulse voltage withstand tests	As per manufactu rer 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 400 C for 16 hrs	0
14	Cold tes	ON	-	Continuous operation at 00 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: Data Requirement Sheets (DRS) of PMU and associated items

1. Phasor Measurement Unit (PMU) –:

The Phasor Measurement Units (PMUs) shall communicate to the Phasor Data Concentrator (PDC) at respective SLDC/RLDC as per the latest version IS/IEC/IEEE 60255-118-1 and IEEE C37.118.2 Standards with all amendments.

S.No	Description of the Features	Offer by the Bidder
1	Device	
2	Manufacturer	
3	Model No.	
4	Country of origin	
5	Minimum Analog Channel	
6	Minimum Digital Channels	
7	CT core	
8	Auxiliary Power Supply Source	
9	Communication ports	
10	Interface ports for Time synchronization	
11	Communication Protocols	
	Measurement Output	
12	Performance Class	
13	Test Compliance as per IEEE 37.118 and IEC/IEEE 60255- 118-1 Standards	
14	Protocol support for SAS	
15	Environmental Condition	
16	Reporting rates (Frame per second)	
17	Configuration Frame	
18	Minimum reporting clients	
19	Active & Reactive Power	
	Other features	
20	HMI facility	
21	Remote configuration Change	
22	Configuration software	
23	PMU integration with PDC	
24	Station Name, Phasor Name, Analog name, Digital Name	
25	Event Recorder	
26	Cyber Security	
27	Self-monitoring, diagnostic features, and alarm to PDC.	
28	Multiple data streams configurable independently.	
	Environmental condition	
29	Temperature	
30	Humidity	

2. GPS based time facility:

S.No	Description of the Features	Offer by the Bidder
1.	Manufacturer	
2.	Model No.	
3.	Time stability of internal time base	
4.	Propagation delay compensation	
5.	Include an offset to permit correction to local time	
6.	Reverting to internal time base upon loss of signal from UTC source	
7.	Resynchronization Delay	
8.	Accuracy of resynchronization	
9.	Interfaces (minimum)	
10.	Environmental Compliance	
11.	Power Supply (in Watts)	
12.	Heat Load	

3. Industrial grade LAN Switch (Layer 2 & Layer 3):

S.No	Description of the Features	Offer by the Bidder
1.	Manufacturer	
2.	Model No.	
3.	Country of origin	
4.	Performance	
5.	Functions	
6.	Layer-2 & Layer-3 features required	
7.	Features to support	
8.	Network management	
9.	Security	
10.	Interface ports	
11.	Mounting	
12.	Cable standard	
13.	Environmental Compliance	
14.	Operating temp	
15.	Power supply	

4. Armored FO Cables

S. No	Description of the Features	Offer by the Bidder
1	Manufacturer	
2	Application	
3	Cable Type	

S. No	Description of the Features	Offer by the Bidder
4	Armoured/Un-Armoured	
5	Wavelength	
6	Attenuation	
7	Band Width	
8	No. of Fibers	
9	Cladding Diameter	
10	Core Diameter	
11	Cable Diameter	
12	Numeric Aperture	
13	Bending Radius	
14	Armored Type	
15	Operating Temperature	

5. LIU

S. No	Description of the Features	Offer by the Bidder
1	Manufacturer	
2	Application	
2	Mounting	
3	No of ports	
4	Features	

Section-4
Support Services

4.1 Support Services

Throughout design, implementation, factory testing, and field installation and testing, the Contractor shall supply consulting assistance, as required by the Employer for site preparation, field installation, and other areas where technical support maybe required.

The Contractor shall be responsible for minor facility renovation, and maintenance of the supplied system upto and including successful completion of the Site Acceptance Test.

After final acceptance of the communications equipment, the Contractor shall offer continuing

technical support and spare parts for the designed life of the equipment or 7 years after the declaration of withdrawal of equipment from production whichever is earlier. However, the termination of production shall not occur prior to Operational Acceptance / Taking Over of the system by the Employer. The Contractor shall review the Employer existing equipment make, integration & switch over recommendation and prepare a detailed field implementation plan.

4.1.1 Technical Support

Consultation with Contractor's technical support personnel and trained field service personnel shall be readily available on a short-term/long-term basis to assist the Employer personnel in maintaining, expanding, and enhancing the telecommunication network upon expiration of the warranty period. The Contractor shall include in their offer(s), a proposal for ensuring continued technical support as stated above.

4.1.2 Contractor's Future Hardware/Software Changes

The Employer shall be informed of all alterations or improvements to the hardware supplied under this Specification. The Employer shall be placed on the Contractor's mailing list to receive announcements of the discovery, documentation, and solution of hardware/software problems as well as other improvements that could be made to supply equipment. The service shall begin at the time of contract award, and shall continue for 10 years. The Contractor shall also include a subscription to the hardware subcontractors' change notification service from the time of contract award through the warranty period, with a Employer renewable option forex tended periods.

4.2 Spare Parts and Test Equipment

The spare parts and test equipment shall be provided for each subsystem as described below.

4.3 System Maintenance

As per DoT guidelines, operation and maintenance of the network shall be entirely by Indian engineers and dependence on foreign engineers shall be minimal within a period of two years from the date of LoA. The contractor shall be responsible to maintain the confidentiality of the Employer’s System Information that Employer shares with the contractor for maintenance period.

4.4 Miscellaneous Supplies

The Contractor shall provide all required consumable and non-consumable supplies necessary to support all installation and test activities through final operational acceptance / Taking over. However, if there are any problems in the SAT and additional consumables are required, the same shall also be supplied by the Contractor at no additional cost.

4.5 Materials Handling and Storage

This section describes material handling and storage requirements.

(a) All the equipment furnished under the contract and arriving at site shall be promptly received, unloaded and transported and stored by the Contractor.

(b) The Contractor shall be responsible for examining all the shipment and notify the Employer immediately of any damage, shortage, discrepancy, etc., for the purpose of Employer information only. The Contractor shall submit to the engineer every week a report detailing all the receipts during the week. However, the Contractor shall be solely responsible for any shortages or damages in transit, handling and/or in storage and erection of the equipment at site. Any demurrage, wharfage and other such charges framed by the transporter, railways, etc., shall be to the account of the Contractor.

(c) The Contractor shall maintain an accurate and exhaustive record detailing out the list of all equipment received by him for the purpose of erection and keep such record open for the inspection of Employer.

(d) All equipment shall be handled very carefully to prevent any damage or loss. The equipment stored shall be properly protected to prevent damage. The equipment from the store shall be moved to the actual location at the appropriate time so as to avoid damage of such equipment at site.

(e) All the materials stored in the open or dusty location must be covered with suitably weatherproof and flameproof covering material wherever applicable.

(f) The Contractor shall be responsible for making suitable indoor storage facilities to restore all equipment which require indoor storage.

Contractor shall inspect pertinent locations, door openings, and other passages at the installation locations to avoid building any components of the system too large for such passages. Further, any components of the supplied equipment too large or too heavy for existing facilities at the

installation locations shall be hoisted or otherwise handled with apparatus as required at Contractor's expense. All special handling charges shall be provided by the Contractor and shall be included in the Contract.

The Contractor shall be solely responsible and liable for any damage to existing facilities at the installation locations caused by the Contractor, any of the Contractor's employees, or any subcontractor of the Contractor. Employer may arrange for the repair of such damage, should it occur, at the Contractor's expense. The Contractor shall take reasonable precautions to protect the installation locations from damage. The Contractor shall not cut, drill into or otherwise alter the installation locations without first obtaining permission from Employer.

Throughout the installation of the equipment, the Contractor shall keep the installation locations free from debris and remove from the installation locations all refuse resulting from any work being done by the Contractor. At the completion of the installation the Contractor shall leave all installation locations in a clean and finished condition.