GUJARAT ENERGY TRANSMISSION CORPORATION LTD.

SARADAR PATEL VIDYUT BHAVAN,
RACE COURSE, BARODA – 390 007.

TECHNICAL SPECIFICATION

FOR

STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

GETCO / E / TS- STATCOM 045 / R1 Dt. 17.08.2024

1. Introduction:

It is the intent of GETCO to install STATCOM Stations at various existing 220kV Substations as given in the schedule-A of Technical Specification. This technical proposal for each STATCOM Station consist of STATCOM connected to the 220kV bus through a coupling transformer (220/ xx kV). MV voltage level (xx kV) of the coupling Transformer can be chosen by the bidder to optimize the offered solution which meets functional requirement of this Technical Specification.

The STATCOM Station shall operate asymmetrically in the leading and lagging MVAR region as applicable to reach the dynamic range specified. The purpose of the STATCOM station is to regulate the voltage of 220kV Bus (PCC/POC). The Configuration and the nominal rating of the STATCOM station is specified in schedule-A

The main building block of the STATCOM should be single phase VSC based convertor valve (multi-level) operating in a way to eliminate or minimize ac filter requirement to High pass filter only and connected to the XX kV bus through air core reactors. The STATCOM may comprise of single or multiple STATCOM units/branches operating in parallel as specified in schedule-A.

2. Relevant Standards:

STATCOM Station shall comply with the following standards (latest edition):

ITEM	DESCRIPTION	STANDARD Technical Spec reference for routine items
1	Voltage sourced converter (VSC) valves for STATCOM	IEC 62927 IEEE 1052 IEC60747
2	Control, protection & monitoring	IEC61000 IEC60255
3	Valve Hall for housing the equipments as above comprising of: - wall bushings for connection between converter phases and decoupling reactors, - piping and tubing connections of the cooling system to converter - connection of the control cabinet with the converter through optical fibers - internal lighting, auxiliary power supply (AC and DC) and powersocket system - internal HVAC system	IEC60071 IEC60270 IEC60137
4	XX kV, dry insulated, air core and air self-cooled decoupling reactors. Mechanically Switched Reactors, half-reactors stacked on above the other, Outdoor installation, Complete with supporting structures	IEC 60076
5	Power Capacitors (MSC etc.)	IEC 60871-1
6	220kV Power transformer (Coupling Transformer)	IEC60076 IEC60354
7	CT's and VT's	IEC 61869
8	Dis-connectors and Earthing Switches	IEC 62271
9	HV & MV Circuit Breakers	IEC 62271
10	Surge Arresters	IEC 60099
11	Auxiliary & grounding transformer	IEC 60076 IEEE C57.32 IS 5553 (Part 6)

12	Neutral Grounding Resistor, charging resistor	IEEE C57.32 IEC60322
13	UPS, UMD, SMPS &Other Power supply units	IEC 62040 IEC 61558
14	Cyber Security	IEC62243

3. Scope of work

This is a turn-key Technical Specification for the Contractor to supply according to this specification, complete STATCOM Station including Modular Multi level Voltage Source Converter (MMC-VSC) based STATCOM units/branches along with associated equipments. The Contractor shall be responsible for the design, engineering, fabrication, transport & delivery to site, civil works, erection, installation, testing, training, commissioning, guarantees/warranties, field performance verification, supply of operational & maintenance spares, special tools & tackles required for operation and maintenance of the complete STATCOM station.

The scope also covers operation of STATCOM, jointly with GETCO, during first six months of the guarantee period and maintenance for initial period of 5 years (excluding guarantee period) after successfully commissioning the system and training to GETCO executives.

The key components of STATCOM units/branch and associated control & protection should be designed, manufactured and tested by the Bidder itself. The bidder must also be responsible for turnkey delivery ensure availability and performance guarantees as well as availability of follow up services and spare parts for running the STATCOM Station.

The Contractor shall also perform the system studies (steady state and dynamic), design verification/validation, material procurement, type testing, quality management, factory inspection/testing, site inspection, field testing, project management and interface management with other Parties and all associated works and services until final handing over of the STATCOM Station in a satisfactory working and operating condition along with the necessary spare parts, consumables and documentation, to the Employer.

The switchgear for connection of STATCOM units/branches provided on the secondary side of coupling transformer shall be of standard voltage rating as per IEC. The switchgear, structure, control, protection and substation automation on 220kV side shall be as per applicable respective technical specification as mentioned in respective Technical Specification.

Generally, the purpose of STATCOM is to improve system stability, provide damping and to smooth out the step voltage change and external compensating equipment (i.e. any existing capacitor and reactor banks) switching and provide VARs as needed to support the 220 kV bus voltage.

In order to get optimum control of MVAR, as well as any existing capacitor and reactor banks (if installed) shall be integrated along with STATCOM control to provide steady state 220 kV bus voltage control in a smooth manner. The operating functions of the STATCOM Station shall include:

- Steady state voltage control of 220 kV bus,
- Balance steady state voltage at 220 kV bus,
- Dynamic over-voltage control,
- Transient and Dynamic voltage stability control
- Damping of Power Oscillations
- Control of temporary power frequency over-voltages
- Prevention of voltage collapse**.**

It is assumed that the arresters will limit any transient and switching surge over voltages and may also, by design, limit dynamic over voltages. The requirement of reactive power compensation guaranteed by the bidder shall not be less than the levels specified considering following.

The total cumulative Capacitive (+ve) and Inductive (-ve) MVAR rated Capacity of STATCOM Station comprising of STATCOM, Coupling Transformer, Coupling Reactor or any filter (if applicable) shall be rated at 1 p.u. voltage, 1 p.u. frequency and 20 deg C ambient temperature at 220 kV Bus (Referred to as “Point of Common Coupling” or PCC).

The rated capability of STATCOM, shall be at 220 kV (Referred to as “Point of Common Coupling” or PCC) and in the steady state frequency range of 48.5 Hz to 50.5 Hz.

The STATCOM Station including STATCOM Units, shall be designed to operate continuously under the worst possible combination of steady state voltage and frequency range of 198 kV to 245 kV and 47.5 Hz – 52.5 Hz respectively and transient and temporary over voltages defined in Clause 5.1).

The ac voltage unbalance at fundamental frequency shall be assumed equivalent to a negative phase sequence component of 1.5 % for equipment rating purposes.

The reactive power compensation levels shall be determined by manufacturing tolerances of the components and measurements carried out using metering accuracy instrumentation at the 220kV feed points to the STATCOM Station.

The reactive power capability shall also be determined by calculations based on test values of appropriate quantities at the discretion of the Employer.

Operation of STATCOM Station shall not excite any resonance condition in connected Power System.

Complete Valve Hall and STATCOM control building (with foundation, cable trenches, plumbing, lighting, fire protection and electrical outlets as well as facilities for ambient temperature and humidity control, as required) to accommodate STATCOM valve, its cooling system, control and monitoring unit, protection system, auxiliary systems, service rooms, workshop, control room, LV Room, Battery room etc. shall be in the scope of this tender. In particular the following, but not limited to this, is included in Scope of Works:

- To perform various system studies covering all the aspects as per Annexure- 1 of the technical specification, Deriving power system parameters, Designing of STATCOM and validation of design.
- The STATCOM valves with their protection, control, monitoring and cooling system.
- Surge protection as required.
- Coupling power transformer required by the STATCOM system.
- All current and voltage instrument transformers as required.
- All circuit breakers, disconnectors, earth switches as required.
- All the bay equipments on the primary side i.e. 220kV side of the coupling transformer and MV side as required.
- All necessary equipments for the control, protection, signaling and measurementsystem of the STATCOM and its interface to the control center as required.
- System alarm and fault recording system as required.
- SCADA and Automation system.
- Auxiliary AC and DC power distribution.
- Automatic switchover between main and backup station service AC feeders.
- Surge protection and overhead lightning protection of the entire STATCOM yard and STATCOM building as required.

- All equipment support structures and foundations as well as trenches as required.
- All bus work including steel structures, foundations, insulators, conductors,connectors, joints, fittings etc. as required.
- STATCOM yard earthing system including connection to the existing substation earthmat.
- STATCOM yard lighting as required.
- All power, control, F.O. cables for the entire STATCOM system.
- Valve hall and complete STATCOM building with foundation, plumbing, lighting, fire protection and electrical outlets as well as facilities for ambient temperature and humidity control as required.
- Operation of STATCOM for 6 months
- Maintenance of STATOM for 5 years after guarantee period
- Any other equipment and engineering required for the proper functioning of the STATCOM

4. Ambient Condition

STATCOM Station should be designed to perform under the ambient conditions as specified in substation details annexure.

5. Power System Characteristic

The power system characteristics parameters shall be as per **Annexure-II** attached separately.

STATCOM Station Characteristics:

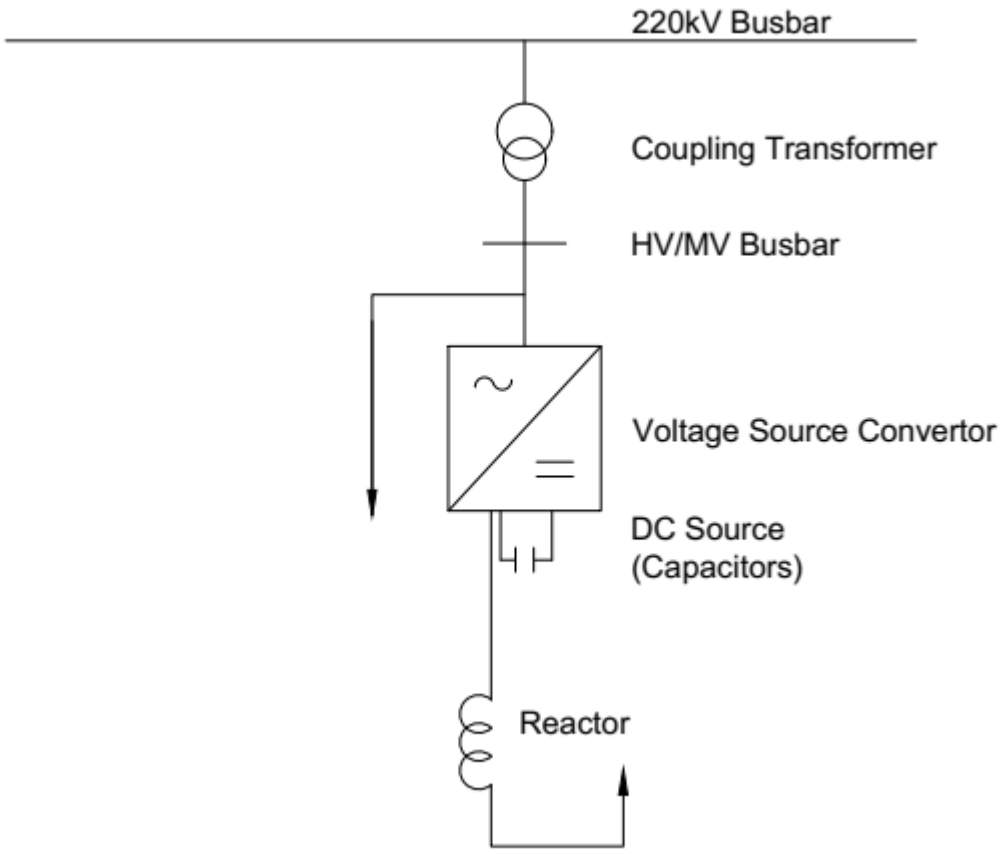

Figure-1 Conceptual Indicative Schematic diagram of STATCOM Station

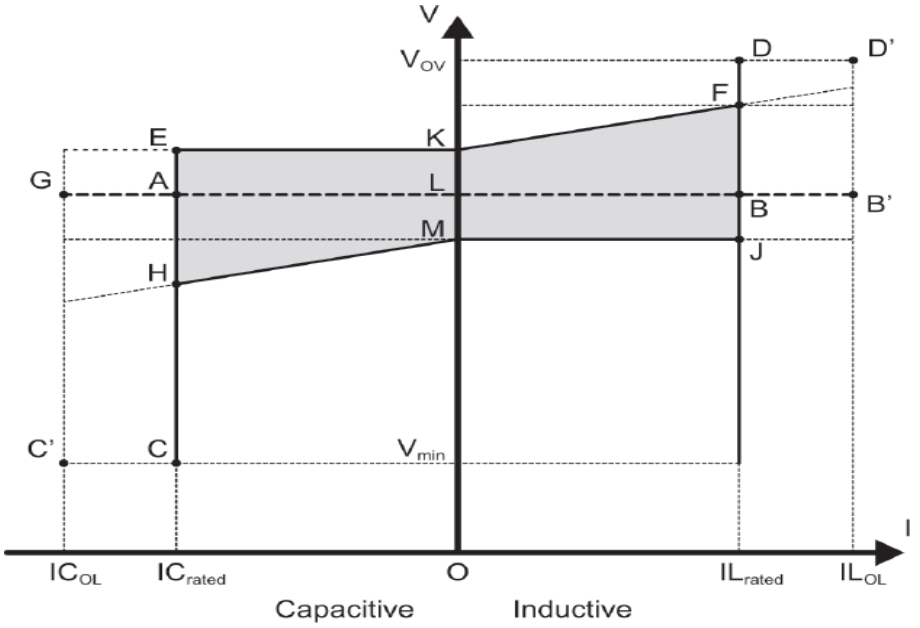

Figure-2 VI Curve of the VSC Portion

5.1 STATCOM Station Ratings

The output of a STATCOM Station can be adjusted continuously over the range illustrated in Figure-3. The following items define the ratings of the STATCOM station equipment.

a) The STATCOM Station should regulate the 220 kV bus voltage to a reference voltage of 220 kV (1.0 per unit, Point L Figure-3), continuously adjustable between 0.95 per unit and 1.05 per unit.

b) The nominal capacitive and inductive reactive power output of the STATCOM should be as defined at 1.0 p.u. ac bus voltage and nominal system frequency, and 20 °C ambient temperature. (Point A and Point B of figure-2)

c) The slope of the STATCOM Station characteristic should be adjustable in steps of not greater than 0.5 % between 1 % and 8 %, on a basis of cumulative MVA capacity of STATCOM Station (A+B in Figure-2).

d) The STATCOM Station should continue to generate reactive power during temporary under voltage down to 33kV (0.15pu) for the duration 5 sec (Point C); the STATCOM system may be tripped (or blocked) if the under voltage persists for more than 5 sec.

e) The STATCOM should continue to absorb reactive power during temporary over voltages in a controlled manner as per the following.

Temporary Overvoltage (at PCC)	Duration
up to 330 kV (1.5pu)	10 seconds
up to 387 kV (1.76pu)	100 m sec
up to 440 kV (2.0pu)	50 m sec

STATCOM Station may be tripped or blocked if the respective temporary over voltagesas mentioned above persists for more than its respective mentioned duration.

f) The STATCOM Station should be capable of repeating temporary operation as defined in any one of item (d) and (e) as above for at least 3 charging cycles in 60mins.

g) The coupling transformer and all bus equipment, such as filter branches (if applicable) and the MV Bus should be rated to withstand the specified continuous and short-term operation, and to withstand or be protected against voltage and current stresses that exceed these conditions.

h) All equipment in the STATCOM Station should be capable of sustaining, without damage, any fault limited by the maximum design short circuit level of the system and the Coupling transformer impedance.

i) The bidder shall assume the negative sequence voltage of 1% at rated short circuit level and provide control to reduce this unbalance.

j) The injected harmonics by STATCOM Station under the full operating range measured at 220 kV Bus (PCC) in accordance with IEEE 2800 and limiting values of individual harmonic distortions and total harmonic distortion shall be shall be as per **Annexure-II.**

k) The STATCOM controls should be designed to correct negative sequence voltage during steady state operation.

l) The switching module design should include an appropriate allowance for stray capacitance and component tolerances.

m) The STATCOM should be designed to prevent, or alternatively to withstand, false firing events, i.e., the firing of any valve at an incorrect time in the cycle or when not ordered. The bidder should describe the details of prevention or inherent withstand capability builtin its design.

6.1.1 Control Objectives

The control system shall control the STATCOM required under this technical specification, as well as any existing switchable capacitor and reactor banks installed.

Operation logic for the breakers, disconnectors and earth-switches in the STATCOM Station shall also be incorporated in the control system. The control shall be programmable and shall have sufficient scope and flexibility to permit re-programming according to future changes/addition in the power system. The operator interface must be integrated in a latest version of Windows environment.

6.1.2 STATCOM Station Functions and Applications

6.1.2.1 Voltage Control mode (Automatic and Manual)

Control of the positive sequence component of the fundamental frequency voltage in steady state and dynamic operation, with slope in the range as specified at clause

6.1- c) above.

6.1.2.2 Fixed Reactive Power Mode

In this mode, the reactive power output of the STATCOM should be manually controlled, by direct operator action. This feature is normally utilized for testing purpose.

6.1.2.3 Steady State Condition

The STATCOM Station shall provide necessary reactive power support to the 220 kV bus (PCC) to compensate for voltage variation under steady state.

6.1.2.4 Dynamic Over-voltage Control Performance

The STATCOM shall be required to provide necessary reactive power support with fast and smooth variation so that over-voltages under dynamic conditions are controlled. The operation of each STATCOM over its range of MVAR from full capacitive to full Inductive capacity and vice-versa shall be on the basis of smooth variation.

6.1.2.5 Transient and Dynamic Stability Performances

The STATCOM Station shall provide necessary reactive power so that transient and dynamic stability of the Employer's system are enhanced.

6.1.2.6 Damping of Power Oscillations

The STATCOM shall provide necessary damping to power oscillations by modulating its output in its entire range based on measured active power or rate of change of frequency at the 220kV bus. The damping controller would track local area oscillations as well as wide area oscillations and control would include several loops each focused on different frequency.

6.1.2.7 Facility for compensation of phase imbalance

Provide negative phase sequence voltage control to minimize presence of negative sequence content of the 220kV bus voltage.

6.1.2.8 Start up and Initial Switching

The operation of STATCOM Station during start-up/initial switching on should not create significant energizing transients causing voltage drop, voltage distortion and swinging of transmission voltage angle at the PCC bus by more than +/-5%. The contractor shall have to demonstrate this analytically during design phase.

6.1.2.9 Gain Supervision and Control

To control regulator gain in order to prevent oscillations and excessive overshoot in the STATCOM response, a gain supervision function shall be implemented.

This shall be an essential function for supervision of stability of the closed loop voltage control. The function of this controller is that when the supervision of the gain in the voltage regulator detects oscillations in the voltage controller output, the gain shall gradually be reduced until stability is reached. Normally it is a changed condition in the transmission system contribution to the closed loop gain that results in the instability. The reduction in the voltage regulator gain shall only balance the external change. The control should be adaptive in order to maximize its effectiveness. Gain reductions should be indicated and the reduction of the gain shall be able to be reset to nominal value by means of commands from the operator interface or automatically. A relative gain factor shall also be able to be changed from a gain optimizer.

6.1.2.10 Coordinated reactive power control of external devices

To optimize the use of dynamic vars versus steady state vars, control of externally connected shunt capacitor or reactor banks as applicable shall be implemented. Such banks may be connected locally to a HV bus or/and at MV bus. For simultaneous control with the supplementary VSC current controller, coordination for the two functions shall be provided. External devices Capacitor / Reactor if installed can be switched ON or OFF to position the steady state operating point of the VSC so as to extend its dynamic range.

6.1.2.11 Supplementary VSC current controller

To optimize the use of dynamic vars versus steady state vars, a control function that slowly reduces or offsets the STATCOM point of operation shall be implemented. By deliberately adjusting the voltage reference setting within a narrow window the STATCOM system output is pushed toward either a specific point or towards a window to preserve dynamic range. This slow operating function is meant to provide for slower controllers, such as externally connected shunt bank to operate and meet the slower long term voltage variations caused by daily or weekly load variations. Rapid changes in the system voltage that call for dynamic compensation will have priority over this type of controller.

6.1.2.12 Gain optimization

To provide operation at optimal regulator gain, a fully automatic optimizing function shall be implemented. This function operates by inducing a small change in the STATCOM output. The gain is adjusted based on the network response signal.

6.1.2.13 Control of Direct Current

During STATCOM operations, any flow of direct current to transformer MV side must be less than 25% of transformer magnetizing current. DC current flow in the transformer should be minimized by an independent control function which minimizes DC current. For presence of up to 0.2% second harmonic in 220kV system, the STATCOM control should minimize dc current flow in the transformer.

6.1.3 Under Voltage Strategy

It is essential that the STATCOM Station operates in a robust manner when transmission system under voltages appears. For transmission system voltages down to ***0.15*** pu, the STATCOM units must operate unrestricted, producing its rated capacitive current. The STATCOM must be designed to operate at transmission system under voltage, even considering that severe voltage unbalance scan appear. The STATCOM must not be restricted by short term negative sequence voltages up to 1.5%, appearing in conjunction with under voltages. The bidder shall provide at the time of detailed engineering, a plot of the STATCOM output versus different AC voltage unbalances.

Transmission system under voltages below 0.15 pu can appear in conjunction with transmission system faults. The STATCOM must ride through during faults and post fault under voltages. The minimum trip delay for the STATCOM Station, upon complete loss of the transmission system voltage shall not be less than 5 seconds. If station AC auxiliary power distribution is affected, critical loads must be fed from DC station batteries, UPS without tripping the STATCOM Station. Adequate capacity must be kept in DC station batteries, UPS to feed critical loads for smooth operation of the STATCOM Station facility. There must be redundant station battery system with each station battery system capable of delivering 100% load.

At under voltage conditions for the transmission system voltage, special control strategies are activated which override the normal control modes presented above. Normally if the voltage is low, the output from the STATCOM will be capacitive. If the voltage in all three

phases goes below a level specified by the Bidder, but not greater than 0.15 pu, a special under voltage strategy may be activated that controls the STATCOM output to 0 Mvar. As soon as the voltage goes higher than 0.15 pu, the under voltage strategy shall be deactivated and the normal control will be in operation.

The STATCOM Station must not be tripped or shutdown automatically for under voltages for duration specified in 5.1c. STATCOM Station must continue to operate at AC system Voltage at any or all the phase dips up to - 0.15 pu.

6.1.4 Over Voltage Strategy

The Contractor shall carry out dynamic stability study upfront in order to assess the dynamic overvoltage requirements. These studies shall include conditions with maximum and minimum short circuit system MVA conditions, single phase and three phase faults as well as stuck breaker condition, outage of nearby generator and also with outage of parts of the STATCOM Station. It is important that the STATCOM Station rides through temporary over voltages and not trip when it is needed the most.

The system should be able to withstand any 3 phase, 5 cycle (100 ms) and single phase 10 cycles (200 ms) fault with consequent loss of a 220 kV double circuit line and loss of a 500 MW generator. The fault duration mentioned above correspond to time assumed for persistence of fault. For other system parameters refer clause 5 above (Power System Characteristic) and Annexure-I.

The 220 kV system and equipment to which the STATCOM Station is connected are designed to with stand switching surge overvoltage up to 2.5 pu and power frequency over voltages up to 1.5 pu with initial value of the temporary overvoltage up to 2.0 pu for 1-2 cycles. Based on arrestor coordination and under the worst case scenario the 220 kV system phase to ground peak over voltages may be expected as follows

i) 360 kVp for 03 peaks
ii) 315 kVp up to 5 cycles
iii) 290 kVp up to 1 second
iv) 260 kVp up to 10 seconds

a) The STATCOM Station shall be designed to withstand these sequential over voltages.

b) If the over voltages greater than 1.1 pu are exceeded in magnitude and duration due to any system contingencies, suitable control action shall be taken by STATCOM Station to bear this kind of contingency.

c) The contractor shall evolve the insulation co-ordination of the components of the STATCOM Station after studies have been conducted to determine the over- voltage profile with the STATCOM connected to the system.

d) The contractor shall demonstrate to the satisfaction of the Employer that STATCOM Station will not excite ferro-resonance and sub-synchronous oscillationin the AC system.

e) It may also be noted that the tripping action for the Employer's 220kV lines is initiated if the overvoltage exceeds 1.1 to 1.15 pu for 4 to 10 seconds. The tripping of 220kV lines is initiated if 1.4 to 1.5 pu voltage persists for more than 100 to 150 milliseconds. The over voltage strategy shall be coordinated with these setting such that the STATCOM Station rides through up to these levels.

6.1.5 STATCOM Station Over load/Over Current

The overvoltage cycles mentioned in clause 6.1.4 above create a corresponding current overload in the STATCOM Station components; the STATCOM Station and its components shall be designed to withstand these.

In addition to the above the STATCOM Station and its components shall be designed to withstand overloading caused due to the following eventualities.

i) Short circuits and ground faults in the 220kV system especially those occurring near to the STATCOM Station and medium voltage bus of the STATCOM Station.
ii) Transient overvoltage due to switching operations and atmospheric effects.
iii) Temporary over voltages.
iv) Short circuits in the transformer secondary circuit such as
    - Bushing terminal fault
    - Flashover across a reactor, Bus Bar and other connected components/switchgear etc.
v) Protection system faults.

If the rated overvoltage is exceeded as a result of prolonged stressing or for other reasons, protection specified elsewhere in the specification shall come into effect to prevent damage.

6.1.6 Dynamic Performance Controls of STATCOM Station

The Bidder must describe in detail, the dynamic reactive power controls for enhancing stability margin and also damp oscillations of any critical frequencies. The dead band for continuous damping control must be very small so that there no discernible sustained oscillations.

6.1.7 Protective Control Functions

The Contractor shall provide all necessary protections including Main and Back-up protections for all protective zones and equipments like transformers, STATCOM Units, MV Bus Bar etc. as specified elsewhere in this specification. The Contractor shall also provide any protective control functions to meet the performance requirement of STATCOM Station.

a) Overvoltage Protection

The Contractor shall provide adequate overvoltage protection as a result of anynormal operation, mal-operation or system event.

b) Over current Protection

The Contractor shall provide adequate over-current protection for the STATCOM Station as a result of any abnormal operation, mal-operation or system event.

c) Gate level control Supervision

The Contractor shall provide adequate Sub module Gate level control supervision.

6.1.8 STATCOM Station Response

STATCOM station response shall be such that the change in measured system voltage to small disturbance should reach 90% of the desired total change within 30ms of the initiating a 5% step change of voltage reference. The maximum overshoot should not exceed 120% of the total change and the settling time should not exceed 100ms, after which the voltage should be within + 5% of the final value. This response characteristic within these limits must be respected when the system three-phase fault MVA is between the minimum and maximum value defined in clause-5. The response of the system voltage using the actual controller should be validated on a real time simulator during the factory acceptance test (FAT). For the purpose of STATCOM Station response time measurement and signal conversion of the voltage, error should not exceed 0.3%. The voltage response acquisition circuit should have a response time no longer than 10ms. However, time longer than 10ms can be allowed provided the requirement of STATCOM response time is met.

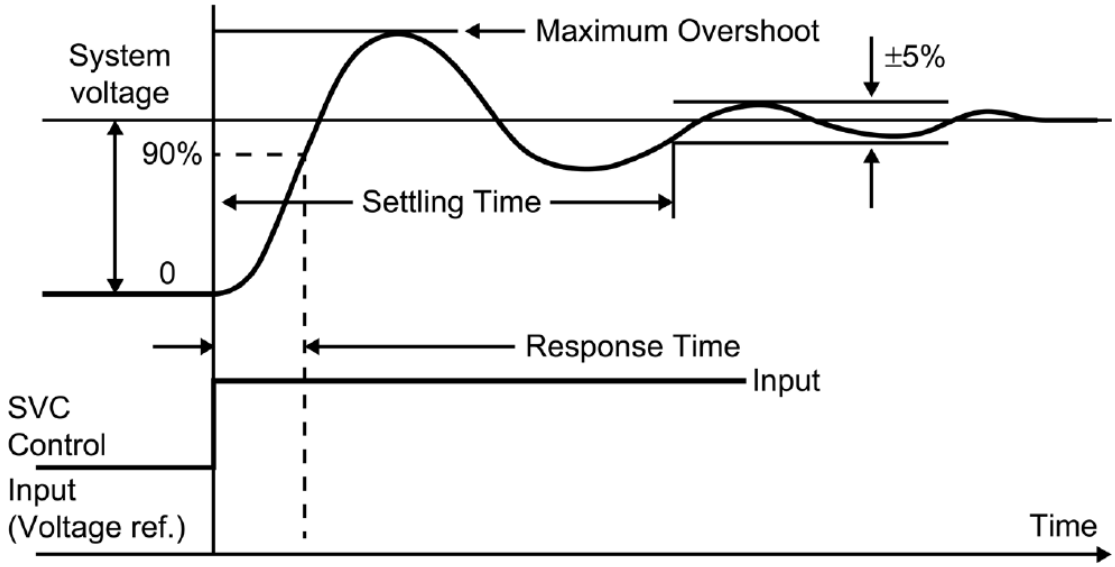

Figure-3 Response and Settling time

6.2 Harmonic performance and AC harmonic filter design (If applicable)

It is likely that with multi-level VSC based technology, no filters or only a small high-pass filter will be needed. The STATCOM shall be operable without ac filters. The STATCOM Station shall be designed to eliminate the effects of any harmonic resonance between STATCOM Unit and the ac system . To limit the harmonic distortion imposed on the 220kV transmission system, additional contribution of harmonic distortion from the STATCOM Station to 220kV system (PCC) should not exceed 1% for total and 0.5% for any specific harmonic.

6.2.1 Harmonic at PCC

The STATCOM Station contribution to the harmonic distortion levels at the STATCOM Station connection point (PCC) to the transmission system, shall not exceed the limits below. Following are the maximum limits given using denominations according to IEEE 2800

6.2.2 Harmonic calculation:

The scope shall be considered as per ***Annexure-II*****.**

6.3 MV Switchyard

- Medium Voltage (MV) delta bus shall be grounded through a Grounding Transformer (i.e. zig-zag winding Transformer) along with suitable resistor in the neutral.
- MV Switchyard of different STATCOM Station branches shall be fenced with the fence height of 3 meter. To minimize the probability of electrical fault suitable arrangement i.e. electrified fence shall be done to prevent the encroachment of unwanted animal or other to minimize the probability of electrical faults (Ph-E, Ph- Ph). Further bus bar arrangement shall be made in a way to minimize the probabilityof electrical faults.
- For MV bus bar, Aluminum conductor (Tube, Rectangular Hollow Section or C- Section) may

be used, however, suitable bus bar end cover/cap shall be provided to avoid any animal/bird entering the hollow space.

6.4 Broadband Interference

6.4.1 Radio Interference

The Contractor shall take necessary precautions in the form of shielding of valve hall and building or Containers to meet its own requirement together with any requirements that may be specified in Section-Project. Further ,the following requirements shall also be met:

a) With the STATCOM Station operating at any load up to rated value and within the design range of firing angle, the radio interference level from electromagnetic or electrostatic inductions generated by the STATCOM station shall not exceed 100 micro-volts/m, under fair weather conditions, at any point outside the station fence.The RIL criteria shall be achieved at all frequencies within the range of 150KHz to 300MHz and with the STATCOM operation at any level up to and including ratedvalue, the design shall provide correcting measures, should the specified design not being realized in the final installation.
b) Measurements of actual RI at STATCOM Station shall be made by the contractor, at points along the above defined contour and at other critical point.
c) RIV (Radio Interference voltage) measured at a phase to ground voltage (156 kVrms) in accordance to NEMA-107 shall not be more than 1000 micro-volts for 220 kV system. For other system voltages IEC/NEMA in the order of preference shall be applicable.

6.4.2 Interference with Power Line carrier & open wire carrier system

The Contractor shall take the necessary precaution in the form of noise suppression techniques and filtering devices to prevent harmful interferences from STATCOM Station to power line carrier (PLCC) system operating on connected AC transmission network. The frequency spectra to be protected are:

System	Frequency spectrum
Power Line carrier	30 kHz to 500 kHz
Open wire carrier	5 KHz to 30 kHz

The Contractor shall provide information on the noise spectrum at the termination of STATCOM Station in the frequency from 5 kHz to 500 kHz.

6.5 Audible Noise

Primary equipment noise levels shall be as specified in the relevant equipment specifications. The Contractor shall limit the audible noise in various areas of the STATCOM Station buildings and Containers to the following values.

Valve hall (Inside)	90dBA
Mechanical equipment are as indoor (measured at 2 meter distance)	75dBA
Mechanical equipment outdoor	75dBA

(Measured at 15 m distance)

Control Room Building*	60dBA
At the limits of STATCOM STATION perimeter fence	80dBA

*This is the background noise from the ventilation system adjacent rooms, control cubicles etc. Printers, recorders may be switched off during measurement.

6.6 Loss Requirements

6.6.1 For bid evaluation purposes the losses will NOT be evaluated. The bidder must guarantee the total losses of STATCOM Station, be less than 1% of the reactive power output individually at its inductive limit and capacitive limit for the cumulative highest reactive power output of STATCOM Station at PCC with worse combination of manufacturing tolerances. For the purpose of total loss measurements, it should be assumed that ambient temperature is 20°C, the PCC voltage & frequency is 1 per unit, and the slope setting is 1 %. The STATCOM Station may not operate at these conditions, but they provide a common base.

6.6.2 The total losses shall include all components, as well as different parts or subsystems of complete STATCOM Station such as coupling transformer, All VSC systems and components, Resistor and Reactors, Control and protection systems, including ancillary devices such as HMI, fault recorders, and SCADA, Auxiliary Power supply systems, Cooling systems, Building ancillary services such as lighting, air conditioning, heating, and ventilation. It may be noted that for the redundant VSC valve levels and dual/redundant control and protection systems, the losses of redundant VSC valve levels and dual control and protection systems shall be considered during loss measurement.

6.6.3 For the dual or redundant systems design of STATCOM Station, such as dual pumps or redundant fans, dual systems losses to be excluded, if the dual system is not in service during the normal operation of the STATCOM Station. However, dual systems should be included if they are required to be in service under the defined operating conditions. The same methodology shall be applied for HVAC (heating ventilation and air conditioning systems).

6.6.4 However, for final acceptance of loss measurement, the contractor is required to submit the detailed calculation of total losses based on measurement during Factory Acceptance Tests of major equipment and systems mentioned above as per relevant Standards such as IS/IEC/IEEE standards. Further for equipment/systems, whose loss measurement cannot be done during Factory Acceptance Test, the same can be measured at site, and a combination of calculation and measurement shall be used to derive the total losses as specified above. During Loss measurement, all fans and pumps; valve room and control room air-conditioning system shall be switched on. However, redundant fans, pumps & air-conditioners shall be kept off during loss measurement.

6.6.5 The losses obtained as above during the factory tests shall be compared with the guaranteed losses as indicated in the relevant schedule of Bid Proposal Sheets**.** In case during measurement and calculation, the total losses as defined above are found to be more than the limit specified, the liquidated damages (LD) shall be recovered @Rs. 167715 per KW for each KW exceeding the guaranteed value individually for both inductive and capacitive rated output limit of STATCOM Station as defined below. These guaranteed loss figures shall be without any tolerance.

LD/penalty for STATCOM Station Sub-System for each category of loss shall apply:

a. Measured Loss exceeding in 0 to +5% band: Nominal LD rates.
b. Measured Loss exceeding in >+5% to +10% band: Double of the nominal LD rates.
c. Measured Loss exceeding +10% (>+10%) then the equipment shall be rejected.

The LD amount calculated as per above shall be deducted from the contract price or otherwise recovered from the Contractor.

6.6.6 The Employer reserves the right to recover the liquidated damages as mentioned above from any running bills of the Contractor. Further the liquidated damages shall not be subject to any ceiling whatsoever and shall be in addition to any other liquidated damages under any other terms of the Contract.

6.6.7 During the factory tests the losses for the following equipment shall be measured / assessed as detailed below: -

Coupling transformer

Losses shall be measured at factory/lab at the maximum rating, at power frequency asper relevant IEC/IS under below conditions:

i. No load loss (Iron loss) at rated voltage and fundamental frequency.
ii. Load loss (copper loss) at rating (As finalized during detailed engineering) corresponding to maximum continuous current and at 75°C.
iii. Transformer cooling equipment's loss (Auxiliary loss) at rated voltage and fundamental frequency.

Reactors

The losses shall be measured at factory/lab at the maximum rating at power frequency as per relevant IEC/IS.

VSC Valves

Converter losses are composed of losses in power electronic switches [insulated gate bipolar transistor (IGBT) or equivalent], made up of conduction and switching losses, and the losses in dc capacitors, resistors, and inductors used within the converter system. Refer IEEE-1052 for calculating VSC losses.

Capacitor

The capacitor losses shall be measured at manufacturer's works at power frequency as well as calculated to obtain the losses in the complete bank on the basis of factory measurement.

Auxiliary System

Aux. power losses shall be calculated from the KW and efficiency of all motors (name plate rating) of the cooling system, air conditioning, ventilation etc. The higher of thetotal losses for the entire auxiliary systems occurring at full capacitive capacity MVAR orfull Inductive MVAR as the case may be shall be considered for arriving at the total losses.

Harmonic Filters, If any

The losses shall be calculated at the maximum STATCOM Station loading at **220** kV and 50 Hz. The calculations shall be on the basis of tested results of the components.

6.7 Selection of Insulation levels

6.7.1 Arrestors

Protective levels of arresters connected to the 220 kV AC Bus Bars of the STATCOM Station shall be coordinated with the insulation and surge arrester Characteristics of the 220 kV

AC systems to which the STATCOM Station is to be connected. The specification and characteristics of the surge arresters installed in 220 kV AC system are given in Section Switchgear Chapter Surge Arrester clause 2.0.The front of wave (FWWL), lightning impulse (LIWL) and switching impulse (SIWL) withstand levels shall be determined by the following margins:

a) A SIWL at least 1.15 times the switching impulse protection level.
b) A LIWL which is an IEC standard level corresponding to the SIWL and shall be at least 1.25 times the lightning impulse protection level.
c) A FWWL which is at least 1.25 times the front of wave protection level.

In addition to above minimum basic requirement the various insulations level of 220 kV equipment shall be as below. The STATCOM Station equipment, coupling transformers etc. shall be co- ordinated accordingly.

	SIWL	LIWL
All equipment including Transformer Bushing and Winding	1050 kVp	850kVp

6.7.2 Valves

The requirement of insulation levels of the valves shall be provided by the bidder along with the bid.

6.7.3 Air clearances

The air clearances shall be determined by the contractor based on the required withstand levels for all waveforms in order to limit the probability of flashover within the STATCOM Station to a target value of one flashover in 15 years.

6.7.4 Switchyard

The air clearances for switchyard equipment shall be equal to or greater than minimum values as specified in IEC-60071. Altitude correction factor (if any) shall also be considered as per IEC.

6.7.5 Leakage distances

The Creepage/leakage distance across insulation shall be determined by the contractor and shall be adequate to ensure that under condition of heavy pollution, the probability of a flash over of an insulator does not exceed one in 15 years. However, the leakage distance for all AC insulators for outdoor installation shall not be less than 25 mm/kV of the maximum operating phase to earth rms voltage at the insulator. The leakage distance of equipment connected to 220 kV systems shall not be less than 6125 mm.

6.8 STATCOM Station availability and reliability

The following definitions apply:

6.8.1 Outage terms

a) Outage
The stage in which an equipment is unavailable for normal operation due to an event directly related to the equipment which results in reduction in STATCOM Station capacity.

b) Scheduled Outage
An outage which can be scheduled at least one week in advance
c) Forced outage

The stage in which the equipment is unavailable for normal operation but is not in the scheduled outage stage and which results in reduction in STATCOM Station capacity i.e. an outage which is not scheduled outage.

6.8.2 Capacity terms

Maximum Continuous Capacity (Pm)
The maximum STATCOM Station capacity (MVAR) for which continuous operation under normal condition is possible.

6.8.3 Outage duration terms

Actual outage duration (AOD)
The time elapsed in hours between the start and end of an outage.

6.8.4 Time Categories

a) The number of hours in the reporting period in a full year, the period year is 8760 hours. If the equipment is commissioned, part way through a year, the period hours will be proportionately less than 8760 hours.
b) Total Outage hour (TOH)
The sum of all outage duration within the reporting period. TOH = AOD

6.8.5 Availability & Reliability Terms

Unavailability

Unavailability is the duration for which the STATCOM Station is not available with specified rating due to forced outages per year. If part of the STATCOM station is unavailable, then the unavailability duration shall be counted proportionally. However if STATCOM (all units/branches) is out then its duration shall count as fully unavailable STATCOM Station. However, If STATCOM unit is out then the STATCOM Station unavailability shall be counted proportionally STATCOM capacity. STATCOM Station Control system outage shall count as full STATCOM Station unavailability. 'OF' is the outage frequency which will be the number of forced outages per year.

The period basis for availability and reliability calculations shall be 12 months. The contractor shall provide calculation to demonstrate that the design will meet the specified guaranteed and design target value of availability and reliability.

Outage times for repair, maintenance and replacement of components shall be based on the premises that all items in the contractors list of recommended spare parts are on hand, that all maintenance schedule of recommended maintenance are adhered to. Reliability calculations shall be made and shall be presented as the expected frequency of unscheduled loss of STATCOM Station capacity. For simultaneous occurrence of events, for either of which a loss of capacity would result, the longer repair time shall be counted.

The facilities shall be assumed to be utilized 100% of the time at 100% load, regardless of

the actual reactive power generated/absorbed by the STATCOM Station. Hence the availability and reliability assessment will be based on the capability of STATCOM Station to generate/absorb the rated reactive power regardless of whether, it is in service or not. The Bidder shall submit the report regarding reliability, availability calculations, criteria and data used in the bid document.

6.8.6 Availability Requirement

The calculated availability of the system considered on the annual basis shall be equal to or exceed the following target values. Also subject to terms and conditions specified the availability per year averaged during the five year guaranteed availability period considering both forced and scheduled outages for maintenance shall be equal to or exceed the values guaranteed by the contractor.
Minimum availability requirement of complete STATCOM Station

Design target for STATCOM Station*	Guaranteed for STATCOM Station*
99%	98%

***Note: In case of more than one STATCOM Station at a Single Substation in a contract, availability referred is the average availability calculated for those STATCOM Stations.**

The outages of STATCOM Station capacity caused by the failure of equipment outside the scope of the contractor shall not be considered for calculation of availability and reliability guarantee. However, such outage shall be restricted to

1) Complete loss of 220 kV supply (at PCC)
2) Human Error.

Circumstances causing curtailment of STATCOM Station capacity that will be included in reliability and availability assessment and which can lead to forced outages shall include but not be limited to the following:

a) Failure of equipment
b) Mal-operation of control and protection system
c) Failure to start
d) Reduction in capacity.

6.8.7 Reliability Requirement

a) **Reliability**
In the assessment of reliability, the following events shall also be considered to constitute a STATCOM Station outage:
   i) A STATCOM Station shut down.
   ii) A reduction of STATCOM Station capacity due to outage of any component of STATCOM Station

The calculated reliability of the complete STATCOM Station shall be equal to or exceed the following design target values. Also subject to the terms and conditions specified, the reliability per year shall be equal to or exceed the guaranteed values stated in the Contract.

The period over which the guarantee is to be in effect, is five years commencing six months

after acceptance of the complete system. The operation of the STATCOM will be monitored during the five year period to determine whether it meets the guarantee.
The total numbers of Forced Outage per year for STATCOM Station shall not exceed the following values:

	Design target for STATCOM Station*	Max acceptable Guaranteed value for each
		STATCOM Station
Total Numbers of Forced Outage	3 X Nos of STATCOM Station	5 X Nos of STATCOM Station

6.8.8 Guaranteed Failure Rate of Sub modules. (Including all component and electronic)

The maximum annual guaranteed failure rate of sub module (including all componentand electronic) shall not exceed 1.0% per STATCOM.

6.8.9 Guaranteed of Failure Rate AC Power Capacitor

The maximum guaranteed annual capacitor failure rate shall not exceed 0.15% except first unit failure. The capacitor shall be considered as failed if its Capacitance value varies more than ±5% of the (actual measured) name plate value. Leakage of oil from the capacitor and visual deformation of the capacitor unit shall be considered as a failure even if the capacitance value is within the tolerance limits.

7. Design Principles

The objective for the design of the STATCOM Station shall be to achieve high level of availability and reliability as specified. Special attention shall be given to design the STATCOM Station to avoid forced outages. The contractor shall conduct thorough designreviews and submit a report explaining the measures taken to minimize the risk of such outages. The Contractor shall give careful attention to related factors affecting STATCOM Station performance such as subsystem & system testing, protective relays co-ordination and proper setting of relays.

Except where greater reliability requirements are specified in these specifications, the design basis for STATCOM Station shall be such that no single contingency downstream from the medium voltage bus shall cause a total outage of the STATCOM Station.

The following general criteria shall be followed for the design of the control system:

a) Use of components similar to those whose reliability has already been proved in use.
b) Use of good design practices, surge protection, filtering and interference buffers to assure immunity to sensitive components and circuits against damage and interference by induced voltages and currents in the external cabling and cubicle wiring.
c) Use of fail safe and self-checking design features.
d) Use of component and equipment redundancy, by means of either duplication or triplication with automatic transfer facilities wherever necessary to meet the requirement of these specifications.
e) Design which in the event of component failures, provide for transfer to a less complex operating mode.
f) Provision of alarm, fault diagnosis & indication

7.1 Design Reports and Design Reviews

During detail engineering, the Contractor shall submit the following Design Reports for review/question/comments by the Employer/Consultant for approval by the Employer:

- Detailed One-Line Diagram and layout with explanations
- Dynamic/Stability Studies (The scope shall be As per Annexure-1)
- STATCOM Design
- Valve Design
- Transformer Design
- Insulation Coordination
- Shunt Reactors Design
- Shunt Capacitor Design
- Dynamic and Steady-State Controls
- Protections
- Automation
- Auxiliary Power
- Any other relevant report requested by the Employer

However the entire responsibility of safe and reliable design shall be with the Contractor. Employer may visit the manufacturers works to inspect design, manufacturing and test facilities. The design review will commence after placement of award with successful Bidder and shall be finalized before commencement of manufacturing activity.

8. STATCOM Station Main Components

8.1 STATCOM Unit/Branch

The main electrical data of the STATCOM Units are the following:

o Rated voltage	20kV Minimum
o Rated frequency	50Hz.
o Redundancy (Sub Module)	2no.or5%whicheverishigher
o Rated Power of each STATCOM unit/Branch	±50MVAR Minimum.
o Valve Cooling	Deionized/Demineralized water

In general the STATCOM units shall equally share the load however under contingency condition it should be possible to run the units with unequal load. Charging of the DC capacitors of Sub module during Initial start-up shall be achieved by means of Resistors and bypass switch arrangement. The charging resistor for DC capacitor of STATCOM Sub module should be designed for three charges per hour followed by appropriate cooling time. Power for the gate level control shall be derived internally from Sub module. The offered STATCOM Units with its Control system shall be suitably located inside the STATCOM Station Building.

8.1.1 STATCOM Valve

The valve shall be designed to meet the performance requirements described in this specification and as described below.
In order to ensure a modern low loss and reliable solution to Employer, the STATCOM valve assembly shall use the Modular Multi-Level (including redundant sub modules) approach. In case Bidder offers an advanced topology over and above Multi-level topology then the advantages of the offered solution must be stated in the Bid.
The valves shall be

- Designed to ensure satisfactory operation according to the overall performance

requirements and include all necessary auxiliary equipments required for smooth and reliable operation.

- Indoor air-insulated and cooled by de-mineralized water.
- Of modular design and have removable Sub- Module for ease of maintenance.
- Mounted to allow easy access for visual inspection, routine maintenance and replacement, and facilities shall be provided to enable the easy access.

The Bidder must describe valve assembly and maintenance aspects of Sub-Modules including grounding provisions of each module for safe maintenance. It should be possible to detach the DC Capacitor from the rest of the sub- module at site.

The design of the STATCOM valves support structures should permit access by the Employer for visual inspection, routine maintenance, and component replacement.

8.1.2 Semiconductor Switches

The electronic switches should be designed with the aim to achieve operation according to the overall performance requirements of the STATCOM Station. The valve shall be designed with individual semiconductor switches applied in a conservative manner with regard to their basic design parameters. The semiconductor switch shall meet the requirements of IEC 60747 except where otherwise specified herein. The proposed semiconductor switch shall be of a type which is in, or ready for, commercial operation with characteristics fully proven by recorded years of operation in other installations. The Bidder shall provide standard data sheet, in the bid, for the semiconductor switches offered.

The semiconductor switches shall be designed to with stand all stresses expected under steady state, transient and temporary overvoltage conditions. Basic semiconductor devices shall be of the Press Pack type, or packaged to provide shortcircuit means in case of device failure such that the STATCOM can continue to operate without interruption.

The adjacent sub module should be protected against possible explosion of semiconductor switch. Under the restriction of redundancy (minimum two or 5% whichever is higher) i.e. the failure of any semiconductor switch or sub module or monitoring device etc. shall not prevent continued system operation. In the event of any of the above failure, the STATCOM shall annunciate and identify the specific location of the failed device and continue operation until such time as repairs can be scheduled. During such time the next shutdown can be availed, the STATCOM must continue to operate without downgrading STATCOM capability.

The switching device's design should include an appropriate allowance for unequal voltage distribution across individual devices in the valve due to stray capacitor and component tolerances.

Each switching device should be able to operate within component ratings, generally with failed sub-module or level. The number of possible failed sub-modules or levels as specified shall be demonstrated to the user, and be consistent with the availability requirements of the STATCOM Station.

8.1.3 Sub module for Modular Multi-Level Topology

The key element of the Modular Multi-Level topology shall be the Sub module. By increasing the number of these sub modules, it is possible to obtain high voltage with extremely low

harmonic distortion and very low dv/dt using low switching frequency that reduces power losses. Sub module shall have the following characteristics:

- Sub module shall be designed to guarantee high maintainability with self-sealing type hydraulic valves and electrical plugs for ease of installation or un-installation.
- VSC sub-modules should be protected against over voltages with appropriate strategies. Description of the failure mode of the switching device and the strategies used following failure should be provided.
- In each fiber optic cable (having multiple fiber cores) used for control/communication purpose of sub-module at least two fiber cores shall remain available as spare for future use.

8.1.4 The STATCOM sub module has DC capacitors that require a charge to allow full functionality and performance. At the startup of the STATCOM Station, the capacitors are discharged.

During the energization sequence of the STATCOM, Capacitors are charged from the main power grid via resistor operated in series to the main connection circuits. Once the desired charging voltages are reached, the charging resistor circuit is bypassed using bypass switch/breaker.

The Type and Rating of the charging resistor and associated bypass switch shall be designed with the aim to achieve operation according to the overall performance requirements of the STATCOM Station and shall conform to relevant Standard.

8.1.5 STATCOM Valve Cooling system -

A closed-loop recirculating system shall be provided with full heat rejection capacity with redundancy for pumps, heat exchangers, and fans, appropriate to the STATCOM Station availability requirements. The cooling system should be able to maintain full capacity at maximum ambient temperature and maximum STATCOM reactive power output. The cooling system should be able to operate at the lowest ambient temperature and zero output specified. The Valve cooling system shall have black start capability and necessary UPS/UMD shall be provided separately for each STATCOM Unit.

The valve cooling system shall be designed to meet the performance requirements described in this specification and as described below.

a) Each STATCOM Unit shall have its own de-ionized water valve cooling system with redundant pumps.

b) For cooling the STATCOM valves, a deionized re-circulating (closed loop) water system shall be used.

c) Water to air heat exchanger shall be used for cooling of this de-ionized water. Water to water heat exchanger shall not be accepted.

d) System shall be designed such that no shut down of STATCOM be resorted to for making up the deionized water in the system. The make-up water should comply with the recommended PH and purity.

e) Cooling water shall have a stable flow rate. The flow rate shall be decided on the basis of extreme operating conditions.

f) The control system for cooling system shall be redundant type including the provision of redundant control supply and main power supply. However, in place of redundant control system for cooling system, suitable alternate mode is also acceptable meeting the requirement of fulfilling cooling system operation even if failure of cooling control.

g) 2x100% pumps with one as standby shall be provided for the primary. Should a pump failure occur, the second pump should automatically switch in without shutting down the STATCOM. An alarm shall be displayed at the control panel for failure of first pump and standby pump in operation.

h) Each cooling system shall be provided with independent/dedicated UMD supply however common battery for both UMD power supply may be accepted. A UMD system will provide an extended capability of the STATCOM Station to deliver reactive power without any interruption, adding a buffer against the system faults or during events such as delayed voltage recovery or TOV.

i) The secondary cooling system shall be redundant type such that it shall be possible to take out 10% (minimum one number) of the cooler module (fan unit) of secondary cooling system without affecting the rated performance of STATCOM).

j) The cooling system should be designed and provided to permit work on faulty pump/ faulty fan without shutting down the system.

k) Normally no make-up water shall be required however in case of expansion vessel level going low; same shall be replenished automatically by means of make-up water tank and make up water pump to be supplied with the system.

l) Contractor shall provide water treatment plant of sufficient capacity. The purification (treatment) system shall be designed to maintain the conductivity below 1 micro siemens. A resistivity cell in the outgoing water from deionizer should detect the depletion of ionized material. Filters and deionizers shall be designed to allow replacement during operation. Normal replacement shall not be required more than once every year.

m) Filters and deionizer/deoxidizer material shall be designed to allow replacement within minutes without shutdown of the cooling unit. (Normal replacement should not be required more than once/year).

n) Primary cooling system shall monitor its own operation and condition of cooling water.

o) The protection system of cooling cycle shall have minimum following alarms:

   i) Depleted deionizing cell
   ii) Low water resistivity
   iii) High water temperature
   iv) Primary pump stopped
   v) Fan stopped
   vi) Primary pump or fan interlock circuits faulty
   vii) Primary cycle(Make-up water) tank level low
   viii) Failure of control supply.
   ix) UMD/UPS fault.

p) Following shutdown alarms / TRIP shall be provided with cooling system protection. Excessive low water resistivity Excessive high water temperature, complete loss of auxiliary supply to primary pumps, low flow, Low Pressure etc.

q) The dissipative components of the converter are cooled with deionized water.

r) The power losses are transferred to the external ambient by means of a deionized water /air heat exchanger. All the piping and other components complete instrumentation set has been mounted on board in order to check the status of the cooling system:
- Conductivity gauge system.
- Flow meter equipped with two set points (alarm and trip).
- Pressure meter
- Two thermometers for inlet and two thermometers for outlet (two set points for alarm and trip)
- Thermostat

s) The status of the cooling system along with associated alarm and trip signals shall be monitored by means of the control system and integrated STATCOM Station Automation System.

t) Replacement of certain cooling equipment (e.g., pumps, fans, cooler unit etc.), if defective, should be possible while the cooling system still operates.

8.1.6 Details of associated phase reactors, charging resistor and bypass switch is given in subsequent section.

8.1.7 Tests on STATCOM Unit Valve

All applicable tests i.e. Operational Type Tests (except Short-circuit test), Dielectric Type Tests & Test for valve insensitivity to electromagnetic disturbance shall be done as per latest edition of IEC 62927. Partial Discharge test shall be done during routine test of each sub module without DC Capacitor in addition to other routine/production tests specified in IEC 62927.

8.2 STATCOM Station Control equipment and operator interface

8.2.1 Control Equipment

The control systems should achieve the functional objectives given in 6.2.The accuracy of voltage should be within ± 1% of the reference voltage. The accuracy of the gradient and linearity of the slope delivered by the STATCOM Station should be defined in relation to the current deviation from the theoretical slope defined in definition of slope. The maximum deviation should be less than ± 5% of nominal current.

The control system design shall be based on single fail criteria i.e. failure of any one component in the system should not result in to outage of the complete system. As a minimum, a dual (hot standby) digital programmable controller shall be supplied for each STATCOM unit/branch and STATCOM Station to control the STATCOM completely including the functions listed as mentioned
below:

a. The controller shall have diagnostic and self-checking features for both itself and for valves, gate firing and drive circuits, interface hardware and software. This is required to reduce outage times and to facilitate fault finding.
b. The Controller shall be reprogrammable. The Employer shall have at least the following possibility for changing the following reference and limit values via HMI:
c. Closed loop Controllers:
The STATCOM Station controller shall have means to modify the reference set points.

This refers to the functionality that will allow all the control parameters to be adjustable within selectable limits and is inclusive of, but not limited to following:

- Voltage controller
- Q controller (reactive power controller).
- Supplementary VSC current controller.
- Other supplementary control functions.

d. Sequence Controllers:
The sequence control and open-loop controllers shall include the control of all switchgears and associated control gear and external devices.

e. The Controller shall have at least 10% excess I/O capacity to allow future program upgrades to satisfy the changing requirements of the power systems or future extensions to the STATCOM Stations. As a minimum a control of up to 4 future HV shunt devices (reactors or capacitors) shall be included in the offer.

f. All control signals available for remote control must also be available locally so as to ensure that a local operator can operate the STATCOM Station if the communications link between STATCOM Station and remote control centers is lost.

g. A changeover switch shall be provided to control the selection of local or remote control.

h. The Contractor shall provide the equipment necessary for the purpose of control, protection and interlocking of all equipments within the scope of supply.

i. The Contractor shall also provide two complete sets of proprietary testing and maintenance equipment for the control system offered and a list of the same shall be included in the Bid.

j. The system shall have adequate soft and hardwired interlocks to ensure correct, sequential and safe operation.

k. The Contractor shall be responsible for design and coordination of control, protection and interlocking system and switching sequences within the STATCOM Station. All necessary interfacing required between AC switchyard equipment and STATCOM Station for the above purpose shall also be included in the scope of the Contractor.

l. The control, supervision and monitoring of STATCOM system shall be through a Supervisory Control And Monitoring System (SCADA) / Substation Automation System.

m. All the data shall be acquired through suitable means from field and various components and control is executed through the redundant HMI. The local STATCOM Station Control system shall consist of; Redundant STATCOM Station controller, STATCOM monitoring system, Interfacing among Controller and Monitoring system for desired STATCOM operations, redundant HMI workstation, Gateway, STATCOM Station Control System Engineering cum Disturbance Recorder (DR) PC with associated peripheral equipments such as color laser log Printers, Color laser jet fault record printer, GPS System, Inverter/UPS-etc.

n. All devices shall be interconnected via redundant Ethernet based IEC 61850 Station LAN Network in Star redundant ring topology.

o. In addition to above, HMI workstation (identical to HMI Workstation provided in STATCOM Station control room) shall also be provided in control room of existing substation.

p. All SAS equipments/components shall be as per GETCO technical specification GETCO/E/TS-SAS & SAS Equipments 3702/R7 Sept, 2022 and associated Addendum-I.

q. Substation Automation System as well as all control & protection IEDs shall be IEC 61850 Ed 2.0 as well as cyber security compliant.

r. The scope also includes the interface required with existing control and protection scheme e.g. Bus bar protection, LBB protection, Bus PT supply etc.
s. The control equipments shall satisfy the reliability and availability requirements specified in this specification.
t. All necessary measures shall be taken to ensure satisfactory operation in presence of harmonic current and voltage, noise and radio interference signals. The equipments shall be designed to operate in the environmental conditions specified in the specification.

8.2.2 Operator Interface

a. Each STATCOM Station shall have an SCADA consists of an HMI which shall provide a Centralized (local) operator control of the STATCOM Station functions. All human interface operations necessary for the control and monitoring of the STATCOM shall be provided at this point.
b. Any abnormal condition requiring operator action or intervention or maintenance on any of the STATCOM Station sub systems shall be monitored as well as annunciated at the STATCOM Station control room in SCADA System and the Substation control room SCADA system.
c. The Local as well as Remote HMI shall include the following diagrams as different screens in the display system as a minimum for control, operation, supervision, reporting and monitoring
   i. Complete STATCOM Units and STATCOM Station single line diagram including HV and MV busses.
   ii. STATCOM Valve Sub module monitoring Status
   iii. Coupling TRF HV Bay
   iv. Coupling TRF LV Bay
   v. AC Auxiliary supply and distribution
   vi. DC Auxiliary supply and distribution
   vii. STATCOM Valve cooling systems
   viii. Interlocking system

d. These bay views shall indicate device status, alarms, trip, voltages, currents,frequency, MVAR etc. The HMI shall provide complete diagnostics on alarm and trip indications as required and discussed in this specification, including SER information.
e. A facility shall be provided whereby the local HMI features and functions shall be accessible from remote. A remote user shall be able to view screens and change STATCOM Station parameter settings and can operate the STATCOM station with same capacity as from Local station in all respect.
f. Access security shall be provided by password for each defined user level (viewer, operator, administrator etc.) to prevent unauthorized access.
g. In case of SCADA system based substation, the SCADA system of STATCOM shall be separate from the substation SCADA system. However, all required interfaces of coupling transformer HV bay shall be obtained in STATCOM SCADA through Gateway interface on IEC 60870-5-104 protocol by providing compatible Gateway.

8.2.3 Control Equipment Test Requirement:

Offered Control equipment shall confirm to the following tests.

- Verification of control equipment performance for auxiliary power supply voltage (ac and

dc) and frequency variations (ac).

- Climatic test, i.e., verification of control equipment performance for a specified range of ambient temperatures and humidity. If climatic test certificates are available for the conditions specified, no further tests are needed.
- Interference tests, i.e., the controls should be tested to operate in the environment of ac substations and suitable surge withstand capability Tests should be carried out, or proof of previous testing provided, in accordance with IEEE Std C37.90.1™ (covering fast transient burst and a damping oscillatory wave) and IEEE/ANSI Std C63.16™ (electrostatic discharge tests).

8.3 STATCOM Station Protection System:

The Protection system design shall be based on single fail criterion i.e. failure of any one component in the system should not result in to outage of the complete system. The Protection System shall be designed with the aim to achieve operation according to the overall performance requirements of the STATCOM Station and shall conform to relevant Standard.

8.3.1 Protection system Design

a) To ensure that faults are cleared within stability critical clearing time, to minimize damage to plant, and to avoid voltage collapse, loss of load or load limitations, Contractor shall provide a high speed main protection scheme. An independent (having separate measurement system) back-up protection scheme shall be provided in the event of the main protection scheme failing or switched out for maintenance.

b) The STATCOM Station shall be completely self-protecting (unit protection). STATCOM Station shall be protected from damage for all conditions of over-current, overvoltage, excessive reactive power loading, unbalance due to loss of capacitor elements, phase-to-phase and phase-to-ground faults, three phase faults, loss of cooling, semiconductor valve or control malfunction, faults (STATCOM, MV system) in individual primary connected components of the STATCOM, HV system faults, etc. The STATCOM Station shall withstand the maximum fault current for a period of the maximum fault clearing time as specified, considering second contingency cases due to the previously mentioned conditions.

c) All protection equipment and systems should be properly co-ordinated to prevent incorrect operations of the protection equipment or systems during normal STATCOM Station operation, including anticipated abnormal conditions on the transmission system, as specified. Fail-safe principles should be applied throughout.

d) The Contractor shall develop protection concept which is subject of Employer's approval. The Contractor shall be responsible for detailed design of the protection systems.

8.3.2 The basic principle and order of precedence for the control and protection shall be, to take care of following:

- Correctly identify a fault, problem or error condition,
- Only if necessary, isolate the minimum number of components, subsystems whenever possible,
- Utilize degraded modes to the maximum extent possible either directly (no interruption of the STATCOM Station operation) or indirectly (by tripping the STATCOM Station momentarily in order to isolate the branch and re-energization of

the STATCOM Station).

- Trip STATCOM Station and Block.

a. Failure of the STATCOM Station Interface (SCADA interface) shall not result in a Protection trip of the STATCOM Station. A fail-safe philosophy shall be implemented to allow the STATCOM Station to operate safely and independently from the STATCOM Station Interface (SCADA interface).

b. Protection equipment shall be designed and applied to provide maximum discrimination between faulty and healthy circuits.

c. The Protection shall be sufficiently sensitive to cater for the full range from maximum to minimum fault level condition. The Protection shall also be suitable for a system fault level equal to the maximum short circuit capacity at each Substation. All current transformer design shall be based on these fault levels.

d. All required protective, control devices, etc. including auxiliary instrument transformers and panels, relays, cabling, wiring, indication, and all other associated plant and material necessary for the effective operation of the protection systems shall be supplied and installed under this Contract.

e. The Contractor shall provide the necessary wiring from existing Switchgear to its control room.

f. The protective relays/IEDs shall be numerical IEC 61850 as well as Cyber security compliant as per GETCO specification GETCO/E/TS- SCP 3703/R5 June, 2022 and associated Addendum-I.

g. Tripping schemes -

- Tripping of MV circuit breakers shall be done by means of two-separated trip signals.
- Duplicate high security tripping circuits for MV Circuit Breaker shall comprise two independent high speed (less than 10 ms) high burden (greater than 150 W) tripping relays for each circuit, each with its own independent DC supply. The trip circuits for all circuit breakers need to be equipped with a “lockout” function and it shall be possible for this to be reset manually and remotely by the operator.

h. The protection for the power system is based on a normal switching state and an occurrence of a single fault. This means that faults resulting from maintenance as well as the simultaneous occurrence of two or more faults are not taken into account.

i. The input circuits of the digital protections shall be monitored by means of a plausibility check. If any incorrect information is found, the protection function shallbe blocked by the protection. All protection relays shall have facilities for monitoring trip circuits. Detection of an interruption in the case of a switched on circuit breaker shall be signaled.

j. Test facilities

- It shall be possible to test the protective device during operation without causing trips. Links/test block shall be provided for isolation of individual protection trip circuits and the common protection trip circuit to each circuit breaker trip coil.
- Separate test facilities shall be provided for each current and voltage transformer secondary circuit so as to give access for testing of protection relays and associated circuits. The Test facility to be supplied shall have two selectable positions, a Service and a Test position. In the service Position, the test switch connects CTs and VTs signals to the Relays and trip commands to the circuit breaker trip coils. In the Test Position, the test switch applies a short-circuit to the CT secondary windings and

open circuits the VT secondary cores and allow injection of secondary current and voltage into the relay. At the same time, the Trip commands to the Circuit Breaker Trip Coils are Isolated. The test Switch supplied shall be to the Approval of the Employer.

k. The protection of the electrical system shall be designed and installed in such a way that the failed equipment is disconnected selectively and automatically. All equipment shall remain operative during transient phenomena, which may arise during switching or other disturbances to the system.

l. Auxiliary DC Supplies

- The protection concept has to be designed in a way so that back-up protection is provided at all times. All protection relays shall be configured in a way that failure of one Auxiliary DC system will not affect the relay. If all DC supplies to the controllers are lost, the STATCOM Station breaker must be tripped via the protection panel.

m. List of typical Protection functions for STATCOM Station

STATCOM TRF HV Bay Protection:

i. Biased Differential protection(87T)
ii. Bus bar Differential Protection (87BB) by integrating in existing Bus Bar
iii. REF protection (64)
iv. Directional Overcurrent & Ground over current protection (67, 67N)
v. Breaker failure protection (50 LBB)
vi. Over flux protection (HV)
vii. Transformer trouble trip relays
viii. Transformer Fire Protection

STATCOM TRF MV Bay Protection:

i. Ground overcurrent protection(51N), used with neutral Grounding Transformer
ii. Under/Over Voltage(27/ 59Ph-Ph) protection
iii. Directional Overcurrent and Ground Over current protection (67, 67N)
iv. Over voltage (Open Delta) protection
v. Breaker failure protection (50 LBB)
vi. Any other specific protection recommended by OEM

STATCOM Branch Protection:

i. Redundant STATCOM Valve Differential protection (87 ST)
ii. Redundant Reactor Differential Protection (87R)
iii. Overload protection (49)
iv. Over current protection inside delta (50,51)
v. Negative phase sequence protection(46)
vi. STATCOM branch over current protection (50, 51, 50N,51N)
vii. Other protection for STATCOM system and Valve assembly envisaged by bidder for reliable and secure operation.

- The protection functions listed above are minimum set of function to be provided by the contractor and any additional protection required to fulfill the requirementof protection system shall be provided by the contractor.
- Protection System for the STATCOM valve portion of the STATCOM station shall be provided in the redundant controllers to isolate the STATCOM valve during internal overload/overvoltage, ground fault etc.

8.4 STATCOM Station Fault Recording System

An integrated Transient Fault Recording (TFR) System shall be supplied, installed & commissioned by the Contractor. This shall include trigger level settings for analog, etc. subject to review and comment from the Employer. Disturbance and event recording facilities are required for local monitoring of the STATCOM following a disturbance on the power system or the STATCOM System. The following inputs are required:

- All analogue signals (output signals)
- All digital signals (control outputs, status indications, commands, alarms and trip indications).
- Internal STATCOM Station control signals/variables to be selectable.
- The accuracy of the TFR for event inputs shall be at least 100 μs (sampling rate of minimum 10 kHz).
- The TFR shall have provision for remote access and retrieval of recorded information on to a PC of STATCOM Local station as well as Operator control room (STATCOM Remote station) For this purpose, a communication link to the Substation LAN shall be implemented.
- The remote software application for the data retrieval shall be included.

Typical List of analog signals to be supervised by DFR

Equipment	Description	Unit
Controller	Reference voltage	pu
	Set points (Y or Q or other, depending on possible control modes)	
	Order from regulator (B or I or Q)	pu
	Voltage measurement used by the controller	pu
	Gain	
STATCOM Station	HV voltage – phase R, Y, B (rms, phase-to-ground)	V or kV
	MV voltage – phase R, Y, B (rms, phase-to-ground)	V or kV
	HV current – phase R, Y, B	A
	MV current – phase R, Y,B	A
	Phase currents of each branch (either in delta or phase)	A
	STATCOM Station total reactive power	Mvar
	STATCOM Station reactive power per phase	Mvar
	Transformer neutral current	A
NOTE—Single-phase values should be recorded separately.		

Typical List of digital signals to be supervised by SER

Equipment	Description

Controller	All control faults
	The status signal of all control functions that can limit or modify the STATCOM Station output (e.g., at end of dynamic range, external shunt device control enabled/disabled)
	STATCOM Station status (e.g., In service, Emergency, Trip, degraded)
	All protections (alarms and trips)
Circuit Breaker HV, MV & Bypass switch	State (closed/open) of each phase
	Pole disagreement
	All protections (alarms and trips) (e.g., low pressure)
Transformer	All protections (alarms and trips)
STATCOM Station Branches	All protections (alarms and trips)
Auxiliary Power	All protections (alarms and trips)
Cooling System	All protections (alarms and trips)
NOTE 1—All trip signals should be recorded individually. For protections that have an alarm level and a trip level, the two should be recorded separately.	

8.5 Air Core Reactors (for STATCOM)

a) Reactors shall be air core, dry type, be suitable for outdoor installation. No tappings on reactor shall be accepted. The insulation level shall be adequate. The contractor shall demonstratecompliancewiththerequirementofinsulationco-ordinationspecified.

b) The insulation of the reactor shall be class F and hot spot temperature rise shall not exceed 105 °C above ambient temperature. Winding temperature rise shall not exceed 80 °C above ambient temperature.

c) The reactor shall be designed to withstand thermal dynamic shocks and mechanical shocks while in service and during erection.

d) The reactor shall fully conform to the relevant IEC standard.

e) The reactor shall be designed to withstand overloading due to over voltage as specified and shall also be subjected to excitation by harmonics; the reactor must be able to withstand such events without deterioration in normal life.

f) All internal (with in a reactor coil) current carrying connections shall be welded/Brazed or compressed joint.

g) All terminals shall be either tin plated or silver plated.

h) Lifting lugs shall be provided for handling of the reactor.

i) The reactor shall be vertically mounted.

j) The reactors shall be subjected to type and routine tests in accordance with the latest issue of IEC-60076 as appropriate to the type of reactor provided.

k) Tests on Reactors: The reactors shall be subjected to type and routine tests in accordance with the latest issue of IEC-60076 as appropriate to the type of reactor provided.

l) All structural and fence metalwork, including foundations, for air core reactors shouldbe designed to avoid, as far as possible, metallic loops and parallel circuits in which induced currents can run.

m) Each phase for STATCOM branch reactor may be divided into two reactors, one on each side of the converter valve to limit short-circuit currents resulting when one reactor is shorted or a ground fault occurs.

n) Supporting structural steel work, including foundations and fences should be designed to help minimize currents induced by the magnetic fields of the reactor.

8.6 AC POWER CAPACITORS (if applicable)

i) General

a) The capacitor banks shall comprise of capacitor units, discharge devices, protection equipment, series reactor as required, earthing switches, suitably connected in series and parallel, mounted at ground level with protected fencing all round. The number, arrangement and connection of capacitor banks shall be designed to suit the requirement of compensator as a whole. If convenient, the capacitor banks maybe used in conjunction with reactors. In this event the rating of capacitor shall be adequate to cope up with the harmonic loading. The frequency variations shall also be considered. To limit the peak in rush current for switching in the capacitors, current limiting reactors with parallel connected damping resistors if required shall be connected in series with shunt capacitor banks.

b) The capacitors shall be provided with internal type fuses. Alternatively fuse less capacitor is also acceptable. The contractor shall provide testing & maintenance equipment which can identify all equipment requiring replacement within 2 (Two) hours of de-energization.

c) Fuses shall not melt nor shall deteriorate when subjected to the inrush current during the life of the bank.

d) With the capacitor charged to a peak voltage, the fuses associated with the healthy elements shall not melt when carrying the discharge current resulting from a breakdown of an element or from an external short circuit.

e) Fuses shall be capable of disconnecting a faulty element over a range of voltage across the unit terminals from 0.9 Un to 2.0 Un. In addition if all the elements insame row of an internally fused capacitor were to fail as a result of a cascading action, the last fuse element to melt shall be capable of successful disconnection with a voltage of not less than 1.5 times.

f) After fuse operation the fuse assembly shall be able to withstand continuously at least 1.5 times rated unit voltage Un across the gap for 10 Seconds.

g) Fuses shall be preferably of the current limiting type but fuse system shall in any event be designed to ensure that energy released into a faulty capacitor unit is less than the valve that will cause rupture or bursting of the container. Evidence shall be submitted to show that the probability of case rupture following internal breakdown is small.

h) The capacitor units shall be outdoor type. The container of the capacitor shall be of stainless steel.

i) Each capacitor unit shall be readily accessible and replaceable without disturbing any other unit. The supporting frames shall be designed to provide adequate ventilation to the units. Contractor will supply suitable tool / device for replacement of any failed

capacitor unit in a bank for easy & swift replacement.

j) The dielectric fluid used in capacitor unit shall be environmentally safe & bio- degradable, non-toxic. Polychlorinated biphenyl (PCB) type dielectric or any of its derivatives shall not be acceptable.

ii) Construction & Design Requirement

a) The capacitors shall conform to IEC-60871. The capacitors shall be provided with internally mounted discharge resisters with characteristics in accordance with IEC-60871.

b) The current limiting reactors (as required) shall be dry type air core reactor and connected in series with the capacitor bank. Resistors as required for the capacitor bank, shall be dry outdoor type meeting the overall functional requirement of STATCOM Station.

c) The capacitor enclosure shall have sufficient strength to withstand without damage or loss of life, mechanical load, both in operation and during erection. The loads shall include electromagnetic forces including those during faults external or internal to the capacitor bank, wind loading, forces due to expansion and contraction causedby ambient temperature and load variation and seismic effects all as specified.

d) The capacitor units shall be interchangeable in order to reduce the spare requirements and simplify maintenance procedures.

e) The capacitor stack shall be vibration free. Stack shall have a fixed potential, that is connected to one electrical points in the bank. The stack shall be of galvanized structural steel.

f) The capacitor racks shall be supplied complete with all capacitor units, insulators, and connection and shall be equipped with lifting lugs/eyes to facilitate assembly into the stacks. The racks shall be constructed of galvanized structural steel. No drillingof galvanized steel shall be allowed. Each rack shall be labeled with the weight of the fully equipped racks, the phase and bank of which it forms a part. The maximumand minimum capacitor unit capacitance which may be substituted into the racks as spares shall be suitably identified. Suitable warning labels shall be affixed.

g) The capacitor shall be specially designed to be suitable for intermittent duty to which they are suitable to and Bidder must indicate evidence of the suitability of thesecapacitors.

h) The capacitors should comply with the overload capacity as per NEMA.

i) The capacitor elements shall be vacuum dried inside the case prior to impregnation with dielectric fluid. After impregnation, the capacitor unit shall be sealed immediately upon removal of the impregnated reservoir.

j) The internal discharge resister of capacitor units shall discharge the unit from peak operating voltage to less than 75Volts within 10 minutes.

k) The capacitor case shall be made from type 409 stainless steel or equivalent stainless steel with all joints welded and tested for leaks.

l) All racks and bus insulators as well as the insulators used to insulate each stack of capacitor from ground level shall be pin cap or post type. The minimum voltagerating shall be 15KV and low frequency wet withstand voltage of all insulator used to insulate

within or between the capacitor rack of a stack shall not be less than three times the actual voltage stress across the insulators. The insulator shall be outdoor type manufactured from wet porcelain. The insulators shall be bolted to the top members of the frame to support electric grade aluminum buses.

m) The size and groupings of the individual capacitor units shall be such that a single blown fuse will not cause the voltage across parallel group to rise by more than 10%.

n) The redundancy to be provided, shall be as per requirement specified regarding reliability and availability of STATCOM Station.

iii) Capacitor Unit Failure Detection

The stages of capacitor units or element failure detection shall be provided as below.

a) A three step unbalanced current protection shall be provided in each capacitor bank to initially generate an alarm when the unbalance limit is reached and finally to trip the bank in case of limit being exceeded.

b) The first stage shall generate an alarm and the capacitor unit shall continue in service. It may be assumed that the bank shall be disconnected for maintenancewithin 2 weeks.

c) The second stage shall generate a separate alarm and a delayed trip signal which will disconnect the bank after two hours.

d) The third stage shall cause immediate disconnection of Capacitor Bank.

iv) Tests on Capacitors

All the tests on capacitor units shall be generally in accordance with the latest issue of IEC publication 60871.

8.7 Coupling Transformer

The Contractor shall provide suitable coupling transformer for stepping down the voltage from 220kV system to a suitable medium voltage value as required for connecting the various branches of STATCOM Station to the HV System.The Medium Voltage side of the coupling transformer to couple with the STATCOM shall not be less than 20KV to ensure optimum power transformation.

The Coupling Transformer shall be designed with the aim to achieve operation according to the overall performance requirements of the STATCOM Station. The transformer should be designed & rated to carry complete capacitive and inductive reactive loading as specified for STATCOM Station including that of mechanically switched capacitor and Reactors etc.), as well as harmonic currents associated with the most onerous operating conditions of STATCOM Station, without loss of life.

The coupling transformer shall be designed in accordance with the most up to date experience in STATCOM application and shall incorporate the latest improvements of design currently employed in the industry. The Comprehensive design review of Coupling Transformer of STATCOM Station shall be carried out either by Employer.

The Coupling Transformer shall be designed based on the design of similar type of Transformer which has been tested successfully for dynamic short circuit type test.

8.9.1 General Requirements

The coupling transformer shall be designed electrically and mechanically for operating conditions peculiar to STATCOM Station operation, which shall include, but not be limited to the following.

a) Electrical insulation problems resulting from the transformer being subjected to voltages of distorted sinusoidal wave shape because of saturation, harmonics, trapped d.c. in capacitors etc.

b) The cumulative effect of electro-dynamic forces produced during valvecommutation or other short circuit conditions imposed by valve design limitation and valve group operation.

c) Harmonic currents due to STATCOM operation, with particular reference to additional stray losses resulting from these harmonic currents.

d) No generation of uncharacteristic harmonics by the transformers.

e) Stresses due to normal control operation and other onerous operations such as blocking and de-blocking.

f) Stress due to fast response requirement of STATCOM for loading from 100% inductive to 100% capacitive and vice-versa.

g) Overvoltage stresses for which STATCOM shall be designed as per specification would apply for transformer also.

h) All other stresses for which STATCOM Station shall be designed as perspecification would apply for transformer also.

i) The transformer and all its accessories like Bushings, CTs etc. shall be designed to with stand without damage the thermal and mechanical effects of any external short circuit to earth and of short circuit across the terminals of any winding for a period of 3 seconds. The short circuit level of 220 kV system to which the transformer shall be connected as per the maximum short circuit level mentionedfor respective Substation in the Section Project. Short Circuit level of the Coupling Transformer shall be as per Short Circuit level of the respective Substation. Short circuitlevel for HV bushing shall be 50 kA for 1 Sec***.***

j) The transformer shall be capable of being loaded in accordance with IEC60076 or the overload conditions as specified which is worst. There shall be no limitation imposed by bushings during its terminal fault.

k) The transformer shall be capable of withstanding the mechanical, stresses caused by symmetrical or asymmetrical faults on any winding.

l) The transformer should be designed to carry a certain level of direct current consistent with the STATCOM design. To ensure minimum harmonic generation, the saturation flux density of the transformer should be higher than the maximum flux density reached over the full steady state (continuous operating) range, andthe bidder should state the margin by which it is exceeded. This margin shall be at least 10%. This maximum flux density (over the full steady state range) is obtainedat the highest secondary voltage during any reactive power generation, highest reference voltage, minimum slope, and minimum continuous frequency. The Contractor shall submit B-H curve to substantiate this requirement. The flux density at the highest secondary voltage shall lie in the linear portion of the B-H curve. Any harmonic generated by the

transformer should be considered by the design of the STATCOM.

m) All protection class Current Transformers in coupling transformer shall be of PX/PS type. Other details of these Current Transformers shall be as per protection/metering requirement and shall be decided during detailed engineering. However, the parameters of WTI Current Transformer for each winding shall be as per Coupling Transformer manufacturer.

n) Transformers shall be capable of operating under natural cooled condition up tothe specified load. The forced cooling equipment shall come into operation by pre-set contacts of winding temperature indicator and the transformer shall operate as a forced cooling unit initially as ONAF up to specified load and then as OFAF. Cooling shall be so designed that during total failure of power supply to cooling fans and oil pumps, the transformer shall be able to operate at full load for at leastten (10) minutes without the calculated winding hot spot temperature exceeding 140 deg C. Transformers fitted with two coolers, each capable of dissipating 50 per cent of the loss at continuous maximum rating, shall be capable of operating for 20 minutes in the event of failure of the oil circulating pump or blowers associated with one cooler without the calculated winding hot spot temperature exceeding 140 deg C at continuous max rating. The contractor shall submit supporting calculations forthe above and the same shall be reviewed during design review.

o) The transformer shall be free from any electrostatic charging tendency (ECT) under all operating conditions when all oil circulation systems are in operation. In general, oil flow speed shall not exceed 1.0 m/sec within winding in the oil flow system of the transformers. The manufacturer shall ensure that there is no electrostatic charging tendency in the design.

In addition to above, Model Technical Specification “Technical Specification: Section-Transformer (160MVA 220/66KV Class)” shall be referred for the Coupling Transformer.

8.9.2 Transformer Characteristics

Clause No.	Description	Unit	Technical Parameters
1.1	Rated Capacity		
	HV	MVA	To meet the performance requirement & ratings of STATCOM. The transformer shall be suitable for 100% reactive loading
	MV	MVA	
1.2	Voltage ratio (Line to Line)		**220kV** / XX(*) **kV**
1.3	Single / Three Phase Design		As per Section-Project
1.4	Applicable Standard		IEC 60076
1.5	Rated Frequency	Hz	50

1.6	Cooling & Percentage Rating at different cooling		ONAN/ONAF/(OFAF or ODAF) : 60% / 80%/100% OR ONAN/ONAF1/ONAF2: 60% / 80%/100% OR OFAF (with 5 x 25% unit cooler if specified in Section Project)
1.7	Impedance at 75 Deg C		
	HV - MV		To be indicated by the bidder with tolerances
1.8	Tolerance on Impedance (HV-MV)	%	As per IEC
1.9	Service		Outdoor
1.10	Duty		Continuous Reactive loading
1.11	Overload Capacity		IEC-60076-7
1.12	Over Voltage withstand condition		As per Specified, elsewhere in this Specification
1.13	Temperature rise over 50deg C ambient Temp		
i)	Top oil measured by thermometer	^{O}C	50
ii)	Average winding measured by resistance method	^{O}C	55
1.14	Windings		
i)	System Fault level		
	HV	kA	50
	MV	kA	To be decided during detailed engineering
ii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1050
	MV	kV_p	*
	Neutral	kV_p	170
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	850
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	460
	MV	kV_{rms}	*
	Neutral	kV_{rms}	70
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	MV		Uniform
vii)	Tan delta of winding	%	< 0.5
1.15	Vector Group (3 – ph) (unless specified differently elsewhere)		YNd*
1.16	Tap Changer		Not Applicable
1.17	Bushing		
i)	Rated voltage		
	HV	kV	245
	MV	kV	*

	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	*
	MV	A	*
	Neutral	A	*
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1050
	MV	kV_p	*
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	505
	MV	kV_{rms}	*
	Neutral	kV_{rms}	77
vi)	Minimum total creepage distances		
	HV	mm/kV	31mm / kV
	MV	mm/kV	31mm / kV
	Neutral	mm/kV	31mm / kV
vii)	Tan delta of bushings		
	HV	%	Refer Note 2
	MV	%	Refer Note 2
viii)	Max Partial discharge level at U_m		
	HV	pC	10
	MV	pC	10
	Neutral		-
1.18	Max Partial discharge level at 1.58 * U_r / √3	pC	100
1.19	Max Noise level at rated voltage and at principal tap at no load and	dB	80
	all cooling active		
1.20	**Maximum Permissible Losses of Transformers**		
i)	Max. No Load Loss at rated voltage and frequency	kW	To be declared by the bidder
ii)	Max. Load Loss at maximum continuous current and at 75^O C	kW	To be declared by the bidder
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW	To be declared by the bidder

Notes:

1. No external or internal Transformers / Reactors are to be used to achieve the specified HV/MV impedances.
2. Tan δ value of RIP (Resin Impregnated Polymer) condenser bushing shall be 0.005 (max.) in the temperature range of 20°C to 90°C. The measured Tan δ value at site should not exceed by 0.001 w.r.t. factory results (measured at approx. similar temperature conditions) during warrantee period.
3. The criteria for Transformer losses shall be "**Copper Loss (Load Loss) > Iron Loss (No Load Loss) > Cooler Loss (Auxiliary Loss)".**
4. **(*) marked parameters shall be decided based on STATCOM Station Manufacturer's requirement.**

8.10 STATCOM Station MV Switchgear

The Switchgear shall be designed with the aim to achieve operation according to the overall performance requirements of the STATCOM Station.

8.10.1 Circuit Breaker

The Circuit Breaker shall comply with the IEC and all other relevant Standards, and as specified in this specification. They shall satisfy the General Technical Requirements and shall be designed to operate in the environmental conditions specified in this specification.

The Circuit Breaker offered should be of SF6 type and of class C2, M2 as per IEC

i. The circuit breaker shall be complete with terminal connectors, operating mechanism, control cabinets, piping, inter pole cable, cable accessories like glands, terminal blocks, marking ferrules, lugs, pressure gauges, density monitors (with graduated scale), galvanized support structure for CB and control cabinets, their foundation bolts and all other circuit breaker accessories required for carrying out all the functions the CB is required to perform.

ii. All necessary parts to provide a complete and operable circuit breaker installation such as main equipment, terminals, control parts, connectors and other devices whether specifically called for herein or not shall be provided.

iii. The support structure of circuit breaker shall be hot dip galvanized. Exposed hardware items shall be hot dip galvanized or Electro-galvanized.

iv. Circuit Breaker shall be equipped with controlled switching and associated singlepole operation & consequent optimization of switching behavior, when used in:
    - Switching of Capacitor Bank
    - Switching of shunt Reactor Bank

    For Technical Requirement for controlled switching device refer Switchgear Technical Specification.

v. The test reports of the type tests shall be submitted for Purchaser's review.

vi. Type Test Report for Reactor Switching Duty test on Circuit Breaker in line with latest edition of IEC 62271-110 shall be submitted for review.

vii. Type Test Report for Back-to-Back Capacitor Bank Switching test as per latest edition of IEC 62271-100 shall be submitted for review for CB wherever more thanone Capacitor bank (MSC) is to be connected to the same MV Bus.

viii. Routine tests as per IEC: 62271-100 shall be performed on all circuit breakers.

ix. The circuit breakers in any of the branches shall be designed to switch off metallic three phase short circuits only limited by the transformer impedance of the STATCOM System (Coupling transformer) with the initial short circuit current and DC component according to IEC 60909-0. Thereby the worst case time constant where the maximum short circuit peak and DC component occur shall be considered. The network shall be considered to deliver the maximum short circuit power of various substations as per technical specification.

8.10.2 MV Isolator and Earth Switch

The isolators and earth switches shall comply with the IEC and all other relevant Standards, and as specified in this specification. They shall satisfy the General Technical Requirements and shall be designed to operate in the environmental conditions specified in this specification.

i. The isolators and accessories shall conform in general to IEC-62271 series as per relevance (or IS:9921) except to the extent explicitly modified in specification.
ii. Earth switches shall be provided on isolators wherever called for.
iii. Switches shall be motor operated with local & remote operation feature and local manual operation feature. Remote operation of Earth Switch is not required.
iv. Disconnector and associated earth switches shall electrically and mechanically be interlocked. In addition Castle Key interlocking facilities shall be provided to mechanically interlock the earth switch and Isolator to the doors of associated branch fence gates and valve rooms (as applicable).
v. The features and constructional details of isolators, earths witches and accessories shall be in accordance with requirements stated.

8.10.2.1 Contacts

i. The isolators shall be provided with high pressure current carrying contacts on the hinge and jaw ends and all contact surfaces shall be silver plated. The thickness of silver plating should not be less than 25microns. The contacts shall be accurately machined and self-aligned.
ii. The contacts shall be self-cleaning& self-aligned type.

8.10.2.2 Base

i. Theisolatorshallbeprovidedwithacompletelygalvanizedsteelbase.Thebase shall be rigid and self-supporting and shall require no guying or cross bracing between phases other than the supporting structures.
ii. The position of movable contact system (main blades) of each of the isolators and earthing switches shall be indicated by a mechanical indicator at the lower end of the vertical rod of shaft for the isolator and earthing switch. The indicator shall be of metal and shall be visible from operating level.

8.10.2.3 Blades

All metal parts shall non-rusting and non-corroding metal. Current carrying parts shall be of non-ferrous material. Bolts, screws and pins shall be provided with lock washers, keys or equivalent locking facilities if provided on current carrying parts, shall be madeof copper silicon alloy or equivalent. The bolts or pins used in current carrying partsshall be made of non-ferrous and non-corroding material. All castings except current carrying parts, shall be made of malleable cast iron or cast steel. No grey iron shall be used in the manufacture of any part of the Isolator.

a. The isolators shall be so constructed that the switch blade will not fall to the closed position if the operating shaft gets disconnected.
b. Isolatorsandearthingswitchingincludingtheiroperatingpartsshallbesuchthattheycannot be dislodged from their open or closed positions by short circuit forces, gravity, wind pressure, vibrations, shocks or accidental touching of the connecting rods of the operating mechanism.
c. The switch shall be designed such that no lubrication of any part is required except at very infrequent.

8.10.2.4 Insulator

The insulator shall conform to IS:2544 and/or IEC-60815. Pressure due to the contact shall not be transferred to the insulators after the main blades are fully closed. The insulators shall be so arranged that leakage current will pass to earth and not between terminals of the same pole or between phases. Creepage distance for insulators shallbe 31 mm/kV for heavy pollution environment. The puncture voltage of hollow insulator columns shall be greater than dry flashover voltage

The name plate shall conform to the requirements of IEC and shall be incorporating the year of manufacture.

8.10.3 Instrument Transformers for STATCOM Station

The instrument transformers shall comply with the relevant IEC Standards. They shall satisfy the general Technical Requirement specified in specification and shall be designed to operate in the environmental conditions specified in this Specification. The instrument transformers provided for control, metering and protective relaying functions shall have voltage & current ratings, accuracy ratings and burden capabilities adequateto provide their designated functions within the overall accuracy requirement of the systems.

Voltage Transformers

Voltage transformers shall comply with the relevant IEC standards IEC61869 (Part-1 and Part-5).

Current Transformers

Current transformers shall comply with 61869 (Part-1 and Part-2). Type tests and routine tests as per relevant IEC.

8.10.4 Surge Arrester

The Contractor shall supply the surge arresters necessary for the protection of the equipment associated with STATCOM Station in accordance with the requirements specified. The bidder shall provide the one line diagram indicating location of proposed Surge Arresters in the bid based on insulation coordination study.

The protective characteristics and discharge duties with respect to the intended application, shall be determined by the Contractor. The surge arresters shall give consistent protection to their associated equipment against over voltages produced by lightning or switching surges, internal or external station faults, and other system disturbances.

The surge arresters shall be rated such that they are able to discharge a specified maximum energy due to the application of lightning, Switching surges, temporary over voltages and faults as determined by insulation coordination studies to be carried out by the contractor, without coming into the temperature region where thermal runaway could result upon subsequent application of maximum transient and steady state voltage conditions.

The arrester housing can be of composite type. The end fittings shall be made of non-magnetic and corrosion proof material.

Internal components shall be designed to eliminate internal corona and also to ensure minimal capacitive coupling with any conducting layer of pollutant on the outside of the porcelain housing Particular attention shall be given to the high discharge currents which some of the arresters may experience in service due to discharge of stored energy of the

ac filter and reactive compensating equipment, tripping of STATCOM etc.

8.11 STATCOM Station Auxiliary Power Supply

The auxiliary supply of STATCOM Station shall conform with the system requirements relating to reliability, availability, and redundancy, performing continuously to help ensure that the complete STATCOM Station operates as per the Employer's requirements. The auxiliary supply provides power to the controllers, cooling system, station supplies, and various other essential and non-essential loads. With the exception of the cooling system, all other essential loads shall also be connected to the dc system of the STATCOM Station.

The auxiliary supply system shall be able to provide a stable supply for the STATCOM Station during system faults such as single-phase faults, phase-to-phase faults, and three-phase faults and LVRT (Low Voltage Ride Through) to allow continuous operation of the STATCOM Station during these transient events.

Bidder shall access the DC Aux. Power requirement of the STATCOM system and based on that separate dual redundant Battery set and Battery Chargers for DC Auxiliary supply shall be provided. The Battery set and Charger shall be of standard rating of 110/220V DC. The Battery set and Battery chargers shall be as per GETCO specifications GETCO /E –TS / BATT/3101/R1 June, 2022, GETCO /E –TS / BATT/3102/R2 June, 2022 and GETCO / E / TS – BCHR / 3202 / R3, June, 2022 respectively in general.

Rating of Battery, Battery Charger sizing shall suit the STATCOM station requirement or else in minimum, size and rating as mentioned in price schedule shall be considered.

The auxiliary AC supply system of each STATCOM Station shall consist of two main incomers and one emergency incomer from DG set. The two main incomers shall be required to be paired to act redundantly to help ensure a certain degree of reliability and availability.

- All MV incomers shall be provided with suitable ACBs, instrument Transformer etc. along with necessary protection system.
- GETCO will provide source of LT Power supply.

LT Panel Board :

415V AC distribution boards shall be provided considering all need of STATCOM Station and STTATCOM Bays with following specific requirements.

8.11.1 Number of feeders and their rating in each board shall be finalized during detailed engineering decided as per requirement of STATCOM Station.

8.11.2 In general it shall be as per GETCO technical specifications GETCO/ E – TS – 4201 / R3 June, 2023

8.11.3 The valve and associated protection shall be designed to tolerate complete loss of first grade auxiliary power (Aux. Power both main incomers) without valve damageor discontinuity (block or trip) in STATCOM operation. It is envisaged to be achieved through Aux power supply transfer scheme for changeover from first grade power supply to DG set and provision of dedicated UPS for cooling system.

8.12 Cabling and Wiring

- Cable laying, termination, wiring, ferruling shall be done as per the industry standard and latest practice.
- The outdoor control cable shall be armored 1100V FRLSH and cabling within STATCOM

building shall be shielded 1100V FRLSH as per specification GETCO/E/TS –CCBL 027/R3 JULY 2022.

- The FO cable shall have as many spare fibers as utilized.
- The FO cable from STATCOM Station to control, protection and monitoring Panels shall invariably be laid within STATCOM building without routing to outdoor cable trench
- The FO cables shall be laid in high grade HDPE duct from the STATCOM device in the yard to the panel in control room. The ducts are to be tied on cable trench at a regular distance of 2 meters. Separate HDPE ducts are to be used for separate FO Cables.
- The F.O cable shall be as per specification GETCO /E/ TS FOC41/R2 June, 2022. However, specific requirements if any shall also be considered.

8.13 Valve Hall and STATCOM control building

- Complete Valve Hall and STATCOM control building (with foundation, cable trenches, plumbing, lighting, fire protection and electrical outlets as well as facilities for ambient temperature and humidity control, as required) to accommodate IGBT valves, its cooling system, control and monitoring system, protection system, AC-DC auxiliary systems, service rooms, workshop, document/ library shall be in the scope of this tender.

9 Engineering Studies

9.1 The bidder should perform engineering studies and submit reports with the bid that support and summarize the rating of the proposed STATCOM Station configuration(s). This should include, but is not limited to, the following items:

i. Report on main equipment rating and design. The bidder should define such items as the STATCOM Station V-I characteristics, design considerations for major equipment rating requirements, verify the STATCOM Station nominal output, and define the maximum fundamental ratings of filter components and other equipment as applicable.

ii. Report on preliminary analysis of harmonic performance. The bidder should identify assumptions and methodology used for calculation of fundamental frequency and harmonic stresses and performance. This should include preliminary verification of the effects of resonance between the STATCOM Station and the ac system, and verification that the filter configuration (if used in proposed STATCOM Station) limits the harmonic distortion and current distortion at the point of connection to less than the limits identified in the specifications. The bidders should provide documentary evidence to substantiate the harmonic generation methodology, against the control system algorithms.

iii. Report on loss evaluation.

iv. Report on audible noise.

9.2 Design verification studies

Pre-manufacturing engineering design and verification studies should be performed by the contractor within the scope of supply after contract awarded. These studies are in addition to the actual STATCOM Station design simulator and field performance tests. The studies should demonstrate that the STATCOM Station meets all system and equipment specified performance criteria. Acceptance by the user does not absolve the supplier's overall responsibility for the proper functioning of the STATCOM Stations specified. The bidder should list all engineering studies.

Engineering design verification studies should include, but not be limited to, the studies described mentioned below

9.2.1 System dynamic performance studies

The scope shall be considered as per Annexure-1.

9.3 Harmonic performance and component ratings studies

The scope shall be considered as per Annexure-1.

9.4 Electromagnetic transients, control performance, and overvoltage studies

The scope shall be considered as per Annexure-1.

9.5 Insulation coordination study

The scope shall be considered as per Annexure-1.

9.6 Software simulation models

The scope shall be considered as per Annexure-1.

9.7 RTDS

The scope shall be considered as per Annexure-1.

10 Tests

All other STATCOM Station components should be tested according the relevant equipment standards and the requirement specified in Technical Specification elsewhere. Field tests should be carried out in accordance with IEEE Std 1303™.

10.1 Type Test

- All the equipments/material shall be fully type tested as per latest IS/IEC standards and as mentioned in the technical specifications of respective equipments/materials.
- TTR of similar equipments of higher ratings shall be considered for bid evaluation only.
- However, in that case, bidder shall have to submit the type test reports of the offered equipments, free of cost, within commencement period, without affecting delivery schedule, in the event of order.

10.2 Factory tests of controls

All the equipments individually and wherever possible, in integration with peer equipments/system shall undergo the Factory Acceptance Test witnessed by GETCO at manufacturer works. It includes all the acceptance test as per prevailing latest standard and mutually agreed by supplier and GETCO during detailed engineering.

The integrated nature of the performance of the STATCOM Station in an electrical grid requires the following tests:

10.2.1

The vendor should perform factory simulator system tests to demonstrate the proper operation of the control system. The control system should be connected to a digital simulator with adequate representation of the electrical network for various conditions. The STATCOM Station controller needs to be representative of control functions, including basic controllers but inclusive of supplementary controls, firing controls, and protective functions integrated into the controllers.

10.2.2

The simulator should provide an accurate network representation including network harmonic behavior, as well as synchronous condensers, power stations, generators (with AVRs), and pump storage schemes, existing HVDC, SVCs and STATCOMs, future SVCs and STATCOMs, FSC (fixed series capacitors), and shunt reactors/capacitors/filters. The bidders and vendor should provide information on the simulator studies to the client prior to the tests being undertaken.

STATCOM Station control function on a simulator should include thefollowing:

a) Verification of each control function.
b) Verification of control linearity.
c) Verification of control redundancy.
d) Verification of the monitoring system.
e) Verification of the protection system with reference to integrated protectivefunctions included in the controllers and firing controllers.
f) Verification of overall system performance for minor and major systemdisturbances.
g) Verification of processor loading of all digital controllers.
h) Verification of STATCOM system parallel operation with other controls in thesystem and control stability.
i) Routine production tests of all control functions, and separately of all protection functions, should be made to demonstrate manufacturing quality.

10.3 Site Pre-commissioning Testing

The supplier shall be responsible for installation, testing and commissioning of the complete STATCOM system. The supplier has to ensure that equipments has sustained no damage in transit, has been properly installed in the field, is safe to energize, and will operate as intended. Following tests shall be carried out in progressive stages, until all ofthe related elements have been checked;

a) Individual equipment tests
b) Independent systems tests
c) Testing of components in group as a functional unit
d) STATCOM system operational (field verification) tests – System energization with primary power and the measurement and final adjustment of STATCOM performances.
e) Dielectric and Insulation resistance checks on primary equipments consisting of Power factor tests, high potential tests.
f) Resistance measurements of transformers, reactors, filter resistors & measuring equipment.
g) Ratio & polarity checks of transformers & measuring devices
h) Magnetization curves of current transformers
i) Insulating oil tests on transformers, reactors & other oil insulated equipment
j) Contact resistance checks of bus connections, jumpers, isolators and earth switches
k) Relevant pre commissioning checks on all equipment as per respective specifications
l) Test on STATCOM valve supervision and monitoring
m) Tests on IGBT modules
n) Tests on cooling system
o) Functional tests on auxiliaries

p) Functional tests on control, protection, fault recorder, SCADA & alarm circuits including protective relay settings and testing.
q) Loss measurement as per clause No. 6.6
r) Mechanical balancing, alignment, capacity, vibration checks
s) Checks of Interlocks
t) Wiring continuity & insulation resistance tests
u) Power abnormality tests for electronic equipment
v) Power supply parameters for electronic equipment
w) Diagnostic software functional demonstration
x) Functional tests on Valve cooling system

10.4 Commissioning Tests

After successful completion of the pre-commissioning tests, all independent sub-system shall be energized or started up in accordance with the relevant approved commissioning procedures to be submitted by the Contractor. These tests shall demonstrate the electrical & mechanical integrity of these sub-systems. During these tests the Contractor shall make the initial adjustment to the equipment for satisfactory operation.

10.5 Site Acceptance Test

After the satisfactory completion of pre-commissioning & commissioning tests the following acceptance tests shall be carried out on each STATCOM Station. The Contractor shall furnish the best procedure for carrying out the tests.

- STATCOM valves firing & supervision test
- STATCOM valves energizing test
- STATCOM Station power rating test
- Harmonic performance test
- Complete Operating Characteristics & Slope Setting
- Static Characteristic of the Uncontrolled STATCOM
- STATCOM small Signal Response Test
- STATCOM Station Control system test.
- Heat run test (the duration of Heat Run test shall be 24 Hours min.)

10.6 Trial operation

After completion of system tests, trial operation for an uninterrupted period of normal operation of not less than10 days is required and during which the converter equipment shall be fully operational. Interruptions attributable to connecting system requirements shall be permitted during trial operation.

11 Commissioning Responsibilities

The equipment supplied for this Contract shall be commissioned at the Sites and brought into Commercial Operation by the Contractor. The Contractor shall provide a Commissioning Supervisor and other staff approved bythe Employer.

The Contractor shall furnish commissioning procedures well in advance and details of test

equipment required and these procedures shall include, but not be limited to, the tests specified above in this section.

The Employer reserves the right to have any additional tests carried out which shall be mutually agreed to between the Employer and the Contractor During the commissioning work the Contractor's Commissioning Supervisor shallassume charge and be responsible for the equipment being commissioned. Employer'sclearance and safety procedures shall apply during the commissioning work andEmployer will nominate a representative to coordinate with the Contractor'sCommissioning Supervisors on matters relating to System operation and control.

The Contractor shall supply the testing equipment for the dielectric tests and all measuring devices, including instrument transformers, oscillograph, etc., for tests performed at the Site. These instruments and instrument transformers shall be previously calibrated against accepted standards.

No inspecting, testing or operation which is required to take place or be done in, upon,or about the Works which have been energized or existing equipment or facilities of Employer which are or may be electrically charged or energized from any source, shall be permitted unless and until a written "permit to work" has been issued for this purposeby the Employer. When such inspecting, testing or operation has been completed, the Contractor shall give written clearance to Employer of said completion. The "permit to work" shall apply and for what period the said permit shall apply and the permit shall only be valid for such date and such period of time.

11.1 Inspection

12.1.1 Inspection in Factory

In order to verify that all the manufacturing of equipment by the Contractor, or material and equipment being procured and provided by the Contractor is all in complete conformance with the requirements of the Contract, the Contractor shall ensure that the inspector or Engineer, or any other agent or agency authorized by Employer in writing, shall at all times have access to all facilities and premises where the manufacturing and supply of the Equipment by the Contractor, or Sub-contractors is being carried out.

The Contractor shall provide detailed manufacturing schedules, quality control and non-destructive testing procedures for approval of the Employer and shall keep such schedules up- to-date. The Contractor shall notify the Inspector in writing at least fifteen (15) working days in advance of each date any material or equipment becomes ready for inspection and shop quality control tests. In addition, notice for tentative dates for type testing of major equipment shall be given 90 days in advance.

In the case of material, certified copies of all such inspection and test reports for chemical analysis and for mechanical and electrical properties shall be available to the Inspector. Copies of the reports shall be given upon request. Test reports of any and all tests performed in the supply shall be certified by the Inspector unless specifically waived.

All inspections or tests carried out by the Contractor and to be witnessed by the Inspector shall be scheduled and performed so as to avoid undue delay in the performance of the equipment.

The Contractor shall provide without cost to Employer all facilities and assistance for the safety and convenience of the Inspector in the performance of the Inspector's duties.

The Contractor shall include in all orders to Subcontractors the requirement that any equipment being supplied by Sub-contractors for incorporation in the equipment shall be subject to inspection and testing by the Inspector or the Engineer or any other authorized agent of Employer. Copies of such order blanked for prices shall be forwarded to Employer.

All of the required tests shall be made at the Contractor's expense, including the cost of all testing facilities, test samples and the like.

The Employer reserves the right to require special tests in addition to those specified in the Contract and the Contractor shall perform such tests, which can be performed either in the Contractor's installations or in any other facilities chosen by Employer.

The Contractor will be advised in reasonable time at Employer's discretion to permit the preparation of facilities and specimens for such additional tests. Unless otherwise provided, such tests shall be in accordance with the requirements of international accepted testing standards and procedures.

The Inspector or the Engineer, or any other agent or agency authorized by Employer in writing, shall carry out the testing and inspection of any part of the equipment in accordance with the procedures herein be low included:

a. Approval of the Contractor's inspection plan and initial evaluation of the Contractor's inspection system.
b. Periodic checks of the manufacturing procedures to confirm effective application of the inspection plan.
c. Inspection of matter and/or verification of inspection records at the Inspector's discretion including:-compliance of raw material swith the requirements of Contract and the require d standard;
d. compliance of manufactured parts and assemblies with the Contract, released drawings, and good engineering practice and manufacturingpractice;
e. check of packing lists to verify that all parts of the equipment listed is packed, including identification and destination of shipments;
f. Periodic inspection of Contractor's design and production, and preparation of progress reports with regard to manufacturing processand procedures;
g. Witnessing of tests;
h. Verification of the Contractor compliance with the equipment delivery schedule, and releases for dispatch;
i. Effectiveness of packing systems for shipment to ensure protection and handling of material and equipment, and plant;
j. The Inspector shall have complete authority to accept or reject, on behalf of the Employer any material, equipment or parts thereof considered unsatisfactory and not in accordance with the Contract;

failure to inspect and accept or reject materials, equipment or any components thereof shall not relieve the Contractor of any of his obligations under the Contract, nor impose any liability whatsoever on Employer.

k. The contractor shall furnish a detailed and comprehensive quality plan,in complete, to the Engineer.
l. The quality plant shall relate the specific and objective manufacturing practices followed by the contractor. Accordingly, the quality plan shall be submitted broadly under the following sub-heads:
m. Raw materials/bought out items and components
n. In process tests/checks to establish successful completion/accomplishment of the process.
o. Final tests/checks in accordance with GETCO specification
p. The quality plan shall be submitted with all references documents to enable Engineer to finalize quality plan. The Contractor shall proceed with manufacturing of the equipment only once the quality plan is approved by the Engineer.
q. In order to ensure timely execution of the contract the Contractor shall ensure timely submission/approval of quality plan.

12.1.2 Site Inspection

The Employer shall have the right to have Inspectors at the sites, on a regular basis or from time to time as may be required with in his sole description to monitor the quality and the progress of the work.
The Inspectors shall have the right to order any special Sites tests deemed necessaryto verify the compliance of the equipment with the Contract.

12 Repair Procedure

12.1 Repairs, if any performed on the STATCOM Station equipment shall be carried out only after mutual discussion and in accordance with mutually agreed upon repair procedure. The Contractor shall submit details of faults, root cause analysis along with proposal of repair procedure for mutual agreement immediately after the fault has been detected. The bidder shall describe the process of repairs to be carried out preferably in India.

12.2 On Site Repair

The contractor shall submit the repair procedure to be carried out at site which involves minor repair, replacement of faulty parts and components etc. to enable GETCO to carry out these tasks by themselves.

13 Spare Parts

The Bidder should provide list of spares as per relevant clause mentioned in Technical specification. The Bidder shall describe how the bidder will respond to the requirement of spare part and services required for the next 20 years after commissioning. Since STATCOM technology is developing fast and there is the risk that constituent parts may become redundant or the manufacturer of certain parts could cease to supply these parts. The Bidder shall state how the requirement of spares or repairs in future will be handled.

Minimum spares to be supplied shall be as per Spare item BOQ. The BOQ is typical and accordingly, any other specific item/material/equipment required for satisfactory operation of

STATCOM station for service life mentioned above shall also be invariably considered in spare to be supplied to GETCO.

14 Civil work

- All the civil work required for entire STATCOM system including but not limited to valve hall, STATCOM control building, civil foundations, cable trenches, chain link fencing, etc. shall be in the scope of this tender.
- Please refer attached 'Technical specifications for 'Civil Works for 220KV STATCOM' - Specification for common points of civil works.

15 Operation and AMC

- The operation of STATCOM during first 6 months of the guarantee period after taking over of the system shall be done by supplier jointly with GETCO.
- The maintenance of the STATCOM for initial period of 5 years (excluding guarantee period) after successfully commissioning shall be carried out by supplier.
- The maintenance includes corrective, preventive and breakdown maintenance.
- During guarantee period, GETCO will do only cleaning and up keeping.
- Any maintenance during guarantee period, if required, shall be done by bidder and five years maintenance period shall start from the expiry of guarantee period of two years after taking over the system
- Bidder shall have to mandatorily quote rates of Operation and AMC in price schedule. In absence of above, bid may be liable to be rejected.

16 Training

- A comprehensive training shall be given to GETCO executives to make them fully familiar with the operation and maintenance of the STATCOM system
- It shall be hands on as well as class room training.
- It shall be conducted on site after satisfactory commissioning of the STATCOM.

17 Bill Of Quantity

The BOQ is in broad and the scope includes the supply of all the material / equipments, civil works etc. whether specifically mentioned herein or not but required to complete the scheme in all respects and thus not limited to the items mentioned in it.

Annexure-1

Scope of the bidder to perform various system studies as mentioned at (A to D) to validate the design of STATCOM.

A. System Contingency study

- For contingency study, the PSS/E file will be provided along with contingency cases to be considered.
- Bidder can also consider contingency criteria based on the CEA published manual on Transmission Planning Criteria-2023 (https://cea.nic.in/wp- content/ uploads/ psp___a_ii/2023 / 03/ Manual_on_Transmission_Planning_Criteria_2023.pdf)

B. System Dynamic Performance study

- GETCO will provide PSS/E file. The load flow model is covered in PSS/E file.
- Dynamic study model / Stability Model / Transient Model can be considered as generic model or as available with bidder.
- Bidder can perform study considering contingencies as mentioned in Point A.
- Bidder can consider contingency criteria / any guidelines based on the CEA published manual on Transmission Planning Criteria-2023 (https://cea.nic.in/wp-content/uploads/psp___a_ii/2023/03/Manual_on_Transmission_Planning_Criteria_2023.pdf)
- Dynamic performance studies should verify that the STATCOM controls the system's dynamic performance during system disturbances, such as major faults (including stuck breakers), and load rejection, and evaluate all functions specified under various system conditions (i.e., heavy and light load conditions). At least following studies for above shall be performed by the Contractor:
- Studies to verify that the STATCOM provides adequate dynamic control to meet the system and STATCOM Station performance criteria for selected local and wide area disturbances.
- Study of response time and of the STATCOM Station's behavior and contribution to the system's recovery from faults.
- Studies to verify the operation of any supplementary controls designed to damp power oscillations following system disturbances.
- Studies to evaluate the interaction of the STATCOM controls with the other nearby control systems, other flexible ac transmission systems (FACTS) devices.
- All supplementary control functions shall be prioritized based on simulation studies. The priority order of these functions shall be intimated during detailed engineering.

C. Software simulation models

- **Stability model**
  The vendor should provide a detailed STATCOM Station dynamics model for use in (PSS/E33) power flow and stability simulation software. The model detail should be appropriate and complete for positive-sequence power system simulation and analysisthat is typically performed with power flow and transient stability programs. All appropriate control features for such analysis will be modeled, and necessary documentation on the theory and use of model should be provided. Stability model should be non-proprietary and freely available for distribution.
- **Transients model**
  The vendor should provide a detailed STATCOM Station transients model for use in [PSCAD and EMTP-RV] transients simulation software. The model detail should be appropriate and complete for transient response calculation of the STATCOM Station. All appropriate control features for such analysis will be modeled, and necessary documentation on the theory and use of model should be provided.

If any other proprietary softwares are used by the contractor for system control design, the contractor shall provide these softwares with perpetual license for use by the Employer.

D. Other studies: Bidder can perform other studies and provide detailed report for the study. If required

- **Electromagnetic transients, control performance, and overvoltage studies-**
  Transient overvoltage studies should be performed with the actual controls modeled to verify that the STATCOM Station equipment is adequately protected against over voltages and over currents

(including excessive valve recovery voltages) from power system transients resulting from switching, fault clearing events, and credible STATCOM Station mis-operations. Concerns that should be evaluated include the following:

a. Study of start-up, including transformer energization, shutdown, switching coordination, and other local area network switching events.
b. Study of STATCOM Station protection and protection coordination.
c. Faults on the high-voltage (HV) and MV bus (single line-to-ground, phase-to-phase,and three-phase).
d. Faults across the VSC, capacitors, and other equipment if used
e. Control coordination between two STATCOM station operating on same PCC (**220kV Bus**), if applicable.
f. Control interaction.

- RTDS
  - The supplier shall carry out SVC system simulation study to demonstrate and tomake sure that the designed system will meet the performance objectives.
  - All control functions shall be verified on a Real Time Digital Simulator.
  - The tests shall include but not be limited to;
    - ➢ Verification of each control function, including HMI.
    - ➢ Verification of control linearity.
    - ➢ Verification of control redundancy
    - ➢ Verification of control of external devices, if any
  - Verification of processor loading of all digital controllers