

## **Additional Clauses to Sub-Section B\_Technical Specifications - Electrical System**

### **27 Static VAr Generator (SVG)**

- 27.1 SVG shall be offered as a containerised, factory-assembled and factory-tested solution, suitable for outdoor installation, with a minimum enclosure protection class of IP30 (Indoor) or IP54 (Outdoor) in accordance with IEC 60529.
- 27.2 The container/enclosure shall be furnished with a corrosion-protection system appropriate to the pollution severity of the Project site (coastal/industrial/desert), determined in accordance with ISO 12944-2.
- 27.3 The SVG shall employ fully controlled IGBT power devices arranged in a cascaded/chain-link multi-level topology, with closed-loop water cooling. Each phase shall have at least one redundant power module, in addition to the modules required for the rated reactive power output. In case of failure of any single power module, the faulty module shall be automatically detected and bypassed, and the redundant module shall be automatically brought into service, without manual intervention. The SVG shall continue to operate at its full rated reactive power output without tripping or derating under such single-module failure.
- 27.4 The SVG shall comprise, at minimum, the following major sub-systems together with all associated equipment, auxiliaries, protection, control, interconnections and accessories required for complete and reliable operation:
- (i) Start-up arrangement: Comprising the soft-start device, starting resistor, switching devices and surge arresters of suitable ratings to facilitate controlled energization of the SVG and charging of the DC capacitors without imposing excessive inrush current.
  - (ii) Control and protection cabinet: Comprising the controller, HMI, redundant control power supplies, protection relays, auxiliary power distribution, indication lamps, emergency stop facility, MCBs and all associated control, monitoring and protection equipment necessary for safe and reliable operation.
  - (iii) Power module assembly: Comprising the converter power modules, DC capacitors, semiconductor devices, gate drive units and associated interconnections. The number and rating of the power modules shall be selected by the Bidder to meet the specified system voltage, reactive power rating and performance requirements.
  - (iv) Coupling reactor/transformer: Comprising the coupling reactor and/or transformer,

as applicable, together with the associated disconnect, earthing switch, surge arresters, bus connections and all accessories required for interfacing the SVG with the Project electrical system.

- (v) Cooling system: Comprising the complete cooling arrangement, including pumps, heat exchangers, piping, valves, instrumentation and all associated auxiliaries. The cooling system shall be adequately sized for continuous operation under the specified site conditions and shall provide continuous monitoring of coolant flow, temperature, pressure and other critical parameters, with appropriate alarm and trip functions for abnormal operating conditions.

27.5 The SVG shall be designed to continuously deliver its rated reactive power output under the specified operating conditions and shall be capable of meeting the following overload requirements without damage or degradation in performance:

- (i) Continuous overload capability of not less than 110% of the rated reactive power output.
- (ii) Short-duration overload capability of not less than 120% of the rated reactive power output for a minimum duration of 1 (one) minute.

Compliance with the specified overload capability shall be demonstrated through valid type test reports or other documentary evidence acceptable to the Employer.

27.6 The SVG shall support operation in, at minimum, the following control modes, selectable locally through the HMI and remotely through IEC 61850, IEC 104 or MODBUS TCP/IP with the SCADA system:

- (i) Constant Voltage Control Mode: Automatic injection or absorption of reactive power to maintain the bus voltage at a predefined reference value within the specified control band.
- (ii) Constant Reactive Power (MVar) Control Mode: Automatic regulation of reactive power output to maintain a user-defined reactive power (MVar) set-point irrespective of system operating conditions, within the rated operating limits of the equipment.
- (iii) Constant Power Factor Control Mode: Automatic regulation of reactive power to maintain a specified power factor at the point of connection by dynamically supplying or absorbing reactive power as required.

27.7 The complete SVG assembly, along with its sub-component, shall be designed for a minimum service life of 25 (twenty-five) years.

- 27.8 The SVG/STATCOM shall be designed, rated and configured based on the recommendations and outcomes of the approved Grid Interconnection Studies, including load flow, short-circuit, dynamic stability, transient stability, power quality and harmonic studies, as applicable. The final reactive power rating, control philosophy, operating range, response characteristics and associated equipment shall ensure compliance with the applicable provisions of the CEA Technical Standards for Connectivity to the Grid Regulations, the CERC Indian Electricity Grid Code (IEGC), the applicable CTUIL/STU connectivity procedures, and the requirements stipulated by the concerned transmission utility, Load Despatch Centre and statutory authorities.
- 27.9 The Bidder shall furnish validated and benchmarked RMS and EMT simulation models of the complete SVG/STATCOM system, together with the associated benchmarking reports and model validation documentation, in accordance with the applicable CEA Connectivity Regulations and CTUIL/STU procedures. The models shall be updated, if required, based on site test results.
- 27.10 Type Test  
Type Test Reports as per IEC 62927 & applicable CEA Connectivity Regulations shall be submitted during detailed engineering for the review of the Employer.
- 27.11 Routine and Factory Acceptance Test  
The SVG shall be offered for Factory Acceptance Testing (FAT) at the manufacturer's works. FAT shall be conducted in accordance with the approved FAT procedure  
Certified routine test reports for all major equipment shall be furnished to the Employer for review and approval prior to dispatch.
- 27.12 Warranty  
The SVG shall be warranted against all material/ manufacturing defects and workmanship for minimum of 5 (five) year from the date of supply.

## **28 Harmonic Filter**

- 28.1 The Harmonic Filter (HF) system shall be designed, manufactured, tested, supplied, installed, commissioned and integrated with the intermediate 33 kV Bus for mitigation of harmonic distortion, and improvement of power quality, in compliance with the applicable CEA Technical Standards for Connectivity to the Grid Regulations, CERC Indian Electricity Grid Code (IEGC), IEEE 519, applicable CTUIL/STU connectivity procedures and other statutory requirements.
- 28.2 The HF shall be designed and sized based on the approved Grid Interconnection Studies,

including load flow, short-circuit, harmonic, power quality and stability studies, as applicable.

- 28.3 The final filter configuration, tuning frequency, capacitor bank rating, reactor rating and switching philosophy shall ensure compliance with the requirements of the Employer, the concerned transmission utility and statutory authorities. The Contractor shall submit all design calculations, studies and supporting documents necessary to substantiate the design and sizing of the Harmonic Filter system, including, but not limited to, the selection of tuning frequency, capacitor bank rating, reactor sizing, harmonic performance and resonance assessment, for the Employer's review and approval.
- 28.4 The HF shall comprise, indicatively, of a Disconnecter, capacitor bank(s), series filter reactor(s), current transformers (CTs), voltage transformers (VTs), damping resistors and/or residual voltage transformers (RVTs), line and earth isolators, lightning arresters, protection, control and monitoring equipment, busbars, interconnections, earthing system and all associated auxiliaries and accessories required for complete and reliable operation.
- 28.5 The capacitor bank and series filter reactors shall be suitably rated and configured to provide the harmonic filtering performance without introducing unacceptable series or parallel resonance over the complete operating range of the Project.
- 28.6 HF shall ensure that the harmonic voltage distortion, harmonic current distortion and power factor at the Point of Interconnection comply with the applicable provisions of IEEE 519, the CEA Technical Standards for Connectivity to the Grid Regulations, the CERC Indian Electricity Grid Code (IEGC) and the requirements of the concerned transmission utility.
- 28.7 The Bidder shall furnish validated and benchmarked RMS and EMT simulation models of the complete Harmonic Filter system, together with the associated benchmarking reports and model validation documentation, in accordance with the applicable CEA Technical Standards for Connectivity to the Grid Regulations and CTUIL/STU procedures. The models shall be updated, wherever required, based on site test results.
- 28.8 Type Test
- The major equipment forming part of the Harmonic Filter system shall be type tested in accordance with the latest editions of the applicable IEC/IS standards. Valid type test reports from NABL-accredited or internationally accredited laboratories shall be furnished for review and approval.
- 28.9 Routine and Factory Acceptance Test

The complete Harmonic Filter system shall be offered for Factory Acceptance Testing (FAT) at the manufacturer's works. FAT shall be conducted in accordance with the approved FAT procedure

Certified routine test reports for all major equipment shall be furnished to the Employer for review and approval prior to dispatch.

#### 28.10 Warranty

All individual components of the Harmonic Filter system shall be warranted against all material/ manufacturing defects and workmanship for minimum of 5 (five) year from the date of supply.

### 29 Phasor Measurement Unit (PMU)

29.1 Phasor Measurement Unit (PMU) System shall facilitate real-time synchronized phasor measurement of the Project electrical system. The PMU System shall comply with the latest editions of IEEE C37.118, IS/IEC/IEEE 60255-118-1, the applicable CEA Regulations, CERC Regulations, Grid-India/CTUIL guidelines, and the requirements of the concerned SLDC/RLDC.

29.2 The PMU System shall be fully compatible with the Phasor Data Concentrator (PDC) installed at the concerned SLDC/RLDC and shall support all communication, configuration and interoperability requirements necessary for successful integration with the Wide Area Measurement System (WAMS). The Contractor shall coordinate with the concerned SLDC/RLDC, Grid-India and other statutory authorities for successful integration and commissioning of the PMU System.

29.3 The system shall include, but not be limited to, the following components:

- (i) Phasor Measurement Unit (PMU) suitable for monitoring requisite number of feeders/elements;
- (ii) GPS-based Time Synchronization System complete with antenna, mounting accessories and connecting cable;
- (iii) Industrial Grade Layer-3 Managed Ethernet Switch;
- (iv) 12-port Light Interface Unit (LIU);
- (v) PMU configuration software;
- (vi) Optical fibre cables, CAT-6 cables, DC supply cables, control cables and all associated connectors and accessories;
- (vii) Panel internal wiring and mounted accessories; and
- (viii) All hardware, software, consumables and auxiliaries necessary for complete

installation, testing, commissioning and reliable operation of the PMU System.

29.4 The PMU shall, at minimum, shall comply with the following:

| Parameter               | Requirement                                                  |
|-------------------------|--------------------------------------------------------------|
| Performance Class       | Class M                                                      |
| Voltage Inputs          | Minimum four (4) sets of three-phase voltage inputs          |
| Current Inputs          | Minimum four (4) sets of three-phase current inputs          |
| Digital Inputs          | Minimum sixteen (16) digital inputs                          |
| Reporting Rate          | 25 fps and 50 fps for a 50 Hz system                         |
| Configuration Frames    | Support for Configuration Frame-2 and Configuration Frame-3  |
| Communication Protocols | TCP/IP, UDP/IP and IEC 61850                                 |
| Local Interface         | Local HMI for configuration, diagnostics and monitoring      |
| Event Recording         | Event recording with time-synchronised data logging          |
| Self-Diagnostics        | Continuous self-monitoring and diagnostics                   |
| Remote Configuration    | Remote configuration and parameterization capability         |
| Data Streams            | Support for multiple independently configurable data streams |

29.5 The PMU shall be capable of measuring, calculating, recording and transmitting, at minimum, the following synchronized parameters in accordance with IEEE C37.118 and IS/IEC/IEEE 60255-118-1::

- (i) 3-phase voltage Phasors (Magnitude and angle),
- (ii) 3-phase current Phasors, (Magnitude and angle),
- (iii) Positive sequence voltage, (Magnitude and angle),
- (iv) Positive sequence current, (Magnitude and angle),
- (v) Breaker Status
- (vi) Protection operated status
- (vii) Frequency
- (viii) Rate of Change of Frequency (ROCOF) -  $df/dt$
- (ix) Analog Values (MW & MVAR)
- (x) Any additional parameters mandated by the said CEA Guidelines or by the concerned SLDC/RLDC/Grid-India/CTUIL.

- 29.6 The PMU shall be synchronized to Coordinated Universal Time (UTC) through a GPS-based Time Synchronization System, either integrated within the PMU or provided as a separate unit. The time synchronization system shall achieve a synchronization accuracy of  $\pm 1 \mu\text{s}$  with respect to UTC and shall support automatic leap-second correction and IRIG-B time synchronization in accordance with IEEE C37.118. Upon loss of the GPS reference signal, the PMU shall automatically revert to its internal time base, generate a loss-of-synchronization alarm and communicate the same to the Phasor Data Concentrator (PDC). The PMU internal clock shall have a minimum stability of 1 ppm and, upon restoration of the GPS reference, shall automatically re-synchronize to within  $\pm 1 \mu\text{s}$  of UTC within five (5) minutes.
- 29.7 The Industrial Grade Ethernet Switch shall be a managed Layer-3 switch suitable for utility substation applications and compliant with IEC 61850-3 and IEEE 1613. The switch shall support VLANs, QoS, multicast communication, redundancy protocols, SNMPv3 and cybersecurity features required for reliable transmission of PMU data to the PDC.
- 29.8 The PMU System shall incorporate appropriate cybersecurity measures including password-protected access, user authentication, secure communication, event logging, Syslog support and access control in accordance with IEC 62351 and the applicable cyber security requirements of Grid-India/CTUIL.
- 29.9 The Bidder shall furnish all software, engineering tools, user manuals, configuration utilities and perpetual software licenses necessary for configuration, operation, diagnostics, maintenance and future expansion of the PMU System.
- 29.10 The Bidder shall undertake the complete installation, testing, commissioning and successful integration of the PMU System with the existing Phasor Data Concentrator (PDC) installed at the concerned SLDC/RLDC, including all coordination with the concerned authorities necessary for successful commissioning.
- 29.11 The Bidder shall establish point-to-point communication between the Project Main Control Room (MCR) and the concerned SLDC/RLDC through leased line infrastructure and shall ensure reliable communication and successful transmission of PMU data to the PDC.
- 29.12 The Bidder shall supply all miscellaneous hardware, software, consumables, mounting accessories, interconnecting cables, connectors, glands, lugs, fastening materials and other items required for the complete installation, testing, commissioning, integration and reliable operation of the PMU System, whether or not specifically identified

elsewhere in the Contract.

29.13 The PMU placement, measurement channels, configuration, communication architecture and reporting parameters shall be determined and approved in accordance with the CEA Guidelines on Unified Philosophy for Placement of Phasor Measurement Unit (PMU) in Indian Grid (dated 19.03.2025), and its associated amendments and the applicable CERC (Indian Electricity Grid Code) Regulations/Interface Guidelines, and shall be as approved by the concerned SLDC/RLDC, Grid-India and CTUIL, finalized during detailed engineering in consultation with the said authorities.

#### 29.14 Tests

The PMU System shall be subjected to tests in accordance with the following standards.

| S. No.                  | Test Description                                                                                                      | Type Test | FAT | SAT |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------|-----------|-----|-----|
| <b>Functional Tests</b> |                                                                                                                       |           |     |     |
| 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                                              | ✓         | ✓   | ✓   |
| <b>EMI/EMC Tests</b>    |                                                                                                                       |           |     |     |
| 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                            | ✓ |  |  |
| <b>Insulation Tests</b>    |                                                                                                           |   |  |  |
| 22                         | Power frequency voltage withstand Test as per IEC 60255-5 for 1kV                                         | ✓ |  |  |
| 23                         | 1.2/50 $\mu$ s Impulse voltage withstand Test as per IEC 60255-5                                          | ✓ |  |  |
| 24                         | Insulation Resistance Test                                                                                | ✓ |  |  |
| <b>Environmental Tests</b> |                                                                                                           |   |  |  |
| 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                                                                             | ✓ |  |  |

#### 29.14.1 Type Tests

Valid type test reports from NABL-accredited or internationally accredited laboratories shall be furnished for review and approval.

#### 29.14.2 Routine, Factory and Site Acceptance Tests

The complete PMU System shall also be offered for Factory Acceptance Testing (FAT) in accordance with the approved FAT procedure.

#### 29.15 Warranty

The complete PMU System, including all associated hardware, software, accessories and auxiliaries, shall be warranted against all material/ manufacturing defects and workmanship for minimum of 5 (five) years from the date of supply.