4.1 TRANSMISSION SYSTEM RATING

The requirements for power transmission are defined in this section. The existing power levels and AC filters requirement shall not be compromised by the Contractor. In addition, wherever not specified, the various overload, reduced ambient, reduced voltage and other power transmission capabilities under the specified conditions quoted by the Contractor in his Bid shall be guaranteed by him for the equipment in scope of the supplies.

The power transmission levels shall be determined by measurement using metering accuracy instrumentation at the AC Side inverter side on 400 kV bus of the back-to-back HVDC station. The power transmission capability may also be determined by calculation based on test values of appropriate quantities at the discretion of the Employer. Any shortfall in power transmission capability so demonstrated, particularly at extremes of ac system voltage and frequency, shall be sufficient justification for the application of penalties as defined in Section 11.

In the calculation of power transmission capability the Employer shall be permitted to assume the most unfavourable combination of control and measurement tolerances, particularly as these affect tap changer position.

All components of the transmission system shall be rated to meet the requirements given in this section and, in addition, the other requirements specified elsewhere in this Specification.

Any limitation on power transmission through the back-to-back HVDC station due to ac system limitation following some contingency (e.g. faults and opening of one or two lines in the vicinity of HVDC station) shall be identified by the Contractor through system studies.

4.1.1

A) DIRECTION OF POWER FLOW:

Direction of power flow shall be from Eastern to Southern region or vice-versa. The equipment under scope of this contract shall be designed for rated power flow including various overloads in both the directions.

B) GENERAL DESCRIPTION AND BASIC OPERATING MODES

The back-to-back HVDC station is in the form of two poles of 500 MW capacities. However, the present scope under this contract shall include refurbishment of Pole-1 i.e. one pole of 500 MW capacity along with interface with existing pole-2 as specified in detail in Chapter -1. The Pole is to be configured as 12 pulse valve group. The back-to-back HVDC equipment and C&P system under present scope shall be designed and rated to operate in

(a) Constant power mode from the Eastern Region to the Southern Region.
(b) Constant power mode from the Sothern Region to the Eastern Region.
(c) Six pulse operation shall not be permitted.

(d) Each pole shall be able to operate separately in above mentioned modes of operation. As well as a combined link of pole-1 and pole-2, as tabulated below:

Mode	Pole-1	Pole-2	Details
Independent mode	Yes	Yes	Both Poles to operate independently
Station mode	Yes	Yes	Both poles to operate as a combined link namely station mode
Station mode and independent mode	Yes	Yes	One pole will be in station mode and other pole during this time will be in independent mode. Tripping of pole in independent mode will result compensation of power lost due to this tripping by the pole which is in station mode, limited to the power capabilities described in section 4.1.3
Hot standby (0 MW power but in blocked state) and station mode	Yes	Yes	One pole will be hot standby mode and other pole during this time will be in station mode. Tripping of pole in station mode will result in compensation of power lost due to this tripping by the pole which is in hot standby mode, limited to the power capabilities described in section 4.1.3.

4.1.2 Co-ordination between HVDC Back-to-Back Pole-1 & 2

Both HVDC poles shall operate as a combined system with integrated and coordinated functions. Necessary exchange of signals along with other interface requirements shall be under present scope of works. Refer **Annexure-Interface.**

4.1.3 POWER TRANSMISSION REQUIREMENTS

The power transmission of the back-to-back hvdc system shall be defined at the 400kV line winding side of the converter transformer on the inverter side of the back-to-back hvdc station.

The power transmission shall be defined as the average over 0.1 s (one tenth second) of the instantaneous power.

The specific power transmission requirements are summarised in below and shall be met over the full ranges of ac system voltage and frequency and of ambient air temperatures specified in Section 2.4.1 and 2.4.2.

The power transmission limits mentioned in the following sections shall be met so that the the limits of reactive power interchange are within the limits specified in Clause 2.4.3.

In addition if the ac bus voltage at either side of the hvdc back-to-back station is below 360kV, the transmitted power capability may be reduced to levels as determined by the Contractor during the detailed design studies but the converters shall be able to operate continuously.

The power transmission capability and the reduction in power level below 360kV AC voltage, as stated above, shall not be less than the existing capabilities.

4.1.3.1 MINIMUM CONTINUOUS RATING

The 500 MW, 12-pulse back-to-back valve group shall be capable of operating continuously at a minimum power level not in excess of 50 MW for the complete range of ac system and ambient conditions given in Section 2.4.1 and 2.4.2

4.1.3.2 MAXIMUM CONTINUOUS RATING

The 500 MW, 12-pulse back-to-back valve group shall be capable of operating continuously at a transmitted power level not less than 500 MW each over the complete range of ac system and ambient conditions given in Section 2.4.1 and 2.4.2 with all redundant coolers and heat exchangers out of service and all redundant thyristors short circuited. In addition, the above continuous transmitted power levels shall be achieved with a higher wet bulb air temperature of 34.5 degree centigrade, with all redundant thyristors short circuited but with all redundant cooler and heat exchangers available for service.

4.1.3.3 TWO HOUR OVERLOAD RATING

The 500 MW 12-pulse poles shall be capable of operating for two hours at a transmitted power level in line with overload capability of existing system as defined in Annexure A and Chapter 2. The two hour overload rating shall be guaranteed by the Contractor over the complete range of ac system and ambient conditions given in Section 2.4.1 and 2.4.2 with all redundant thyristors short circuited and all redundant coolers and heat exchangers in service.

The frequency of application of 2 hour overload shall generally be governed by the calculation principle as outlined for determining the 'Inherent Overload Capability' described in section 4.1.3.5 below. However the Contractor shall guarantee two hour overload power transmission at least once in every 12 hour period.

4.1.3.4 FIVE SECOND OVERLOAD RATING

The 500 MW 12-pulse back-to-back hvdc valve group(s) shall be capable of operating for five seconds at transmitted power levels which in line with overload capability of existing system as defined in Annexure A and Chapter 2. with all redundant coolers and heat exchangers out of service and all redundant thyristors short circuited.

The full five second transmission capability defined above shall be available for the complete ranges of ac system frequency and voltage given in Section 2.4.1 and 2.4.2. The five second overload rating shall be achieved without tap changer operation.

It shall be permissible to apply the five second overload power once in any five minute period, except during maximum of five minutes before and maximum of 30 minutes after operation at the two hour overload. Lower time limitations than the ones specified here shall get dictated by the inherent overload capability of the pole.

4.1.3.5 INHERENT OVERLOAD CAPABILITY

The pole shall be capable of operating at increased capability that is inherently available depending upon the ambient temperature conditions, cooling equipment availability, ac filter and shunt capacitor status, prior loading and any other relevant parameters. Feature for display of this inherent capability shall be made in the control room as specified in clause 4.7.1.4.

The bidder shall furnish in his bid power capability curves of the proposed converters which shall show power vs time for different ambient temperatures from 15 degrees to 50 degrees centigrade in steps of maximum five degrees for the following conditions of prior loading and available redundancy:

1. Converters operating at Maximum continuous power rating as defined in 4.1.3.2.
2. All redundant thyristors and redundant coolers and heat exchangers available.

The bidder shall declare the converter power transfer capability for equipment in his scope when ambient temperature is above 50 degrees centigrade. Further if the ambient temperature is higher than 50 degrees the necessary control actions to be specified by the contractor.

4.1.3.6 AC SYSTEM STABILIZATION MODULATION

The back-to-back hvdc system shall be capable of operating in all modes and at all transmitted power levels with a power modulation from minimum power rating as defined in Clause 4.1.3.1 to its five second overload capacity as defined in Clause 4.1.3.4 around the operating power level. The purpose of this ac system stabilization modulation is to damp power swings that may occur in either side Eastern or Southern region.
The power modulator shall be designed in such a way that the amount of modulated dc power corresponding to swings in the disturbed region does not tend to destabilize the healthier region. To enable this the conditions of both the regions shall be monitored continuously during modulation and otherwise and feedbacks given to the controller(s) to act in the desired manner. The design of the modulator shall take into consideration and avoid any possible adverse interaction between Pole 1 & existing pole-2. The Contractor shall check the proper working of the modulator using digital computer and simulator with suitable network representation of Indian grid. The network representation for simulator studies shall be mutually agreed between the Contractor and the Employer/Engineer.

The modulation frequency shall be adjustable over the range 0.1 Hz to (x2+2) Hz where x2 is the highest oscillating frequency of Indian grid.

4.1.3.7 RUN BACK CONDITION

The runback levels shall be matched with the existing run back levels of the HVDC system. The HVDC Contractor shall be responsible for arranging the signals required for hardwiring the equipment status of the switchyard equipment required in the converter station for control and protection purposes such as run back control, frequency control etc. at the respective converter stations.

Hardwiring of equipment status of both - HVDC Vizag (Annexure: Vizag HVDC SLD) and 400kV Jeypore (PG) and Gazuwaka (PG) AC station (Annexure: 400kV Vizag SLD) for the purpose of implementation of runback controls shall be in contractors scope. This shall include implementation, including supply and installation of terminal boards, signal conditioning equipment and shall also include supply, laying and termination of cables to relevant HVDC and HVAC equipment. The interface for such signals shall be through Interface cubicle to be installed in Switchyard control room.

If during detailed system studies it emerged that any signal is to be brought from remote generating stations/substations for control purpose of HVDC station, the Employer shall provide these signals in the above interface cubicle.
In case any transducer / signal conditioning is required, the Contractor shall supply and commission the same. During this implementation of hardwiring of equipment

status, if the existing cable trench does not have space for laying cables contractor shall provide new cable trench for the purpose, depending on space availability at site.

4.1.3.8 Increased Reactive Power Absorption

The use of higher-than-normal firing and extinction angles either temporarily to control overvoltages or continuously to assist in reactive power management may be utilised by the Contractor provided that all equipment's (equipment delivered by contractor under the present scope as per chapter-1 of this specification) are adequately rated and that all the requirements of this specification are met.

However if the contractor wishes to propose any additional reactive power compensation equipment to meet the reactive power requirements of the project, the same shall be proposed by the contractor in his design proposal, in line with requirements mentioned in chapter-1 of this specification.

4.1.3.9 CONTROLLED SHUT DOWN

The HVDC transmission system shall be shut down in a controlled manner by the automatic reduction in the power order accompanied by appropriate ac harmonic filter sub-bank switching. The contractor shall arrange the shutdown sequence and timing to, in following order of importance:

i) Prevent the generators tripping due to excessive harmonic currents
ii) Prevent generator over speed
iii) Prevent generator over voltage

Other than the initial power reduction to stabilize frequency, the power order reduction shall not be at a rate greater than that which can be followed by the connected generator(s) without requiring special measures.

4.1.3.10 OPERATING SCENARIOS

4.1.3.10.1: BASE OPERATING CONDITIONS

This HVDC link shall interconnect the Eastern Region with the Southern Region. The following operating conditions shall form the basis of the studies:

- Synchronized operation of North-East/Eastern region, Western region and Northern with isolated Southern region.

- Synchronized operation of All India Grid including southern region also.

4.1.3.10.2: CONTROL OF FREQUENCY DURING ASYNCHRONOUS OPERATION

The normal operation of the Vizag HVDC shall be with Eastern, Western, Northeast Region, Northern Region and Southern Region operating in synchronous manner.

Under asynchronous operation of rectifier and inverter end ac system, it shall be possible to operate the HVDC system in frequency control mode in which the power flow through Vizag HVDC to control the frequency of the Eastern Region or that of Southern region at a target value (Freq Target) provided the frequency of the other grid does not deviate beyond the specified band (Frequency band 47.5 Hz to 51.5 Hz)

It shall be possible to set the Frequency target anywhere within the range of 47.5 Hz to 51.5 Hz in steps of 0.05 Hz, provided the frequency of the other region is within the Frequency Band. The Frequency Target shall be met within 0.05 Hz of the setting. It shall also be possible to set the Frequency Band by setting lower limit and upper limit to a value between 48.5 Hz to 51.0 Hz. While trying to meet the Frequency Target the Frequency Band shall not be deviated for more than 0.01 Hz.

Under certain circumstances, separation of Rectifiers and Inverter AC grids due to tripping of the interconnecting lines between the regions i.e. Southern and Northern/Western/Eastern/North-East region may occur. To take care of such unknown separation of the regions and the asynchronous operation of the grid, the rectifiers end ac system frequency shall also be monitored and the power transmitted by the HVDC system shall be controlled automatically to ensure that the Converter AC Bus frequency does not deviate from nominal (50 Hz) by more than the permissible levels. This shall be monitored by comparing AC bus frequency between rectifiers and inverter and if the difference between the two is more than the pre-determined level for pre-defined duration (Values shall be determined by the Contractor in consultation with Employer during detail system studies), automatic activation of frequency control shall be made. Under such situations, the frequency control function at the HVDC station shall control frequency of the Rectifier/Inverter end AC system within pre-defined band.

4.1.3.11 LOW AMBIENT CONTINOUS RATING

The HVDC system shall be capable of operating continuously at transmitted power levels at least 10% (ten percent) higher than the maximum continuous ratings given in Clause 4.1.3.2 for all:

A) -Dry bulb ambient air temperatures in the range 0°C to 33°C.
-Wet bulb ambient air temperatures up to 23°C.
-400 kV ac bus voltages in the range 380 kV to 420 kV on Vizag Eastern and Southern bus
-Redundant coolers and heat exchangers not available for service.

b) -Dry bulb ambient air temperatures in the range 0°C to 33°C.
-Wet bulb ambient air temperatures up to 23°C.
-400 kV ac bus voltages in the range 360 kV to 440 kV on Vizag Eastern and Southern bus
-Redundant coolers and heat exchangers available for service.

4.2 DYNAMIC PERFORMANCE OF THE HVDC SYSTEM

4.2.1 GENERAL

The HVDC system shall conform to the performance requirements specified herein. It shall be designed to optimally co-ordinate all aspects of its controls to ensure safe and reliable operation and shall assist the ac system following disturbances. The performance requirements shall be met under all specified ambient conditions, modes of operation and ac system conditions and parameters as given in Section 2 of the Specification. Further, reference may be made to IEC60919-Part2 and Part3 on Performance requirements of High voltage Direct current systems.

The Contractor shall perform a low order harmonic resonance study, to prove that the control system does not excite low order harmonic resonances. During the study the low order harmonic filters connected to the commutating bus bars shall not be represented in the model in designs which do not include low order harmonic filters as minimum AC filter requirement for all operations of HVDC system.

The principal objectives of the design shall include:

1. Optimal response of HVDC controls following step change in ordered parameters like current, power, dc voltage and firing angles etc.

2. Stable operation of the dc system following major disturbances.

3. Stabilization of ac system following disturbances.

4. Control of temporary over voltages and avoidance of self-excitation of the generators.

5. Avoidance of excitation of subsynchronous resonance in the generators.

6. Control of frequency of Southern grid and Eastern grid.

7. Automatic limitation of power levels as defined in clause 4.1.3.7 depending upon system configuration.

8. Successful post fault recovery of HVDC station shall be ensured in a coordinated manner between pole-2 and pole-1.

9. It is to be ensured and demonstrated that disturbance from one side ac network is not transferred to the other side ac network and cause commutation failure.

10. Low frequency oscillations generated (beat frequency) due to frequency difference
between Southern and Eastern side shall not propagate into ac networks.

4.2.2 STABILITY OF OPERATION

The back-to-back hvdc converter station and equipment shall be designed and rated to ensure stable operation and proper response to disturbances as specified herein.

The stable operation of the system shall be demonstrated by studies using digital computer and HVDC simulator in accordance with Section 10 of this Specification. The response shall be verified later to the extent possible during system tests as mentioned in Clause 9.3.6 and acceptance tests as mentioned in Clause 9.3.5.

4.2.2.1 CONTROL SYSTEM STABILITY

The Contractor shall demonstrate, to the satisfaction of the Employer that the hvdc control system, will be stable under all operating conditions and cannot excite oscillations particularly subsynchronous and low order harmonic resonances between the hvdc and ac systems. The control system shall be tuned for optimal overall performance for all conditions & configurations of the ac system network.

The test to be carried out shall include but not be limited to the following:

1) The Contractor shall demonstrate that the dc system responds to various step order changes in the current order in a fast and stable manner. The demonstration shall be done with a dc power transfer level of 0.1 pu, 0.5 pu and 1.1 pu each with a step change in current order upto at least plus and/ or 50 (fifty) percent.

   In addition to above following cases shall also be studied:

   a) Current order step from 1.0 pu to 0.92 pu.
   b) Current order step from 0.92 pu to 1.0 pu applied
   immediately after the step of a) has settled.
   c) Current order step from 0.92 pu to 1.0 pu.
   d)Current order step from 1.0 pu to 0.92 pu applied immediately after the step of c) has settled.

2) The response to power order step changes shall also be demonstrated in a similar fashion as that for the current order step changes but now with a step size of 0.5 pu only.

   The Contractor shall also indicate if the power/current control system response as demonstrated by tests in 1) and 2) above is sufficient to accomplish power modulation function which is required to be designed for power modulation between minimum continuous rating and the five second overload rating for oscillation frequency defined at 4.1.3.6. If not, then suitable tests shall be performed by the Contractor after approval by the Employer/Engineer.

3) Positive step change in margin angle control when operating at minimum margin angle and positive and negative step changes in margin angle control when operating at a higher than minimum margin angle. The Contractor shall select an appropriate step change in margin angle control greater or equal than the maximum possible step utilised by the controls.

4) Changes in ac bus frequency at the maximum rate and of the maximum amplitude as determined from stability studies for the condition of the maximum load rejection or fault which leaves one or both valve groups operating or for which the dc transmission system is required to recover. The Contractor shall also indicate if the power/current control system response as demonstrated by tests in 1) and 2) above is sufficient to accomplish power modulation function which is required to be designed for power modulation between minimum and maximum power up to five second overload rating under the complete range of frequencies defined at clause 4.1.3.6

5) The Contractor shall also demonstrate that the control system does not excite low order harmonic resonances in the ac system for certain system configurations which otherwise could have been avoided by a proper design of the control system. Robustness of the control system in this respect shall be demonstrated by the Contractor for a test system supplied by the Employer/Engineer on simulator during dynamic performance studies to the total satisfaction of Employer/Engineer. Low order non- characteristic harmonic filters on the commutating bus bars shall not be used in demonstrating the control system performance regarding excitation of the low order harmonic resonance.

6) The contractor shall also demonstrate that the control system neither adversely impacts nor gets adversely impacted by the control system of existing pole-2 by any means or whatsoever. The same shall be demonstrated by the Contractor for a test system supplied by the Employer/Engineer on simulator during dynamic performance studies to the total satisfaction of Employer/Engineer.

4.2.2.2 RECOVERY FROM FAULTS

The dc transmission system shall be capable of recovery in a controlled and stable manner without commutation failures during recovery following ac and dc system faults.

Recovery shall be considered effective when 90% of the ordered pre-fault transmitted power, is achieved and maintained. The converter equipment supplied shall be designed to ensure that recovery can, with the ac system as described in this

Specification, be effective within 500 ms following the clearance of the fault, with no delay in the commencement of power flow.

The control equipment shall be provided with the facility to adjust both the delay between fault clearance and the start of recovery and the rate of recovery. In the former case a delay, adjustable but preset, between zero and 500 ms and in the latter case a recovery time, adjustable but preset, between 100 ms and 1000 ms shall be provided.

The recovery shall be coordinated within the poles (pole-1 and the existing pole-2) so that smooth recovery of both poles is possible.

The recovery capability specified above shall be demonstrated by the Contractor for 5 cycle 3-phase to ground and 10 cycle 1-phase to ground faults at least for the fault cases to be furnished by the Employer/Engineer.

4.2.3 AC SYSTEM STABILIZATION

To assist in the recovery of the network the hvdc back- o-back system shall be able to continue operating with reduced ac busbar voltages.

The converter equipment shall be dimensioned to operate at rated current with ac bus voltage reduced to 30% of nominal during three phase faults, and to zero on one phase during single line to ground faults, for a period of 1 second followed by voltage recovery to 85% with the converter elements operating at up to the maximum overload current rating. During the 1 second low voltage condition initial commutation failures may occur but the valve groups shall recover. This shall be demonstrated by the Contractor on the simulator. Valve firing systems utilising energy from across the converter valves shall be adequate to permit transmission of power, and to perform any planned control or protective sequences, while such reduced voltage conditions persist.

In addition:

(a) The minimum voltage at which the low voltage current limit control (LVCL) comes into effect shall be adjustable. The minimum current setting of the limiter characteristics shall also be adjustable between 0.1 p.u and 0.9 p.u linearly. The equipment shall be designed to work over the whole range. The intent is to have the capability to maintain the highest possible current during the fault.

(b) The post fault current order shall be adjustable to the maximum transient or inherent overload capability of the system.

(c) Provision shall be made for a stabilizing power order change proportional to or dependent upon the change in frequency from the pre-fault value. The possibility of using some other actuating signal for stabilization control shall be investigated and the suitability of the chosen signal compared to other options shall be demonstrated to the total satisfaction of Employer. It shall be the responsibility of the Contractor to make available the required signals at the required locations. However, in case remote signals are required, the same shall be discussed during engineering phase.

4.2.4 CONTROL OF TEMPORARY OVERVOLTAGES

The temporary overvoltage, as stated in Clause 4.4.3.1, shall not exceed 600 kV on either side i.e. 1.50 times the nominal ac bus voltage. The actual temporary overvoltage shall be determined by the Contractor but equipment shall be designed for temporary overvoltages not less than the values given in Clause 4.4.3.1.

Subsequent reduction of temporary overvoltage shall be effected by actions within the back-to-back hvdc station in order to:

1)Prevent any possible self-excitation of generators.
2)Prevent overheating of surge arresters
3)Prevent damage to or loss of life of equipment

In all cases this shall be achieved without ac harmonic filter switching unless, as noted in Clause 4.4.1.1, such switching does not cause any restriction in the recovery phase. The Contractor shall demonstrate that the converter valves are capable of continuing to operate under the highest temporary overvoltage conditions which could occur with the valves deblocked and also that the valves are capable of deblocking under the highest temporary overvoltage conditions within 5(five) cycles of the initiation of the fault or disturbance.

The ac busbar voltages at both sides i.e Southern and Eastern bus shall be restored to within the normal voltage range within 1 (one) second following the clearing of any HVDC back-to-back station fault or load rejection. If the dc converter equipment has been unable to restore full ordered power transmission within 1 (one) second period the ac filter banks or sub-banks may be switched off provided that sufficient filtering remains connected to allow continued operation of any remaining transmission capability.

4.2.4.1 LAST LINE DISCONNECT

The HVDC station shall be adequately rated and protected should either or both of its converters (rectifier or inverter) gets completely isolated from the rest of the ac system following faults within the complete range of operating conditions specified in this specification.

4.2.5 CONTROL OF FREQUENCY

The back-to back station shall be able to operate in the frequency control mode in which the power flow through back-to-back shall be varied to achieve the target frequency of either of the two sides at a target value (FTR) provided the frequency of the other side does not deviate beyond the specified value (FTS). It shall be possible to set the FTR to a value within the range 48.5 to 51.0 Hz, at a step of 0.05 Hz. If within the capability of the back-to-back station, and the limits of FTS are not violated, the frequency of the region shall be met within ±0.05 Hz of FTR. The FTS shall be settable to a range 49.0, 49.5 or 50.0 ± x Hz, where x can be value settable from 0.05 to 1.5 Hz with a step of 0.05 Hz. While attempting to meet FTR the chosen range of FTS shall not be deviated by more than ± 0.05. Frequency control shall be at pole level. Design of Frequency control of one Pole shall be coordinated with other Pole.

4.2.6 AVOIDANCE OF SUBSYNCHRONOUS RESONANCE

The Contractor shall ensure, by carrying out all necessary studies, that the dc system will not excite the mechanical, electromechanical or other natural frequencies of the nearby Turbo-Generator sets individually or combined. The results from such studies, which shall be carried out digitally and with appropriate simulator, shall be made available to the Employer/Engineer, complete with all assumptions and representations of control equipment. The studies shall be carried out with adequate representation of both the regions within the complete range of operating parameters specified. The studies shall be completed by the Contractor to the satisfaction and approval of the Employer/Engineer. A list of required data is to be submitted by the Contractor to Employer/Engineer.

Among other things, the contractor shall demonstrate that the HVDC control systems do not excite or have negative damping over the complete range of natural frequencies of generators mentioned above. If analytical studies show that there may be problem areas under some operating conditions, the Contractor shall optimize and modify control transfer functions so as to achieve the best overall response for system stability without unwanted side effects. In designing the HVDC control system, the Contractor shall take the necessary measures to avoid the possibility of high gain high amplitude dc modulation exciting the above mentioned torsional oscillations.

The contractor shall also provide logic and any equipment necessary to detect abnormal level of SSR activity prevailing at the HVDC station and trip HVDC if required.

Should, during operation, evidence appears which is indicative of natural frequency resonances in the generators or turbines caused by hvdc system operation, it shall be incumbent upon the Contractor to remedy the situation by whatever changes or modifications are required in equipment of his supply.

The specified performance of the hvdc system controls shall be met preferably without the need for communication between the generating station controls and the dc controls at the sub-loop level. Simplicity and reliability shall always remain as design objectives.

4.2.6.1 SSR MONITORING

The settings of the sub-synchronous (SS) activity monitoring equipment is to be determined based on studies and the levels of SS activity present at site during operational experience. The monitoring equipment will be set at a level above this normal level to avoid spurious operation. Furthermore any trips caused by the operation of the SS activity detector which are due to events beyond the control of the contractor will not be counted against the contractor's reliability and availability guarantee.

SSTI protection shall be provided by the contractor in addition to SSDC controller, so that SSTI protection trips the HVDC for uncontrolled oscillations. The SSTI protection thus provided shall be independent from SSDC controller.

4.3 REACTIVE COMPENSATION

The requirements for reactive power compensation and management are defined in this section. The reactive power interchanges between the back to back converter station and the ac system shall be maintained within the limits specified herein.

The reactive power interchange levels shall be determined by measurements using metering accuracy instrumentation at the termination of 400kV AC lines with the back-to-back station on Southern and Eastern Side. The instantaneous vector sum of the 400kV ac infeeds at each converter station shall be used to determine the total converter station reactive power interchange with the ac system.

On the Eastern side it shall be measured at interconnection point of back-to-back ac bus with the existing Vizag AC Switchyard and on the Southern side it shall be measured at the termination of double circuit line. The instantaneous vector sum of the 400kV AC infeeds at each converter station shall be used to determine the total converter station reactive power interchange with the ac system.

The reactive power exchange limits with AC system shall be in line with clause 2.4.3 and on the southern side the reactive limits mentioned in clause 2.4.3 shall be exclusive of reactive power drawn by the line charging shunt reactors of double circuit line, as shown in Annexure: Vizag HVDC SLD

The Contractor shall use the existing equipment for reactive compensation and voltage control features for Control & Protection upgrade under present scope. Equipments supplied by the Contractor shall meet the existing filters specifications and shall not compromise the existing filter ratings.

In all calculations of reactive power interchange the magnetizing currents of all transformers; the reactive power consumption of auxiliary loads which could be fed from the 400 kV ac systems; the direct voltage drop and losses of converter valves; the losses of all equipments; and any other factors relevant to reactive power generation or consumption shall be taken into account. The applicable voltage and frequency at which the reactive power interchange limits are specified shall be particularly noted and respected. The calculations shall assume the most onerous values of temperatures, reactance, firing & extinction angles and other tolerances.

The existing reactive compensation equipment shall be controlled and coordinated to ensure that the hvdc system operates correctly and recovers from disturbances as specified in these specifications.

4.3.1 CONTROL AND SWITCHING

Reactive power control shall be affected by switching shunt connected linear reactive elements which may include capacitors or harmonic filter sub- banks. In addition, the converter valve groups may, if so designed and rated, be operated at increased delay or extinction angle to control reactive power interchange; however the requirements regarding transmitted power, harmonic performance, and component outage shall be met when operating in this mode.

All switching for reactive power control shall be performed on load by existing circuit breakers or load break switches.

The control of reactive power interchange shall be fully automatic and shall be continuously monitored. The control equipment, however, shall allow both automatic and operator initiated switching, in the latter case adequate annunciation shall be provided to the operator. After a switching of a reactive power element (switchable bank/sub-bank of a filter/capacitor) to meet the reactive power exchange/filtering performance, further switching of reactive power element shall not be required for DC power change of less than 5% in either direction.

The reactive power control system shall also be capable of switching reactive power elements and of controlling the reactive power absorbed by the converters (if the converters are rated for this mode of operation) in order to achieve a target reactive power interchange with the ac system within the range as described in Section 2 of this volume. The target value shall be met for all power levels between the minimum power level and the two hour overload power level for all ac system voltages between 380 kV and 420 kV and for all frequency values between ~~48.5 Hz and 50.5Hz.~~ 47.5 Hz and 51.5 Hz.

4.3.2 Switching necessary to maintain the AC bus voltage within the ranges given in clause 2.4.2 is permissible for smaller than 5% change in transmitted power. The range of 400kV bus bar voltages shall be adjusted in line with clause 2.4.2. The actual value, for power change before switching shall be verified by the Contractor during system studies.

4.3.2.1 THE REACTIVE POWER EXCHANGE AND VOLTAGE CONTROL MODES

Suitable controls shall be provided to regulate the reactive power management from the converter station during steady state and dynamic conditions. In all modes of operation the equipment and operating personnel safety shall override other control aspects. The following aspects shall be kept in view while designing the reactive power support and control of the station:

•The requirement to control overvoltage shall take precedence over harmonic performance and reactive power exchange requirement.
•The reactive power controller shall be capable of operating in automatic and manual modes. In the manual mode the controller shall provide appropriate annunciation to help the operator in deciding the switching of the filter bank / sub-bank.
•The reactive power control system shall also be capable of switching reactive power elements and of controlling static or synchronous compensators (if used) and of controlling the reactive power absorbed by the converters (if the converters are rated for this mode of operation) in order to achieve both

a)A preset and operator adjustable ac bus bar target voltage within the range 0.90 to 1.10 p.u.; or
b)A preset and operator adjustable target reactive power interchange with the ac system within the range of plus and minus 300 MVAR.

These shall be closed loop control systems and no additional equipment shall be supplied to meet the above requirements. These requirements may be viewed as target values which may be met within the capability of the available equipment in the station i.e. no additional equipment is envisaged to meet these requirements. Therefore, it is recognised that under certain operating conditions it may not be possible to actually meet the target values. However, within the available equipment the control system shall select the bank / sub-bank arrangement which will give the closest approach to the target value while maintaining adequate filtering from within the banks available for service. The control logic shall provide a facility for cyclic changeover of identical banks periodically to equalise the wear & tear of switching equipment.
The contractor shall determine the safe operating boundaries of the system while operating at the extreme of the above reactive power exchange values. The conditions to be studied and mutually agreed between the contractor and the Employer.
•It should also be possible to switch filter banks / sub-banks either manually or automatically when HVDC is not operating i.e. when converters are not energised. The equipment during this operation shall be fully protected w.r.t. overvoltage etc. through control and protective actions.

4.3.2.2 OVERVOLTAGE CONTROL

The bidder shall propose a fully automatic strategy to control overvoltages at the 400 kV buses. The overvoltage control strategy shall aim at controlling the steady state, temporary and transient overvoltages. The logic to control the overvoltages shall fully coordinate with the overvoltage control strategy adopted by the Employer in its 400 system.

While forming the strategy it may be noted that the normal operating voltage range is between 380-420 kV. As such the action of the RPC and/or overvoltage controller shall aim at normally maintaining the voltages within 380-420 kV. Switching in of filter banks / sub-banks at voltages which shall result into exceeding the above voltage range should be restricted. However, if the overvoltage is not due to the actions within HVDC the RPC should attempt at reducing the voltages when these are between 420 kV-440 kV by either using the firing angle / filter switching or both, while still having enough filters to meet the filtering performance requirements.

The employers strategy for the overvoltage control is that the tripping action for the Employer's 400 kV lines is initiated if the overvoltage exceeds 440 kV for 400kV lines for 5 seconds. The instantaneous tripping of 400 kV lines is initiated if 1.5 pu voltage persists for 100 milliseconds. The HVDC's overvoltage strategy shall be co-ordinated with this setting.

4.3.3 VOLTAGE CHANGE ON SWITCHING

AC harmonic filter sub-bank and bank switching for reactive power interchange, bus voltage, and harmonic performance control shall not result in ac bus voltage changes in excess of the limits specified below.

To meet the requirements specified the filter bank and sub-bank fundamental frequency reactive power output shall be limited. In addition the controls of the HVDC converters may be used to limit the voltage change on switching of ac harmonic filters or other reactive power compensating equipment.

The voltage change shall be expressed in percent of the voltage prior to switching and the average value of the three phase 50 Hz ac bus voltages shall be used. The voltage after switching shall be that value which exists after converter firing angles have been adjusted but before any tap changers have operated.

It is permitted to use the converter control to limit voltage change in switching provided the converters are fully capable and rated for the same.Thus if converters are used to absorb a part of reactive power generated by a filter at the time or just prior to switching the converter must be capable to continue absorbing the reactive power required to meet the requirements of voltage change on switching as specified below 4.3.3.1

The voltage change on switching requirements as defined in clause 4.3.3.1 have to be demonstrated up to the rated capacity of the pole-1&2 when any one or both the pole operates.

Further, when first, Harmonic filter is connected during deblocking, the converter control action for voltage change shall be co-ordinated with the line protection setting to prevent tripping of lines on overvoltage.

In no event shall switching on or off of a filter bank at either converter result in a commutation failure, including the switching due to a fault within a filter bank except for faults within the high voltage capacitors or other high voltage components of the filters. For faults at the high voltage section of the filters a single commutation failure may occur but the subsequent commutation failures shall be avoided. Nor shall such switching alter the dc power transmitted when operating in any identified mode of operation. The reactive power exchange limits and the harmonic performance may, however, be exceeded transiently from limits given in section 2 and clause 4.10 of this specification provided it has no other adverse effect.

In all cases self-excitation of the nearby generator(s) shall be avoided and, if filter banks or sub-banks are removed to achieve this, the system shall subsequently be capable of recovery and operation as specified.

4.3.3.1 REQUIREMENTS AT VIZAG EAST

For both the directions of power flow (In both, stand alone operation and with joint operation) the following limits shall apply for Pole 1 within the capability of existing owner's equipment.

1. For ac filter bank or sub-bank or any other switchable shunt element switching to control voltage or reactive power interchange which is required as a result of transmitted power change (in excess of five percent of rated as specified in Clause 4.3.1), the voltage change shall not exceed 5% (five percent) with the ac system short circuit level in excess of 2000 MVA at nominal bus voltage and frequency. For short circuit levels in excess of 3000 MVA voltage change shall not exceed 3.5%.

2. For ac filter bank or sub-bank or any other switchable shunt element switching due to faults which require the disconnection of the filter bank or sub-bank or any other switchable shunt element, the voltage change shall not exceed 5% (five percent) with the ac system short circuit level in excess of 3000 MVA.

   The ac system fault levels given above are the levels on the Vizag East 400kV ac busbars with the HVDC converter station isolated from the busbars along with all filter banks.

4.3.3.2 REQUIREMENTS AT VIZAG SOUTH

For both the directions of power flow (In both, standalone operation and with joint operation) the following limits shall apply for Pole 1 within the capability of existing owner's equipment.

1. For ac filter bank or sub-bank or any other switchable shunt element switching to control voltage or reactive power interchange which is required as a result of transmitted power change (in excess of five percent of rated as specified in Clause 4.3.1), the voltage change shall not exceed 5% (five percent) with the ac system short

circuit level in excess of 1500 MVA at nominal bus voltage and frequency. For short circuit levels in excess of 2300 MVA voltage change shall not exceed 3.5%.

2. For ac filter bank or sub-bank or any other switchable shunt element switching due to faults which require the disconnection of the filter bank or sub-bank or any other switchable shunt element, the voltage change shall not exceed 5% (five percent) with the ac system short circuit level in excess of 2300 MVA.

The ac system fault levels given above are the levels on the Vizag south 400kV ac busbars with the HVDC converter station isolated from the busbars along with all filter banks.

4.4 INSULATION COORDINATION

The Contractor shall replace existing surge arrestor with latest design of surge arrestor Valve equipments from dc, fundamental frequency, harmonic, ferro-resonant, switching surge and lightning impulse, Steep front over voltages under all steady state, dynamic and transient conditions.

The Contractor shall satisfy the Employer/Engineer that the insulation of all equipment supplied within the station is properly protected and coordinated in accordance with the Contractor's normal practice and with the specific requirements detailed herein. The insulation coordination shall be designed for all transmitted power, as specified in Clause 4.1 of this Section.

Arcing horns etc. shall not be used for the protection of equipment from overvoltages.

The Contractor shall perform all necessary studies and shall submit a detailed report on insulation coordination covering all-important parameters according to IEC 60071-5to the Employer/Engineer. The contractor shall not finalize the design of any equipment which might be affected by changes in protective levels until the report has been approved by the Employer/Engineer.

The report shall detail the characteristics of the surge arresters and shall demonstrate that the selected insulation protective and withstand levels, discharge and coordinating currents, and arrester ratings and discharge capabilities are adequate and comply with the requirements of this specification. It shall also detail all insulation and air clearances and leakage distances and shall justify the selected values.

The report shall detail the limits of all equipment parameters which could affect the insulation coordination. If, at any time, any relevant parameter of equipment supplied by the Contractor is altered, the Contractor shall resubmit the report.

If, on testing, it is found that any parameter is outside the limits established then the Employer shall have the right to reject the equipment subject to the provisions in the General Conditions.

4.4.1 GENERAL REQUIREMENTS

Prevention of any excessive voltage being applied across any insulation shall be primarily by limitation of the over-voltage by circuit design and equipment parameter selection. Surge arresters, built in accordance with the requirements of the relevant clause in Section 6 of this Specification, shall be provided to ensure that surge voltages are limited to the design levels of all equipment.

Arcing horns etc. shall not be used for protection of equipment from overvoltages.

4.4.1.1 LIMITATION OF OVERVOLTAGES

Blocking of the converter valves to protect them and other dc side equipment from sustained overvoltages appearing on the ac system shall not be permitted and the back-to-back hvdc station equipment supplied shall be adequately rated to allow both continued operation and deblocking under the maximum overvoltage conditions including the dynamic overvoltage and any ferro-resonant overvoltages which may be present.

The use of converter valve group controls to limit temporary (dynamic) overvoltages shall be permitted provided that the valves and other converter equipment are adequately rated and that the Contractor shall demonstrate, to the satisfaction of the Employer/Engineer, that such action is both effective and reliable.

The restriction of temporary overvoltage by switching off of ac filters or shunts capacitors or by switching on of shunt reactors shall only be permitted if the Contractor demonstrates, to the satisfaction of the Employer/Engineer, that subsequent recovery and operation of the converter equipment is not thereby restricted.

Should, due to unforeseen contingencies or circumstances, the temporary overvoltage exceed that calculated based on the requirements of this Clause, including the margin given in Clause 4.4.3 and the system impedance definitions given in Clause 4.4.3.1, the equipment shall be protected. The Contractor shall provide all necessary detection, logic, and control equipment required to protect the equipment in this event.

4.4.1.2 SPECIAL COORDINATION REQUIREMENTS

The Contractor shall take into account the possible ac line discharge energy which could be present in the back-to-back hvdc station arresters. In addition the Contractor shall ensure that the discharge duty of the Employer's arresters is not increased due to infeed from the back-to-back hvdc station.

The Contractor shall coordinate the ac filter bank surge arrester characteristics so that these arresters will discharge the energy in the ac filter and shunt capacitors (if used) and will prevent the capacitors from being charged to a level which can not be discharged by other arresters connected to the 400 kV ac system.

In general insulation coordination design of Pole-1 shall be coordinated with existing Pole-2 such that none of the equipments are stressed during operation. Also simultaneous tripping of both poles shall be considered for transient and temporary overvoltages.

4.4.2 DEFINITIONS

For the purposes of insulation coordination, the following definitions are used in this clause.
It should be noted that standard test voltage wave forms shall be used by the Contractor to test equipment.

4.4.2.1 DC VOLTAGE

The dc voltage is the crest value of any unidirectional voltage ignoring commutation overshoot or transient spikes of less than 1 ms duration. Valve winding to ground voltages are to be considered as dc voltages.
Steady state dc voltages are defined as voltages which can exist for a period in excess of 5 seconds.
Temporary dc voltages are defined as voltages which can exist for a period in excess of 60 ms.

4.4.2.2 50 HZ VOLTAGE

The 50 Hz or fundamental frequency voltage is defined as excluding harmonics, resonant and ferro-resonant effects which can cause distortion of the fundamental frequency wave form.
Steady state 50 Hz voltages are defined as voltages which can exist for more than 5 seconds.
Temporary 50 Hz voltages are defined as voltages which can exist for more than 3 cycles.
Temporary 50 Hz voltages may also be referred to as dynamic overvoltages.
Transient voltages - less than 3 cycles.

4.4.2.3 SWITCHING IMPULSE VOLTAGES

Switching impulse voltages are defined as transient voltages which may be superimposed on either dc or 50 Hz voltages which, for the purpose of defining which wave forms occurring in practice shall be tested for or treated as switching impulses, have a rise time to crest in excess of 20 microseconds and which may be assumed to have decayed to zero within 10 ms.

4.4.2.4 LIGHTNING IMPULSE VOLTAGES

Lightning impulse voltages are defined as transient voltages which may be superimposed on either dc or 50 Hz voltages which have a rise time to crest of less than 20 microseconds and which may be assumed to have decayed to zero within 0.1 ms. Lightning impulse voltages are not caused only by lightning.

4.4.3 DETERMINATION OF OVERVOLTAGES

The Contractor shall determine the highest transient and temporary overvoltages which can occur with the equipment parameters selected and with the ac system as defined in this specification.

The Contractor shall also allow for single phase to ground and three phase to ground faults on the ac system, generator(s) tripping, and control system malfunctions.

The Contractor shall design the convertor equipment to withstand a maximum continuous system voltage of 440 kV. Calculations for determination of arrester energy requirements should be based on a maximum prefault voltage of 440 kV and in order to introduce a safety margin, a 15% increase in the arrester energy shall be designed for.

4.4.3.1 TEMPORARY OVERVOLTAGES

a) Limitation
The Contractor shall provide all equipment necessary to limit the temporary 50 Hz voltages as defined in Clause 4.4.2.2 above on the 400 kV busbars.

- 490 kV crest phase to ground;
  and
- 850 kV crest phase to phase.

In addition, to prevent operation and overstressing of the Employer's arresters, the Contractor shall limit the temporary over voltages, including harmonic, resonant, and ferro - resonant effects on the 400 kV ac busbars so that:

- 675 kV crest phase to ground is not exceeded by more than three peaks;
- 565 kV crest phase to ground is not exceeded for more than ten cycles;
- 510 kV crest phase to ground is not exceeded for more than twenty cycles.

In the calculation of temporary overvoltages the Contractor shall allow for blocking of valve groups from any power level up to the full transmission capability corresponding to the relevant system conditions and for the maximum load rejection which could occur and leave one or both valve group deblocked. The connected ac harmonic filters and shunt capacitors shall be assumed to be that with the highest MVAr applicable to the mode of operation.

For the purposes of calculation of temporary overvoltages the data is given in Section 2 of this Volume for transmitted powers up to the two hour overload rating of the converters. The contractor shall also allow for single phase to ground faults with line tripping, three phase to ground with line tripping, dc side faults, generator/transformer/filter tripping and control system malfunctions etc. while evolving the overvoltages.

b) Equipment Design

The converter equipment shall be designed for temporary overvoltages which are not less than 1.5 times 420 kV on both Southern & Eastern sides of 400 kV ac busbars with converters blocked and also for deblocking from this condition. The converter equipment shall be designed for temporary overvoltages which are not less than 1.2 times the ac system pre disturbance voltage (which can be up to 440 kV) for not less than 5 seconds following de blocking with the converters deblocked. The Contractor shall undertake to confirm during final design studies that the temporary overvoltage factor of 1.2 is adequate and if not to adjust design accordingly at his own cost.

4.4.3.2 TRANSIENT OVERVOLTAGES

In the calculation of transient overvoltages the Contractor shall consider at least:

a) Lightning surges propagating down the ac overhead lines, including direct strikes to line conductors;
b) Lightning surges due to direct strikes within the converter station in the event of shielding failure;
c) Steep fronted waves resulting from flashovers or faults, including those within the valve hall and to ground from the valve windings of the converter transformers;
d) Over voltages due to switching of converter transformers, ac filters and shunt capacitors, shunt reactors, 400 kV and 400 kV or other equipment; for reclosure of ac filters and capacitor banks, residual voltage on the capacitors shall be taken into account. The saturation effects of converter Transformer due to presence of remanent flux shall be taken into account.
e) Overvoltages due to fault initiation and clearing of single phase and three phase to ground faults which may be cleared by ac circuit breakers; Possibilities of breaker restrikes shall also be considered although the breaker should be designed as restrike free.
f) Faults within converter equipment, including control malfunctions;
g) Over voltages due to blocking of one and two 500MW 12-Pulse valve groups;
h) uneven distribution of over voltages, particularly within the converter valves;
i) commutation overshoot, particularly when operating at higher than normal firing or extinction angles; coupled with dynamic overvoltage conditions;
j) arrester location relative to protected equipment and arrester characteristics.
k) Lightning surge transfer due to high transformer ratio should be verified as per IEC 60071-5

4.4.3.3 ARRESTER PROTECTIVE LEVELS

The transient overvoltages imposed across insulation shall be limited by surge arresters. Dynamic overvoltages may also be limited by the surge arresters but only if the arresters are adequately rated for such duty.

The Contractor shall carry out DC simulator and/or computer studies to satisfy the Employer/Engineer that both the chosen insulation levels and the selected arrester ratings, protective levels, discharge currents, discharge capabilities and expected frequency of discharge operation, charge transfer, absorbed energy and thermal energy are adequate. The basis for determination of insulation withstand levels, arrester locations and arrester protective and durability characteristics shall include, but not be limited to, all the overvoltages conditions described in Clause 4.4.3.1 and 4.4.3.2.

The front of wave, lightning impulse, and switching impulse protective levels of the arresters shall be based upon the highest voltages which can appear across the arrester, or combination of arresters where appropriate, when the highest practical discharge currents are flowing in the arresters.
The discharge current (coordinating current) shall be determined by the Contractor appropriate to the arrester location and line and equipment parameters. The 8/20 microsecond wave coordinating discharge current shall be 10 KA, 15 KA or 20 KA as applicable.

The arrester protective levels shall allow for the possibility of flashovers which could cause high discharge currents in lower rated arrester and, particularly within the valve groups, unequal sharing of voltage between arresters connected in series. Where multi-column arresters are used or arresters are connected in parallel, unequal sharing of the discharge current shall be taken into account.

The arrester shall be capable of discharging without damage the charge and energy appropriate to the arrester point of connection during any credible operating, dynamic or transient overvoltage conditions and in particular, the arrester across the valves or valve group shall be capable of discharging the associated terminal equipment charged to the maximum voltage resulting from conditions above, with consequent flashover to ground of the upper transformer valve winding terminal.

For the purpose of arrestor energy rating it shall be noted the line auto reclose sequence consists of one reclosure before lock out.

4.4.4 SELECTION OF INSULATION LEVEL

The front of wave (FWWL), lightning impulse (LIWL), and switching impulse (SIWL) withstand levels shall be determined from the protective levels afforded by the surge arresters to the location being considered. All the equipment supplied in the back to back converter station shall be tested for all the above withstand levels.

The requirements for insulation levels of the converter valves are specified in Clause 6.1.4 of this Volume.

4.4.4.1 AC SIDE EQUIPMENT

All equipment connected to the 400 kV ac bus, including insulators and air clearances shall have

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

In addition to the above basic requirement, the SIWL shall, in any case, not be below 1050 kV for all equipment except for bus post insulators where the SIWL shall not be less than 1175 kV. The LIWL for circuit breakers, bushings and other equipment shall not be below 1425 kV except for bus post insulators where the LIWL shall not be less than 1550 kV and the LIWL for the internal insulation of transformers and reactors shall not be below 1300 kV.

The ac filter capacitors, and shunt capacitors or capacitors associated with static compensators (if used), shall have a switching impulse margin 5% higher than specified above, i.e. not less than 1.20 times for SIWL, but retaining 1.25 times for LIWL and FWWL.

The ac filter reactors and resistors (if air insulated) and any VTs or PTs within the filter shall have increased margins of not less than 1.30 times protective level for LIWL and FWWL, and of not less than 1.20 times protective level for SIWL.

4.4.4.2 OIL INSULATED EQUIPMENT

For all equipment with oil insulation and with arresters connected within 5 m of the terminals, the LIWL shall be an IEC standard value. This value shall not, for the internal insulation, be less than:

a) 1.40 times the switching impulse protective level;

b) 1.20 times the lightning impulse protective level;

c) 1300 kV for equipment connected to the 400 kV ac bus.

The SIWL shall not be less than 0.83 times the LIWL as determined above, nor below 1050 kV for equipments connected to the 400 kV ac bus.
The FWWL shall not be less than 1.20 times the front of wave protective level.

4.4.4.3 DC SIDE EQUIPMENT

The dc side air clearances, insulators, equipment, dc filter components, etc., shall have

a) a SIWL at least 1.20 times the switching impulse protective level ;
b) a LIWL at least 1.25 times the lightning impulse protective level ;
c) A FWWL at least 1.25 time the front of wave protective level ;

4.4.5 AIR CLEARANCES

The air clearances shall be determined by the Contractor based on the required withstand levels for all wave forms from dc to front of wave in order to limit the probability of a flash over within the valve hall to one flashover in 20 years and one flashover in 10 years on the AC side.

4.4.5.1 AC SWITCHYARD

The air clearances shall be equal to or greater than the minimum values used by the Employer for equipment with the same withstand level.

Within the ac switchyard the air clearances for 400 kV ac connected equipment, shall not, be less than:

Phase to ground:	3.5 m
Phase to phase:	4.0 m
Section Clearance:	6.5 m

For equipment or insulation where a SIWL or LIWL other than 1050 kV or 1425 kV respectively is applicable the minimum air clearances shall not be less than those given in IEC 60071-2. The relevant Indian Electricity Rules shall also be considered.

4.4.5.2 DC SWITCHYARD

For equipment or insulation within the dc switchyard the minimum air clearances shall be determined in line with IEC 60071-5. The correction factors for site altitudes above mean sea level shall be applied as applicable.

Outdoor bushings shall have a flash distance of not less than 12mm per KV for vertical Bushings and 10.5 mm/kV for horizontal Bushing of applied steady state DC voltage as defined in Clause 4.4.2.1 where the flash distance is the shortest distance between the bushing cap and the nearest ground plane.

4.4.6 LEAKAGE DISTANCES

The leakage distance across the insulation shall be determined by the Contractor and shall be adequate to ensure that the probability of flashover due to failure to withstand the applied steady state voltage shall not exceed one flashover in 75,000 hours of operation on the ac side or one flashover in 150,000 hours on the dc side.The specified probability for flashover shall be considered on per insulator basis only.

4.4.6.1 AC EQUIPMENT

The leakage distance for all ac insulators & bushings shall not be less than 43 mm per kV of the maximum normal operating phase to ground voltage at the insulator. The maximum normal operating voltage is defined as the

crest value of the voltage, including voltage distortion effects divided by the square root of 2.
For equipment connected to the 400 kV ac bus the leakage distance shall not be less than 10500 mm.

4.4.6.2 DC EQUIPMENT

For all insulators and bushings which are subject to direct voltage stress, including converter transformer valve winding bushings and valve winding insulators and wall bushings, the average value of the voltage as defined in Clause 4.4.2.1 shall be used to define the minimum leakage distance.

The base voltage applicable for calculation of valve arrester creepage distance shall be

$$U_{creepage} = \left(\sqrt{\frac{1}{3} + \frac{\sqrt{3}}{8\pi}}\right) * CCOV$$

The specific creepage distance for valve arresters shall be 14 mm/kVrms.

The minimum leakage distance (excluding tolerances) shall not be less than

Insulator Type	Rectifiers	Inverters
RTV coated Porcelain insulator (only for DC disconnectors and DC neutral and DC Filter insulators of BIL up to 650kV)	50 mm/kV	50 mm/kV
Outdoor Silicone rubber insulators and bushings *	50 mm/kV*	50 mm/kV*
Porcelain insulator (only for DC neutral and DC Filter insulators of BIL up to 650kV)	60 mm/kV	60 mm/kV
Indoor composite for valve hall	20 mm/kV	20mm/kV

* Leakage distances less than 50 mm/kV shall be acceptable for:

- Outdoor silicone rubber bushings due to manufacturing limitations and
- HVDC equipment's requiring necessary internal/external insulation co-ordination.
- Necessary justification for leakage distance less than 50mm/kV shall be furnished during detailed engineering subject to the approval of the employer. However, leakage distance of less than 45mm/kV shall not be

acceptable and all equipment support insulators including BPIs shall have a leakage distance of not less than 50 mm/kV.

Leakage distance less than 50 mm/ kV and flash distance less than 12 mm/ kV shall not be acceptable for outdoor jointed bushing.

Outdoor bushings shall be only of Silicone rubber type. The requirement of 20 mm/kV within the valve hall applies to all Silicone rubber insulators and bushings external to the valve, the definition of valve being as given in IEC 60700-1.

4.5 HVDC CONTROLS AND PROTECTION SYSTEM

4.5.1 GENERAL

The control and protection system supplied for HVDC station shall be based on the most modern and proven, microprocessor-based technology available in the market. Control of the Station shall be organized into a hierarchy of control systems and locations in a logical manner. The Contractor shall also provide the equipment necessary for the control, protection and interlocking of all the equipment's within his scope of supply as well as for

a) 400kV Bus bars on Southern & Eastern grid feeding HVDC stations.

b) 400KV AC system (associated with HVDC) sub-station automation

The Contractor shall be responsible for complete coordination of controls, protections, interlocking and switching sequences within the station as well as for the system (including HVDC associated 400kV AC system) as a whole.

Both HVDC poles (Pole under present scope and existing pole i.e. Pole-2) shall operate as a combined system with integrated and coordinated functions.

The control and protection equipment shall satisfy the reliability and availability requirements specified in the relevant section.

Only numerical based protection system shall be supplied for HVDC and associated AC switchyard.

All protection settings shall be properly coordinated with the discharge currents of arrestors and capacitors located in the various zones for all operating modes.

The Contractor shall design his equipment to operate in the environment of an HVDC system. In particular, all necessary measures shall be taken to ensure satisfactory operation under the worst case of harmonic currents and voltages present in the stations/ system, noise & radio interference generated by the back to back converter station.

The equipment shall be designed to operate with the environmental conditions as specified in Section 2. The control and protection system shall satisfy the general technical requirements specified in Section 3.

The requirements specified herein shall be considered as the minimal requirements. The Contractor shall provide any other protective features required/ deemed necessary by him for the equipment within his scope of supply.

Contractor shall be responsible to carry out AC breaker TRV studies to prove that the TRV requirements of the filter breaker (Sub-bank/Bank) and converter breakers with the proposed control strategy of the contractor are within the TRV capability of the installed breakers at site.

Wherever necessary, the contractor shall use the new CVT/CVD as supplied by the contractor based on TS requirement 1.2.vi of this specification for the purpose of control and protection.

Any extra cabling needed for satisfaction of technical requirements of the project shall be in the contractor's scope.

4.5.2 CONTROL SYSTEMS

4.5.2.1 GENERAL CONTROL CONCEPTS

The concepts of the Control systems shall be based on the following:

a) Wherever feasible, the controls are to be broken down to control the smallest practicable unit or block of power.

b) Transient and dynamic damping controls shall be provided.

c) Frequency controls shall be provided.

d)Facilities for the input of an external load frequency control (LFC) power order signal shall be provided.

e) Additional controls required by the Contractor to meet the functional objectives or any other control related objectives in this Specification shall be provided.

f) The converter controls shall maintain the power flow at the value ordered by the operator either on the station hvdc control panels which shall have facility to control the pole-1&2 directly or from some external LFC signal. The rectifier controls shall normally control the transmitted DC current and the inverter controls shall regulate the DC voltage. Inverter current control shall be provided to maintain stable transmission during disturbances. Any additional modes of control shown to be required shall also be provided.

g)The converter controls shall ensure that the hvdc system does not continuously overload ac system by limiting effective power order or compensating the ordered power to a value which stabilizes the ac systems within the steady state frequency criteria

h) The converter controls shall utilize the fast control action possible with hvdc system to suitably stabilize the ac system by rapidly increasing or decreasing the power flow transiently above or below the ordered value in response to ac system stabilizing control signals. The Contractor shall provide suitable stabilizing signals for this purpose. Such signals shall have no steady state effect, i.e. the stabilizing signal shall decrease to zero in the steady state. Full use of the available short- time overload capability in the converters shall be made for purpose of ac system stabilization.

The controls shall be stable under all steady state and dynamic conditions. Particular attention shall be paid to operation under severe transient load generation imbalance leading to large change in the frequency deviations occuring at the maximum rate accompanied with distortions in the voltage wave forms due to detuning of ac harmonic filters and faults.

The controls shall automatically makeup for power flow reductions in any converter group below the ordered value, due to sudden loss of capability, by increasing power in the other converter group within its overload capability.

i) The controls shall ensure that power transmission is maintained at the last ordered value in the event that the power order signal is lost for any reason.

j) All the converter controls shall be designed to accept signals provided to control the power flow due to:

i) Changes in power in response to system load (LFC input signals).
ii)Changes in generator capability or sending end frequency.
iii)Changes in receiving end frequency.
iv)Six Additional unspecified inputs.

k) The controls shall provide for power flow in either direction.
l) The controls shall ensure smooth transition without any ac or dc system disturbance when transferring from any one operating mode to another operating mode.
m) The power setting shall be adjustable anywhere from minimum to the maximum operating limits with a linear rate which shall be adjustable between 1 MW per minute and 600 MW per minute. The minimum step size shall be 1 MW.

i. The control shall provide the facility to utilise the available & possible continuous & short time overload capacity, as defined in clause 4.1.3 on an integral basis on prevailing ambient condition & available coolers & heat exchangers. Information to this effect shall also be made available (displayed) to the operator.
ii. The controls shall be designed to utilise the full overload capability of the Pole-1&2 for extended durations as defined in clause 4.1.3.3. Information shall also be made available to the operator indicating the remaining power x time area (power time product) available for overloading.

n) Power shall be allowed to be transmitted under conditions of loss of part of the ac filters and/or of the specified frequency deviations. All measures necessary to prevent instability caused by distortion in the ac waveform or by magnification of harmonics in the ac voltage waveform shall be provided. The HVDC control system shall minimise adverse impact, if any, on ac side on energising the converter.

o) The controls shall provide a high speed of response and accurate, stable and drift-free operation over the complete range of operation, and simultaneously ensuring that the HVDC is not feeding power into the generators.

p)The controls shall minimize reactive power requirements under steady state operating conditions consistent with the requirements to permit proper firing of converter valves and maintain successful commutation.

q)The controls shall minimize generation of non-characteristic and characteristic harmonics, prevent harmonic instability and adverse interaction with control system in the connected ac system including those from nearby converters, generator excitation systems, SVC's etc. The controls shall limit and protect against any over voltage situation arising due to resonance phenomenon of AC lines.

r)The controls shall maintain power transmission under conditions of reduced sending end ac voltages with smooth transition between different converter control modes. Should power transmission capability be reduced by an amount equivalent to the margin value, then this shall be compensated for in the controls in order to restore full transmission capability.

s)The controls shall be utilized both to limit fault current and to assist in smooth and rapid recovery from ac system faults.

t)The controls shall provide protective limits including low voltage and current limits to protect the hvdc converter equipment.

u)The controls shall be provided with redundancy in the critical control elements (e.g. current order control loop, etc.) and in the protection systems to ensure continuous operation of safe and orderly shut-down of equipment as appropriate to the fault condition. Back up protection shall also be provided for the event of failure of the main protection.

v)The controls shall be coordinated with hvdc converter equipment protection. w)The contractor shall choose appropriate commutation margin angle to minimise probability of commutation failures. AC system faults, which may transiently dip AC voltage on any one or more phases up to 15% shall not cause repetitive commutation failures(one commutation failure may occur) for the operating conditions defined in this specification. The control systems shall prevent occurrence of commutation failures during switching of equipment within the converter station and switching of lines terminating at the converter station.

x)The controls shall incorporate any other special features based on the Contractor's research and development work and experience that may be of significant benefit to the overall control and protection of the hvdc back-to-back link system.

y)Redundancy shall be provided in hvdc station controls and Pole level controls e.g. station control, reactive power control, pole control, valve control, VBE and valve cooling control etc. At a time one of the duplicated control systems shall be active and other in hot standby mode with automatic/ manual changeover selection facility shall be provided. Faulty measuring system or problems related to the control card/s

in one control and protection system shall not cause outage of the HVDC converter and shall disable the faulty control system.
Control shall be provided with supervisory functions at each level .Further, supervisory function should ensure that sudden loss of input signal shall not lead to immediate tripping of either pole.

Contractor shall carry out study to assess suitable operating mode of Vizag HVDC when machines from generating station are connected in islanded mode as well as radial mode to Vizag Bus (Eastern and Southern side).

The necessary controls/operating restrictions based on the study for above operating scenarios shall be decided during detailed engineering. Contractor shall also note that existing system does not have a smoothing reactor. Hence, all control systems proposed in this refurbishment scope shall consider this aspect for the purpose of control system design, as applicable.

4.5.3 DETAILED REQUIREMENTS FOR CONVERTER CONTROLS AND PROTECTION SYSTEM

4.5.3.1 GENERAL

Control and protection systems shall be fully tested in accordance with the requirements in Section 9 prior to shipping. The factory system Test (FST) of Control and protection systems shall be carried out in India. Also the contractor is required to have a replica of the project for testing purpose in their lab to carry out dynamic performance and high level controllers testing. Hence, the delivery of project cubicles to site shall be independent of testing and tuning of higher levels controls, So that project schedule is not affected.
The real time simulator for such simulations to be done in FST shall have a minimum time step of 50 microsec, so that all dynamics are covered in these real time simulations.

The Contractor shall demonstrate to the satisfaction of the Employer that the design of the control and protection systems shall fully meet the requirements of the Specification. The demonstration shall be carried out at the end of the design phase, but before the design is frozen, on a simulator having a system representation approved by the Employer.

The control and protection system shall be only numerical and microprocessor based technology with modular construction for HVDC and HVAC systems.

All changes related to adjusting the minimum alpha in the rectifiers and minimum gamma in the inverter, gain settings of various control loops, time constants etc., to the extent of redesigning and implementing a particular control function resulting in modified control characteristics and control loop response, shall be possible by making necessary software changes at any phase of testing, commissioning or during operation. Independent and separate adjustments of parameters for each control loop shall be possible.

The Contractor shall determine and specify the limiting values of gain and time constants for the critical system based control functions e.g., frequency controller, damping controller, current controller, margin angle controller etc., which should not be violated in order to maintain sufficient stability margins for the individual control loops and the overall control loop for the network configuration as used during design and optimization of the control system.

Where applicable, the final gain settings determined during commissioning shall operate within 60% to 80% of the settings range for each gain adjustment. If necessary, the Contractor shall revise the control circuitry to achieve this result. The margin current input to the inverter end converter controls shall not exceed 10% of the rated Pole full load current.

The Contractor shall provide all circuits and interfaces necessary for deblock/ block (and connect/ isolate) of 12 pulse back-to-back valve group for start-up. Deblock/ block (and connect/ isolate) sequences for Blocks shall ensure that the equipment is brought into/ out of service smoothly and with minimal disturbance to the other valve groups.

The Contractor shall provide a means of selecting either manual or automatic tap changer control via the control switches on the control board or through the functional keyboard / mouse. Tap changer discrepancy alarms shall also be provided
When a microcomputer based control system is adopted the potentiometer for control parameter setting need not necessarily be put to use.

The tap position of the converter transformers shall be integrated to new control system. The integration details of converter transformer tap with existing control system is attached in Annexure-Transformer Tap Interface

The protection panel details of the existing system is as per Annexure- Panel layout existing station.

4.5.3.2 TEST FACILITIES

The Contractor shall provide test facility and test equipments as required to enable safe and comprehensive testing of the complete control and protection system, including control loops and sequences, either overall or element by element, without having to disable numerous interlocks and without the danger of affecting the power flow.
Provision of monitoring points and other facilities within the control or protection cubicles for easiness of testing shall as far as possible not involve shorting of the main CT secondary circuits feeding any of the protections. However if shorting of CT secondary within the control/ protection cubicles is unavoidable for example testing of protections while the HVDC system is in service then such shorting shall be made possible only by means of insertion of test jacks or special test plugs or test switch into sockets intended for such use.

These special test plugs and sockets shall be of such design that when the test plug is inserted it first shorts the CT secondaries before opening the protection circuits. When the protection circuits are fully opened, their leads shall be accessible for injection of current signals for test purposes. Similarly when the test plug is withdrawn, it shall first complete the CT secondary connection to the protection before removing the direct short of CT secondaries.The test plugs shall be interlocked so that the input and output signals of the system being tested shall not affect the running block. The location of the test plug preventing energisation shall be annunciated to the operator.

4.5.3.3 AC Busbar Protection

The Busbar protection scheme shall incorporate low impedance differential relays. The relays shall be numerical type with modular construction.

The zone of protection for the Bus bar protection shall be as per Annexure Vizag HVDC SLD for Busbar protection.

The Busbar protection shall have two sets of independent measuring schemes (i.e. main and check feature) and both must operate simultaneously to initiate tripping.

Automatic and continuous supervision shall be provided to give warning of the out of balance current having reached an undesirable value and, in such cases, a secondary short circuit may be applied to protect the relaying system, if necessary. Alarm shall be generated in such an eventuality enabling the operator to take further necessary action.

The Busbar protection shall be designed to avoid unnecessary tripping due to any CT mismatch between converter station CT's and others 400 kV CT's.

The bus-bar protection scheme shall:

(a) have a measuring relay with a maximum operating time up to trip impulse to trip relay for all types of faults of 10 milliseconds at 5 times setting value
(b)Operate selectively for each zone of bus bars
(c) Give hundred percent securities
(d)Incorporate separate check zone feature relay
(e) Incorporate continuous supervision for CT secondaries against any possible open circuit and if it occurs shall render the relevant zone of protection inoperative. Zonal protection contact shall be bypassed automatically and the affected zone shall be protected by check zone only or vice-versa
(f) Not give false operation during normal load flow in bus bars
(g)Incorporate clear zone indication
(h) have three (3) single phase measuring elements and provide three zones of protection for breaker and a half schemes and four zones for two main and transfer scheme out of which one zone shall be for each bus and one check zone.
(i) Include individual high speed tripping relay (operating time not to exceed 10 milliseconds) , with 6 pairs of hand reset contacts, for each 400 kV circuit breaker in addition to the required auxiliary alarm contacts.
(j) Be transient free in operation.
(k) Include continuous dc supply supervision.
(l) include protection in/out switch for each zone with all necessary contacts for each switch including switch status output contacts.
(m) Shall allow the use of different CT ratios for the different feeders
For further information Annexure: Control, Relay and Protection Panels to be referred
Any extra cabling needed to implement this protection shall be in the contractor's scope.

4.5.3.4 AC Breaker Failure Protection

- AC breaker failure protection shall be provided for all circuit breakers. The breaker failure protection shall result in tripping of the "next-in-line" HVAC breakers in the station/nearby Employer's yard. In cases where there are no back-up breakers that can be tripped, a trip signal shall be provided for tripping the relevant remote breaker.

- The scheme shall include a breaker failure initiating relay (BF) associated with each protective relay system viz. bus-bar, differential etc. a breaker failure relay (50 BFR) which measures the current flowing through the breaker being protected against failure, a breaker failure time delay relay (62 BF) and the breaker failure lockout relay (86 BF). The operation of both relays BF and 50 BFR shall initiate timer 62 BF which in turn shall operate 86 BF. 86 BF shall trip all breakers adjacent to the failed breaker.

- The relay BF shall:

  - be single pole type
  - have an operating time less than 15 milliseconds
  - have a resetting time less than 15 milliseconds
  - The breaker failure relay 50 BFR shall:
  - have three single phase measuring elements
  - have an operating time of less than 15 milliseconds
  - have a resetting time of less than 15 milliseconds
  - have two measuring element for phase fault and one measuring element for earth fault measurement
  - be of numerical type
  - have a setting range of 20-320% of rated current for phase over current and 20- 80% for ground over current
  - have a continuous thermal withstand of two times rated current irrespective of the setting adopted
  - have separate timer

- The timer 62 BF shall:

  - be suitable for 220V DC supply
  - have a continuously adjustable setting range of 0.05 to 0.5 sec on pick up

- The high speeds tripping (86) relay shall:

  - be instantaneous with operating time not to exceed 10 milliseconds & reset within 20 milliseconds
  - have the number of contacts required for the protective scheme and alarm / annunciation functions plus two pairs of NO, NC potential free spare contacts for future use; contact resetting shall be preferably by pushbutton. Electrical or mechanical reset is acceptable
  - have necessary supervisory relays

- be dc operated
- be provided with operation indicators for each element/ coil

- The flag relays shall:

  - be hand reset auxiliary relays with flag indication
  - have six elements
  - have a minimum of three NO and three NC contacts or combination contacts (NO & NC) as required for each element

The Bidder shall provide all equipment to meet the above requirements and make the scheme fully comprehensive.

For further information Annexure: Control, Relay and Protection Panels to be refered

4.5.3.5 Pole Discrepancy Protection for Breakers

All the existing 400 kV . breakers are provided with suitable protection to guard against operation with phase/pole discrepancy. Upon closing or tripping of a breaker if there is a time delay between making/opening of the breaker contacts in the different phases, beyond acceptable limits, determined by the Bidder, then the breaker shall be tripped. In case of the breaker failing to trip the next in line breaker shall be tripped automatically.

4.5.3.6 Trip Circuit Supervision Relays

The trip circuits leading to all h.v. breakers shall be continuously monitored for their healthiness and in case of an open circuit/short anywhere in the trip path an alarm shall be generated and the trip circuits disabled.

For further information Annexure: Control, Relay and Protection Panels to be referred

4.5.3.7 AC Filter Protection

Not Used

4.5.4 CONTROL CIRCUITS AND PROTECTION SYSTEMS

4.5.4.1 GENERAL

The Contractor shall provide the equipments necessary including ZFCT, as per scope in Section 1.2, for the purpose of controls, protections of all the equipment in the scope of the contractor. The entire control, monitoring, metering, recording, annunciation etc. for the complete system associated with pole-1 and existing pole-2 shall be carried out by the contractor from the control room.

The Contractor shall provide adequate protection to ensure that all converter equipment is fully protected, and shall ensure that protection is properly coordinated with interconnecting AC system and between HVDC Pole-1& existing Pole-2 systems.

The Contractor shall further be responsible for coordination and integration of controls, protections, interlocking schemes and switching sequences of the entire station including the existing equipments.
The Contractor's scope shall also include a common Control operator desk to control, monitor & operate entire system from control room
The control equipment shall satisfy the reliability and availability requirements specified in Chapter 11.

The Contractor shall design his equipment to operate in the environment of an hvdc station. In particular, all necessary measures shall be taken to ensure satisfactory operation under the worst case of harmonic current and voltage being present in the station and noise and radio interference generated by the converter station. The equipment shall be designed to operate in the environmental conditions specified in Section 2 of this Specification.

The control and protection system shall satisfy the general technical requirements specified in Section 3.

Only static, numerical and micro processor based control and protection systems with modular construction for 400 kV AC and HVDC system shall be used.

Complete sub-station automation system based on IEC 61850 including hardware and software for remote control station along with associated equipment's for 400kV Bays, Lines, Reactors,Filter sub-banks, converter transformers and other equipment as shown in Annexure Vizag HVDC SLD shall be provided by the contractor in this project scope. The equipment required for remote control station shall be supplied at the Substation to be identified during detailed engineering. Detailed technical specification of this sub-station automation systems are found in Annexure Sub-station Automation System.

4.5.5 PROTECTION SYSTEMS

The requirements specified herein are the minimum. The Contractor shall be responsible for defining the actual protection requirements & schemes for the HVDC system and associated AC switchyard.

All the protective devices shall be capable of responding correctly to all types of internal or external faults even in the presence of the harmonic currents produced by the converters and during system frequency excursions.

Clear indication of the operation of each one of the protections shall be obtained in the Control Room.

Main protection (including redundancy) shall be provided to ensure safe shutdown of equipment. Back-up protection shall also be provided to protect equipment in the event of main protection failure.Whenever, integrated control and protection systems are provided, utmost care shall be taken in the design to ensure that the system

meet high reliability and availability as required for HVDC stations and associated AC system.
The protection equipment shall be designed to be fail-safe and shall ensure high security, so as to prevent unnecessary shutdowns or outage due to protection equipment failures etc. This shall be achieved by organising all the protections covered in this clause or elsewhere in the technical specification, into two systems A & B, where both systems are active or the vendor shall implement suitable checks before tripping in order to ensure highest stability against false trips. Each of the systems shall include the main and back up protections specified. Systems A & B shall be identical in all respect and both systems A&B shall be physically, electrically and operationally independent from each other and shall be placed in separate panels/cubciles, such that the proper operation of each system shall not be compromised in any respect by the shut down of the other system. Generally the main and back-up protections shall utilize different principles. Where utilization of different principles is not possible, backup protections utilising similar principle shall be employed.

All protection trips due to equipment failure shall result in a lockout trip- requiring manual reset. All protection trips shall be separately alarmed.

Since the existing Control and protection system does not have redundant systems, field signals entering into the control room are dedicated to single system only. However, for implementation of fully independent redundant control systems, field signals shall be independently provided for each system (A&B). Hence, contractor is responsible for arranging all the necessary signals required from field for implementation of this redundant system scheme so that System A & B are independent. If any signals which cannot be independently provided to System A & B due to switchyard equipment limitations, multiplication of such signals for providing to the redundant system shall be accepted.

For the equipment which are not part of this refurbishment scope, the protection principles and settings shall preferably remain same, however if the contractor wishes to change the principles/settings the contractor shall prove (through simulations/calculations) that the changes made does not endanger the existing equipment rating.

4.5.5.1 CONVERTER PROTECTION

The Contractor shall provide adequate protection to ensure that all converter equipments are fully protected and shall ensure that all protections are properly coordinated between Pole-1&2 and with interconnecting AC system.

At least the following DC side protections shall be provided:

- Converter short circuit
- Converter differential protection
- Converter over current
- Excessive DC harmonic voltages
- DC Overvoltage
- DC Over current
- AC Overcurrent

•High Commutation Voltage
•Valve failure to fire and unintended firing
•Repeated commutation failure
•Differential currents (to detect converter and DC side ground faults while in operation)
•Excessive firing angles/ prolonged by-pass pair operation.
•Excessive Fundamental frequency or second harmonic on DC side
•Line winding & Valve winding over voltage protection

The Contractor shall also provide any additional protection, which he deems necessary or desirable for protection of the converters.

Protection shall be provided to prevent "converter start" should there be a permanent ground fault on the AC connections to the converter valves.

Converter commutation failure protection shall, in addition to normal protection, include fast-acting circuits to take precautionary control action to minimize the occurrence of commutation failures. Adjustments shall be provided for on site optimization of commutation failure recovery circuits. For microprocessor-based control & protection systems, on-site changes shall be easily achievable through software changes.

Pole faults (including auxiliary power supply failures), which also require rapid removal of HVAC voltage from valves, shall be cleared by initiating immediate blocking of the converters followed by tripping of HVAC circuit breakers feeding the valve groups. Such tripping of breakers shall be initiated only when essential for protection of converter equipment.

Protections shall order the converters to be blocked and tripped for permanent loss of AC supply to the converters or steady state/ dynamic persisting low AC system voltage, under any of the specified operating modes.

Each main and back-up protective feature shall be arranged to operate trip coil circuit via electrically separate contacts from the respective main and back-up lock-out tripping relay or self-reset tripping relay, as applicable. Separate contacts from each tripping relay shall be used in both the trip coil circuit of each circuit breaker. All signals from the main and back-up/ redundant protective features shall be carried over separate cables. Similarly both trip coil circuits of each breaker shall be activated by signals carried over physically separate cables from the respective protection cubicles. Existing cables shall be used. However, any extra cables, if required, due to work carried out by contractor shall be in scope of Contractor as mentioned in 4.5.1.

Tripping of HVAC circuit breakers for permanent block and valve faults, as well as for any other protection(s) for which the Contractor deems it necessary to trip the AC supply breakers, shall be via lockout relays.

In the event of a fault on the HVAC system requiring tripping of a circuit breaker that feeds the valves, the protection shall order the affected valve group to block immediately and then trip the HVAC circuit breaker. The Contractor shall ensure the adequacy of this method from the viewpoint of ensuring safe opening of these AC circuit breakers under all reasonable conditions. Particular attention shall be given to the problem of delayed arc extinction due to the presence of direct current components.

4.5.5.2 CONVERTER AND POWER TRANSFORMER PROTECTION

The Contractor shall provide equipment to fully protect each power transformer. Wherever protection functions are combined, duplication of protection function with hot standby facility shall be provided. Protection equipments supplied by the Contractor shall include, at least, the following forms of protection:

a) High speed biased differential protection with harmonic restraint.

The protection shall:

- Be numerical type with faulty phase indication.
- Have an operating time not greater than 30 milliseconds for 5 times the setting.
- Have unrestrained quick operation for heavy faults.
- Have an adjustable percentage bias setting in the range of 20-50%.
- Be rated for 1 Ampere
- Have second harmonic or other inrush proof features and also should be stable under normal over fluxing conditions. Magnetising inrush proof feature shall not be achieved through any intentional time delay e.g. use of timers to block relay operation or using disc operated relays
- Have a bias varying with through current
- Have a minimum operating current setting of 0.15 Amp or less for in zone faults
- Include necessary separate interposing current transformers for angle and ratio correction or have internal feature in the relay to take care of the angle & ratio correction.
- Have a disturbance recording feature to record graphic form of instantaneous values of current in all windings in twelve analogue channels in case of 400kv class and above transformers and 6 analogue channels for lower voltage transformers, during faults and disturbances for the pre fault and post fault period. The disturbance recorder shall have the facility to record the following external digital channel signals apart from the digital signals pertaining to differential relay.

    - REF protection operated
    - HV breaker status (Main and tie)
    - Buchholz/ OLTC Buchholz alarm/ trip
    - WTI/ OTI/ PRD alarm/ trip of transformer

  Necessary hardware and software for downloading the data captured by disturbance recorder to the personal computer available in the substation shall be included in the scope.

b)Transformer H.V. line side differential protection shall be in line with clause no. 4.5.5.2a).

c)Over current protection on the primary side and secondary side.

The over current protection shall:

- Be of numerical type single-phase elements with indication for faulty phase(s).
- Have IDMT characteristics with a definite minimum time of 3 sec at 10 times setting (Standard Inverse).
- Have an adjustable setting range of 50-200% of rated current.
- Have a low transient overreach, high set instantaneous unit with a continuously variable range of 5 to 20 times of rated current

- Have drop off/ pick up ratio >95%
- Include hand reset flag trip indicators.

d)Ground over current protection on grounded HV Wye-connected winding.

The protection shall:

- Be of solid numerical type with one single phase element
- Have IDMT characteristic with a definite minimum time of 3 sec at 10 times setting (Standard Inverse)
- Have an adjustable setting range of 20-80% of rated current.

- Have a low transient over reach, high set instantaneous unit with a continuously variable setting range of 5 to 20 times of rated current
- Include hand reset flag trip indicators.

e) Thermal protection.

f) Converter transformer over flux protection shall have the following features:

- Operate on the principle of Voltage to frequency ratio and shall be phase to phase connected
- Have inverse time characteristics, matching with transformer over fluxing withstand capability curve.
- Provide an independent 'alarm' with the time delay continuously adjustable between 0.1 to 6.0 seconds at values of 'v/f' between 100% to 130% of rated values
- Tripping time shall be governed by 'v/f' Vs. time characteristics of the relay
- Have an accuracy of operating time, better than 0.10%.
- Have a resetting ratio of 98 % or better.
- Be acceptable as a built in feature of numerical transformer differential relay.

g)Numerical Restricted Earth Fault Protection shall

- Be single pole type
- Be of current/ voltage operated high impedance type
- Have a current setting range of 10-40% of 1 Amp./ have a suitable voltage setting range.

- Be tuned to the system frequency
- Shall be acceptable as a built in feature of Clause no.4.5.5.a.

Any other protective feature deemed necessary by the Contractor. The Contractor shall provide all necessary interfaces between the converter transformer protection and his other converter protection equipment.

All Other existing transformer protections like Tap changer oil surge,Pressure relief device, Winding temperature high, Fire protection ,Buchholz surge and Oil Temperature high etc shall be tested and integrated into the proposed protection systems to take necessary alarm/trip actions, as required.

Any extra cabling required to implement above protections shall be in contractors scope as referred in 4.5.1.

4.5.5.3 AC BUSBAR PROTECTION

i) Redundant (1+1) numerical Bus Bar protection scheme for each bus system (Bus1 + Bus 2) for 400kV shall be provided. The scheme shall be engineered so as to ensure that operation of any one out of two schemes connected to main faulty bus shall result in tripping of the same.

ii)Each Bus Bar protection scheme shall

a)have maximum operating time up to trip impulse to trip relay for all types of faults of 25 milli seconds at 5 times setting value.
b)operate selectively for each bus bar
c)give hundred percent security up to 50 KA fault level
d)incorporate continuous supervision for CT secondary against any possible open circuit and if it occurs, shall render the relevant zone of protection inoperative and initiate an alarm
e)not give false operation during normal load flow in bus bars.
f)incorporate clear zone indication.
g)be of phase segregated and triple pole type
h)provide independent zones of protection (including transfer bus if any). If the bus section is provided then each side of bus section shall have separate set of bus bar protection schemes
i)include individual high speed electrically reset tripping relays for each feeder
j)be transient free in operation
k)include continuous D.C. supplies supervision.
l)not cause tripping for the differential current below the load current of heaviest loaded feeder .

m) shall include necessary C.T. switching relays wherever C.T. switching is involved and have 'CT' selection incomplete alarm

n) include protection 'IN/OUT' switch for each zone

o) shall include trip relays, CT switching relays (if applicable), auxiliary CTs (if applicable) as well as additional power supply modules, input modules etc. as may be required to provide a Bus-bar protection scheme for the complete bus arrangement i.e. for all the bay or breakers under this specification as per the Single line diagram for new substations. However for extension of bus bar protection scheme in existing substations, scope shall be limited to the bay or breakers covered under this specification. Suitable panels (if required) to mount these are also included in the scope of the work.

iii) Bus Bar Protection shall be provided as a standalone protection system. Built-in Local Breaker Backup protection feature as a part of bus bar protection

scheme shall also be acceptable. LBB protection shall be separate in case input to bus-bar protection has been taken from tie breaker in half diameter scheme.

iv) At existing substations, Bus-bar protection scheme with independent zones for each bus will be available. All necessary co-ordination for 'AC' and 'DC' interconnections between existing schemes (Panels) and the bays proposed under the scope of this contract shall be fully covered by the bidder. Any auxiliary relay, trip relay, flag relay and multi tap auxiliary CTs (in case of biased differential protection) required to facilitate the operation of the bays covered under this contract shall be fully covered in the scope of the bidder.

The test terminal blocks (TTB) to be provided shall be fully enclosed with removable covers and made of moulded, non-inflammable plastic material with boxes and barriers moulded integrally. All terminals shall be clearly marked with identifi-cation numbers or letters to facilitate connection to external wiring.
Terminal block shall have shorting, disconnecting and testing facilities for CT circuits.

For further information Annexure: Control, Relay and Protection Panels to be referred

4.5.5.4 AC BREAKER FAILURE PROTECTION

AC breaker failure protection shall be provided for all circuit breakers in Vizag HVDC station. The breaker failure protection shall result in tripping of the "next-in-line" hvac breakers in the station and the associated breakers in the existing switchyard. In case, there are no back-up breakers that can be tripped within station, a trip signal shall be provided for tripping the relevant remote breaker.
Contractor shall be responsible for complete implementation and integration of the scheme.

For further information Annexure: Control, Relay and Protection Panels to be referred

4.5.5.5 AC FILTER PROTECTION

AC filter shunt/bank protection shall be designed based on available AC filter CT inputs at Site. AC filter protections **philosophy: Filter protection** shall be **through one main and duplicated** (redundant **and independent) filter protection which can be either through numerical or conventional or integrated protection (Software based) which is depicted below:**

Protection System 1	Protection System 2
Main	Main
Back Up	Back Up

Notwithstanding above, Backup protection of filter sub bank i.e., back up protection system 1 can be realized through protection system 2 and vice versa.

Main Filter protections and Back up Filter Protections shall protect each filter branch against damage by the following (but not be limited to):

- over voltage
- excessive reactive power loading of filter equipments
- Main Capacitor overloads
- Phase to ground faults
- Filter over currents (fundamental and harmonic overload)
- Filter resistor overloads
- Filter resistor unbalances
- Filter capacitor unbalances (based on open delta principle)
- Breaker failure protection

Additionally, AC filter Bank protection shall have:

- AC Filter Bank Differential protection
- AC Filter Bank over current protection

All the filter protections shall be designed so that annunciations obtained are on a phase basis for ease of identifying the faulty phase of the filter branch.

Tripping of filters shall not be initiated by over/ under frequency.

Any extra cabling required to implement above protections shall be in contractors scope.

4.5.5.6 AC OVERVOLTAGE PROTECTION

Suitable protections shall be provided for the HVDC stations by the Contractor against temporary and steady state overvoltages in the ac system. The exact requirements and settings shall be co-ordinated with the requirements specified in Clause 4.4 of this specification. AC overvoltage protection shall be provided at station level to protect swithchyard equipments even if converters are not energised.

4.5.5.7 Under/ over frequency protection: Under/Over frequency protection shall be provided, with selectable setting limits ranging from 47.5 Hz to 51.5 Hz

4.5.5.8 Bus/LINE REACTOR PROTECTION: NOT USED

4.5.5.9 415 V STATION SERVICE TRANSFORMER PROTECTIONS: NOT USED

4.5.5.10 PROTECTIONS FOR ELECTRICAL STATION SERVICE SYSTEM: NOT USED

4.5.5.11 Inter zone Protection

The inter zone covering the area between each HVDC bay (CWD10/CWD20/CWD30/CWD40/CWD50) and converter transformer/filter sub-banks is provided with High impedance inter zone protection. This protection shall be replaced with Low impedance inter zone protection. Details of the existing inter zone protection is as per Annexure – Inter Zone protection

4.6 INTERLOCKING AND AUTOMATIC SEQUENCES

Existing interlock: key interlock system located in the control room shall be used and interfaced with new control and protection system, to permit entry into the restricted area of the valve hall and filter sub-banks only under safe conditions, i.e., when the converter is stopped and AC & DC connections to the valves are isolated & grounded.

If the contractor wants to replace the existing key interlocking system or if the contractor is unable to make the existing key interlocking functional then the contractor has to provide a new key interlocking system for the purpose of key interlocking, the same may be accepted.

The sequence for converter automatic start/ stop shall include all sequential operations such as switching AC filters, starting/ stopping compensators, starting/ stopping converter unit, management of reactive/ active power flows etc. as available in the existing system, such stability of HVDC is maintained in line with Chapter 4.2.2 When in automatic mode, individual control shall not be allowed and vice-versa. The Contractor shall ensure that the automatic sequence and interlocking systems are designed to ensure complete safety of personnel, hazard-free equipment operation, and fail-safe operation in the event of component failure.

Such interlocking shall also be provided for all those areas where personnel entry is prohibited during energised condition.

The interlocking provided for switching equipment shall be such that it does not restrict maintenance of the equipment when de-energized.
Control circuits, including the interlocking required for remote closing, and the controls required for remote tripping of AC breakers and disconnectors shall be supplied.

Interlocking of earth switches Q-41& Q-42 associated with CWD10 and CWD20 respectively with the isolators of Vizag bays present in 400kV Vizag station (Annexure 400kV Vizag SLD) shall be in contractor's scope.

4.7 OPERATOR CONTROL, MONITORING AND SUPPORT SYSTEMS

4.7.1 DC/ AC OPERATOR CONTROLS

4.7.1.1 GENERAL

All hardware such as computers, computer peripherals/ accessories, testing equipments etc. and networking products proposed and implemented shall confirm to latest products based on industry standard. The Contractor should ensure that at the time of final approval of hardware configuration, all the above hardware is current industry standard models and that the equipment manufacturer has not established a date for termination of its production. Any hardware changes proposed after contract agreement shall be subject to the following:-

a) Such changes/ updates shall be proposed and approval obtained from Employer along with the approval of Drawings/ documents.
b) The proposed equipment shall be equivalent or with better features than the equipment included in the Contract.
c) Complete justification along with a comparison showing the original and the proposed hardware features/ parameters including brochures shall be submitted to the Employer for review and approval.
d) Changes/ updates proposed shall be at no additional cost to the Employer.

With all normal operator controls affected through the dual, redundant computer based operator interface system.

The bidder shall provide redundant HMI with redundant LAN and redundant Control panels, so that in case of failure of any HMI/LAN/Panels of one system, other system shall be used for controlling both HVDC and AC system.The control functions to be provided from the equipment control panels shall include at least those listed under Table 4.7.2.2.

It shall also be possible for operator to know individual alarms by selecting the particular panel on the display monitor.

i) At the converter station, a digital display of measurands and analog display of associated HVAC yard at Vizag, including status of circuit breakers, isolators and Ground switches shall be provided in the converter station control room.

4.7.1.2 HVDC AND AC CONTROLS

The Contractor shall provide control facilities in station control room that shall include but not be limited to, the functions shown in Table 4.7.2.2 and Annexure - VIZAG_HVDC_IO_LIST

A description of major hvdc control functions is outlined below.

(i) Master Control

Master control refers to the common control functions that affect all connected valve groups. These functions are power order, power direction, power limit, power ramp rate and reactive power control etc. The power flow through the back-to-back DC connection is maintained by the power order as set by the station operator.

The power ramp rate controls the timing sequence for loading at a preselected rate. The power limit control enables the operator to set different limits to optimize loading for varying conditions.

(ii)Block Control

All the requirements as mentioned above for power order set control, power direction selection, power limit and power ramp rate control shall also be provided to control the block. Tap changer control selection (Auto/Manual) shall be provided at the block control level along with facility to control tap changer position in either mode. Facility to start/stop of the pole shall only be provided at the pole control level for simplicity.

(iii)HVDC System Control Mode Selection

The following basic control modes shall be provided:

a) Power Control Mode

   In constant power control mode, the control system shall accept the scheduled power order signal from the station control room.

b) Current control mode

c) Control Mode Change Over

   Separate control for the pole shall be possible through pole control level with all the associated facilities at that level as brought out in (ii) above. In addition it shall be possible to exercise control of reactive power exchange with the ac systems on both sides within a selectable band about a fixed target value which shall also be selectable. Possibility to affect a voltage control shall also be provided within the selected band of reactive power exchange with the ac systems.

Transient free transfer of the pole from pole level control to Master control level and vice-versa shall be possible
level and vice-versa shall be

iv) possible. Miscellaneous Operator

a)Valve Group Block/Deblock

This control is used by the operator to stop (block) or start (deblock) a valve group. Under typical circumstances, a power order is set, a power direction is entered, all auxiliaries are started and a contact closure is used to signal deblock. A normal stopping sequence initiated by "Block" contact starts a sequence that causes the voltage and current to drop to zero.

b)Direction of Power Transfer

This selector switch enables the operator to change the power flow direction. Interlocks will be provided which will prevent the operator from changing power direction while HVDC system is operating or while there exists any conditions which, on reversal of dc power direction, would result in damage to the equipment.

c)Valve Group Connect/Isolate

Facilities shall be provided for connecting and disconnecting the block.

d)Block Start/ Stop

This control shall enable start or stop of the complete Block, and shall take care of all interlocks, start/stop preconditions and sequences automatically

e)Valve Hall Ground Switches

These remotely controlled motor operated grounding switches are provided in the valve halls to ground the valves for maintenance etc. Operation of valve hall shall be possible in group from the operator desk in control room Provision shall be made (key-operated pushbutton) for defeating the interlock in the event of failure of ground switch operation.

f)Emergency Stop:

An emergency stop button on block basis shall be provided in the control room. Operation of this button shall automatically ramp down at a fast rate the direct power, lead to blocking of the converters and reach safe shut down of concerned block.

4.7.1.3 STATION CONTROL & STATUS FACILITIES

The Contractor shall provide the control facilities from the operator control desk through a LED monitor and keyboard/ mouse system. These facilities shall include all control operations, digital setting, indicating devices, Station single line diagram and symbols, any other special control devices and meters required for control and monitoring of the complete HVDC system. The layout of the station single line diagram, together with control, indicating and metering devices on the control desk shall be logical, compact, of pleasing appearance, and shall facilitate efficient supervision and operation of the station by the operator.

The control facilities from the operator control desk (including all control operations, digital setting, indicating devices, Station single line diagram and symbols, any other special control devices and meters required for control and monitoring of the complete HVDC system) shall be integrated with the new VPS display system under present scope. All material supply, installation, commissioning of the integration of the Control facility of HVDC Pole 1&2 with the new VPS display system shall be in present scope.

4.7.1.3.1 STATION LEVEL STATUS SUPERVISION

The position of each switchgear, e.g. circuit breaker, isolator, earthing switch, transformer tap changer etc., shall be supervised continuously. Every detected change of position shall immediately be displayed in the single-line diagram on the station screen, recorded in the event list and an option to take hard copy printout of event list shall be available. Alarms shall be initiated in the case of spontaneous position changes.

The switchgear positions shall be indicated by two auxiliary switches, normally closed (NC) and normally open (NO), which shall give ambivalent signals. An alarm shall be initiated if these position indications are inconsistent or if the time required for operating mechanism to change position exceeds a predefined limit.

4.7.1.4 SYSTEM INDICATIONS & POWER MEASURING FACILITIES

The Contractor shall provide DC and AC system/ equipment indication facilities in the station control room that shall include, but not be limited to, the functions shown on Tables 4.7.2.1. shall provide comprehensive overview of the entire HVDC and AC system to facilitate control and monitoring of the station from LED monitors/operator work station. Alarms of pole-1&2 shall be indicated & displayed directly/ through Master Control Station.
3-Dimensional graphic representation of thyristor valves and valve cooling piping network shall be provided on station monitoring system. The graphical representation shall also display faulty thyristors in different colours indicating faulty thyristor position.

Table 4.7.2.1 provides a list of ac/dc metering facilities required, which shall be included on VPS and LED monitors.
Pressure, temperature and relative humidity of each valve hall shall also be displayed in the control room. Alarm(s) shall be raised in case any of the parameters exceed limits.
Low ambient temperature capabilities and overall power transfer capabilities including possible overload capability (ref. Clause 4.1.3) shall be automatically calculated and displayed on the LED monitors on operator’s request. The Contractor shall provide any additional metering quantities, as he deems necessary for safe operation of the station.

4.7.1.5 ENERGY METERING: NOT USED

4.7.2 SYSTEM REQUIREMENTS

4.7.2.1 GENERAL

The main control and monitoring systems shall be configured as dual redundant computer based systems in a main and hot standby configuration. The operator control, monitoring and support system could be integrated with station control system. Outage of any subsystem or complete loss of one system shall not affect the control and monitoring of the HVDC station. The system shall be based on open system concept in hardware and software and industry standard communication protocols and graphical user interface.

The redundant, computer based system shall accept control inputs from the Operator by means of LED monitor/ mouse etc. and send these commands to the HVDC and the HVAC control systems. The system shall gather alarm, status and measurand data from the plant and display it to the Operator on the mimic diagram on LED monitors, loggers etc. as further

defined below. The system shall be so designed that no alarm and status data or control data shall be lost.

4.7.2.2 MAIN SYSTEM POINTS LISTS

The Contractor shall determine lists of control points, status points, alarm points and measurand points required for the system at HVDC station and submit these for approval of the Employer together with a study describing in detail the design philosophy.

All status changes shall be processed by the system in such a manner that intermediate states of the device being monitored, for example, travel time of an isolator, are checked and alarmed when they exceed normal time limits.

A list of impulse measurand points for quantities such as MW hours, MVAr hours shall be given. A list of analogue measurand points for quantities such as MW, kV, Amps, and temperature etc., shall be provided together with proposed ranges and details of scaling networks. A list of digital measurand points shall be given with details of formats, function etc.

Table 4.7.2.2 Controls & Indications at Vizag Station

	Signal Name	Block–I &II
	CONTROLS SIGNALS	
1.	Power order	√
2.	power order ramp	√
3.	power order limit	√
4.	power/current control	√
5.	Power direction	√
6.	Current order setting	√
7.	Current ramp start/stop	√
8.	Current order ramp setting	√
9.	Current limit setting	√
10.	Start/Stop & Block/deblock	√
11.	Power Swing modulation on/off	√
12.	DC power /current control	√

13.	Frequency control/on/off	√
14.	Frequency target/limits	√
15.	Frequency Control	√
16.	Power Modulation Control on/off	√
17.	Power Modulation Control	√
18.	Connect/isolate Blk	√
19.	RPC auto/man off switching	√
20.	RPC Volt /Reactive Selection	√
21.	RPC MVAr/Voltage set points	√
22.	AC Filter (bank/ sub-bank) breaker open/close	√
23.	Conv. Trans Breaker open/close	√
24.	AC Filter (bank/ sub-bank) Disconn open/close	√
25.	Con. Trans Disconn open/close	√
26.	Tap changer auto/man	√
27.	Valve group block/deblock	
28.	Valve hall Gr. Switch open/close	√
	INDICATIONS	
29.	Valve group start/stop	√
30.	DC OP Mode Pwr. /current	√
31.	Valve group connect/isolate	√
32.	Power direction	√
33.	Protection initiated power order	√
34.	Blocked/deblock Blk-2	√
35.	DC Station overload in use	√

36.	Power ramp in progress	√
37.	Stabilization control on/off	√
38.	Tap changer Auto/Man ind.	√
39.	Block connect/isolate ind.	√
40.	Power direction normal/reverse	√
41.	Runback activated ind.	√
42.	Frequency control on/off	√
43.	Frequency control activated	√
44.	Power Modulation on/off	
45.	AC bay Circuit breakers ind.	√
46.	AC bay disconnectors ind.	√
47.	AC Filter (Sub-bank) Circuit breaker ind.	√
48.	AC Filter (Sub-bank) disconnector ind.	√

The above list is indicative only. The actual signal can more than the indicated in the above list.
In addition to the above, the contractor shall provide control and monitoring at remote control centers i.e., Main NTAMC, Backup NTAMC and RTAMC. Further, full remote operation capability shall be provided by extending an Operator Workstation (OWS) to NTAMC, Manesar. This shall be in addition to the standard IEC 60870-5-104 protocol integration for telemetry and control. Annexure: NTAMC Remote Operation may be referred for further information.

The communication of signals to the Sothern and Western Remote load dispatch centers (RLDC) shall be as per the statutory requirements Annexure: Communication and statutory requirement.

The list of signals mentioned in Table:4.7.2.2 and the list mentioned in Annexure: Communication and statuary requirement are indicative only. The actual signal can be more than the indicated in the above list.

4.7.3.1 Computer Information System Requirement:

1) A COMPUTER BASED INFORMATION SYSTEM SHALL PERFORM FOLLOWING FUNCTIONS:

- Initiation of commands to control HVDC system.

- Control and monitor the Valve cooling system.

- Monitoring of process data to give brief overview as well as a comprehensive view of each subsystem.
- Operator guidance under normal, and particularly, under contingency and emergency operation.
- Sequence of event recording and alarm system.
- Process data archiving and trending.
- HVDC system Performance management system.
- Maintenance management system.
- Soft copy of complete station documentation shall be available on Operator Work Stations.
- All the system trends shall be available at least for one year period and retrievable on demand from the main storage system.

The process data logging shall have hourly/ daily logging of station data. The formats of the log sheets (Up to 20 No) for data logging shall be furnished to the Contractor during detailed engineering. The Contractor shall use these formats and develop displays on station control and monitoring system. The data logging in the computerised log sheets shall be automatic. However, manual data entry by station operator shall also be provided for the process data, which cannot be logged automatically by the system in the operators log sheets. It shall be possible to take printout of operators log sheet on daily basis. Archiving and back up storing facility of the log sheets shall be possible and facilities for deleting the records and taking backup on external hard disk shall be provided.

a) Display pages shall be provided, listing alarm and status changes in chronological order. For operator's guidance, details of faulty equipment, fault tracing, troubleshooting and restoration procedure should be available for all major alarms/ Emergency conditions. Display pages shall also be provided showing system single line diagrams, the status of the system and all pertinent measurands.

b) Input Conditioning and Scanning.

The input termination and signal conditioning facilities shall be an integral part of the system. The monitoring system shall scan all input contacts at a speed compatible with the resolution time of 1 millisecond.

c) Event Time-Tagging & Sorting.

Upon the acquisition of alarms and status change of events and their respective time information from the input scanner, the system shall store this information in the appropriate memory storage areas. The system shall determine the real-times-of-occurrence of each event. This shall include providing the required compensation for any time delays introduced during input signal conditioning, such as for contact bounce suppression, etc.

The system shall also sort the inputs received from the various scanners according to the real-time-of-occurrence. The time tagging and sorting shall result in monitor displays being organized in accordance with true sequence of events occurrence.

d) Determination of Event Categories.

The system shall allow for the allocation and re-allocation when necessary of attributes to each alarm and status point, which shall determine how they shall be processed by the system, displayed to the operator and printed on the various logs on demand that may be required by the Employer/ Engineer.

The attributes that can be assigned to an alarm point shall include but not necessarily be limited to the following:

- Major Alarm
- Warning Alarm
- Minor Alarm

e) Legends

Each point shall be provided with an individual legend of up to 50 alphanumeric characters. The legend shall constitute an English language description of the event.

f) General Alarm Annunciator Mode

When no major alarms are prevalent in an unacknowledged state, the VDU display shall function as a General Alarm Annunciator. It shall display all alarms as they occur in chronological order.

The sequence of acknowledge and reset shall be generally arranged as follows:

Input Condition	**VDU DISPLAY**		**Audible Alarm**
	Time Display	**Legend in**	
Alarm-on	Flashing	Alarm colour	On

Acknowledge	Steady	Alarm colour	Off
Alarm-off	Flashing	Return to norma l colour	Off
Acknowledge	Alarm and return to normal display erased	Off	Off

g) Dedicated Major Alarm Annunciator Mode

Upon the occurrence of any major or warning alarm(s), the designated display page shall automatically assume the role of a dedicated major alarm annunciator.

The incoming major and warning alarms(s) shall appear flashing and thus provide an uncluttered, dedicated annunciator of major and warning alarms. Any existing and acknowledged major and warning alarms prior to the occurrence of new major or warning alarms shall be retained and displayed on the screen with a steady legend.

The sequence shall be same as defined for "General Alarm Annunciator Mode" above.

The display monitor shall revert back to the role of "General Alarm Annunciator" when all the major and warning alarms have been acknowledged by the operator and after a fixed predetermined length of time (e.g. 30 second). Each new major alarm that occurs shall also be displayed with the oldest unacknowledged major/ warning alarm being shifted to a memory.

On operator’s request, all active alarms at any point of time, shall be displayed on the monitor and printed as and when required.

h) Display monitor (Alarms & Status)

The display monitor shall primarily serve as an aid to the Station operator in the control & operation of the HVDC Station both under normal and abnormal system conditions.

Sequence of event record shall be automatically stored on permanent memory such as hard disk or CDROM in files when buffer memory is full, which should be easily retrievable by operator for taking hard copy printout. Prior Alarm shall be displayed on VDU to prompt operator to free space on hard disk for further archiving or automatic dump to backup memory should be initiated. This could be achieved by deleting oldest files or transferring to hard disk / CDROM. Facilities shall be provided to select and display different pages on the monitors. The Contractor shall implement a suitable scheme whereby the operator shall be made aware of the presence of preceding/ existing events, as well as have a means of recalling these events, on the display screen, via the keyboard/mouse. There shall be facility of sorting alarms by class, point number, device etc and display on monitor.

The display monitor shall handle the following types of event messages, which shall be displayed in different colours:

a) Equipment status changes;

b) Major alarms;

c) Warning alarms;

d) Minor alarms.

i) Printer Formats

The printers shall print event messages on demand from operator in chronological order. Each event shall be displayed on one line only.

j) Event Printout

The output printers shall provide a hard-copy record on demand from operator of events and their return-to-normal transitions, in a sequential order, along with their respective times of occurrence. This record shall be used for system fault analysis and maintenance purposes. Operators shall have facility to retrieve sequence of event log from permanent memory and take hard copy printout. It shall also provide a record of all change in status of switchgear equipment and protection relays whether initiated automatically by any controls/protections or manually along with the respective time(s)-of-occurrence of such changes.

k) Summary Printouts

The output printers shall provide summary printouts on demand from operator to take hard copy printouts of current contents of any Display monitor. The summary printouts shall include alarm summary, blocked-out point summary, test point summary and periodic self-testing and checking summary.

The alarm printout shall also include special character identification of each alarm according to its assigned hierarchy, e.g. major, warning or minor alarm.

The Contractor shall make provisions, via the interactive terminal, for the alarm and summary printouts to be individually printed on any of the system printers.

l) Out-of-Service

In the event a printer is temporarily out-of-service, facilities shall also be provided to allow the Operator to transfer the printing to another printer. The faulty printer status shall be displayed on Display monitor and initiate audible alarm.

m) Periodic Time Synchronization Facility

The system shall be capable of accepting a periodic time synchronization signal from the station master clock system. Upon receiving and decoding this periodic signal, the system shall automatically adjust the system real-time clocks accordingly. It shall also be possible to adjust time manually through the interactive terminal.
When system time is adjusted, the system shall record the time at which the adjustment is made and the new system time on the associated interactive terminal The format shall be: HH:MM:SS:mmm Time corrected to HH:MM:SS:mmm.

2) The converter station operator control & monitoring shall be through a Display monitors as well as through a keyboard/ mouse. The operator station shall be equipped with at least three full graphic LED colour monitors. The user interface shall be latest and based on industry system standard such as Windows NT and shall support and fully utilise the concepts and flexibilities offered in these systems. The design of the software shall be such that all actions that can change the system configurations or can lead to loss of information or are critical to the system are reconfirmed before execution

The main functional tasks to be initiated from this keyboard/ mouse shall, apart from the HVDC control functions, shall include other functions that are essential for the proper operation of the system, as recommended by the Contractor and approved by the Employer.

It shall be capable to perform all functions for entire substation. It shall use industrial grade components. Processor and RAM shall be selected in such a manner that during normal operation not more than 30% capacity of processing and memory are used. Supplier shall demonstrate these features.

The capacity of hard disk shall be selected such that the following requirement should occupy less than 50% of disk space:

i)Storage of all analog data (at 15 Minutes interval) and digital data including alarm, event and trend data for each year of station operation. Archiving facility on Backup storage devices shall be provided.
ii)Storage of all necessary software,
iii)20GB space for EMPLOYER'S use.

Supplier shall demonstrate that the capacity of hard disk is sufficient to meet the above requirement.

3) SYSTEM SUPERVISION & DISPLAY

The system shall be comprehensively self-monitored such that faults are immediately indicated to the operator, possibly before they develop into serious situations. Such faults are recorded as a faulty status in a system supervision display. This display shall cover the status of the entire substation including all switchgear, IEDs, communication infrastructure and remote communication links, and printers at the station level, etc.

4) CONTROL DIALOGUES

The operator shall give commands to the system by means of mouse click located on the single-line diagram. It shall also be possible to use the keyboard for command activation.

5) USER-AUTHORITY LEVELS

It shall be possible to restrict activation of the process pictures of each object (bays, apparatus) within a certain user authorisation group. Each user shall then be given access rights to each group of objects, e.g.:

- Display only.
- Normal operation (e.g. open/close of switchgear)
- Restricted operation (e.g. by-passed interlocking)
- System administrator

For maintenance and engineering purposes of the station OPERATOR CONTROL AND MONITORING SYSTEM, the following authorisation levels shall be available:

- No engineering allowed
- Engineering/configuration allowed
- Entire system management allowed

The access rights shall be defined by passwords assigned during the login procedure. Only the system administrator shall be able to add/remove users and change access rights.

6) REPORTS

The reports shall provide time-related follow-ups of measured and calculated values.
The data displayed shall comprise:

Trend reports:

- Day (mean, peak)
- Month (mean, peak)
- Semi-annual (mean, peak)
- Year (mean, peak)

Historical reports of selected analogue Values:

- Day (at 15 minutes interval)
- Week

- Month
- Year

It shall be possible to select displayed values from the database in the process display on-line. Scrolling between e.g. days shall be possible. Unsure values shall be indicated. It shall be possible to select the time period for which the specific data are kept in the memory. Following printouts shall be available from the printer and shall be printed on demand:

i. Daily voltage and frequency curves depicting time on X-axis and the appropriate parameters on the Y-axis. The time duration of the curve is 24 hours.
ii. Weekly trend curves for real and derived analogue values.
iii. Printouts of the maximum and minimum values and frequency of occurrence and duration of maximum and minimum values for each analogue parameter for each circuit in 24 hr period.
iv. Provision shall be made for logging information about breaker status like number of operation with date and time indications.
v. Equipment operation details shift wise and during 24 hours.
vi. Printout on adjustable time period as well as on demand for MW, MVAR, Current, Voltage on each feeder and transformer as well as Tap Positions, temperature and status of pumps and fans for transformers.
vii. Printout on adjustable time period as well as on demand system frequency and average frequency.

7) TREND DISPLAY (HISTORICAL DATA)

It shall be possible to illustrate all types of process data as trends - input and output data, binary and analogue data. The trends shall be displayed in graphical form as column or curve diagrams with a maximum of 10 trends per screen. Adjustable time span and scaling ranges must be provided.
It shall be possible to change the type of value logging (direct, mean, sum, or difference) on-line in the window. It shall also be possible to change the update intervals on-line in the picture as well as the selection of threshold values for alarming purposes.
The system shall allow the operator to set up each trend recorder page by an interactive routine at the console, which allows him to:
•Select any analogue point from database and allocate it a trend recorder trace.

•Set the scale factor and zero offset for each trace.
•Set the time scale for each trace. The smallest time interval required shall be one minute. The system shall also indicate on each page the database allocated to each trace and the scale and offset factors applied. Trend displays shall be updated automatically in real time, with operator selectable update rate between five seconds and one minute.

A facility shall be provided to store historical data in Juke Box/NAS storage. Archived data for operator selected variables for a minimum period of one year shall be stored at a time. This data shall be transferred to back up memory after nominated intervals.

8) AUTOMATIC DISTURBANCE FILE TRANSFER

All recorded data from the IEDs with integrated disturbance recorder as well as dedicated disturbance recording systems shall be automatically uploaded (event triggered or once per day) to a dedicated computer and be stored on the hard disc.

9) DISTURBANCE ANALYSIS

The PC-based workstation shall have necessary software to evaluate all the required information for proper fault analysis.

10) IED PARAMETER SETTING

It shall be possible to access all protection and control IEDs for reading the parameters (settings) from the station operator controls and monitoring system. The setting of parameters or the activation of parameter sets shall only be allowed after entering a password.

11) AUTOMATIC SEQUENCES

The available automatic sequences in the system should be listed and described, (e.g. sequences related to the bus transfer). It must be possible to initiate pre-defined automatic sequences by the operator.

a) Blocking of a Point

This facility shall be provided for the use of the station operator to enable him to quickly and easily block or unblock, manually by means of software, any number of points including control points, alarm points, status points and measurand points. As each point is blocked or unblocked, a message shall automatically be displayed on the event list.

Prior to implementing any blocking/ unblocking function, the system shall automatically present the legend for the selected point on the display monitor. All blocked control and status points shall be clearly indicated on the appropriate displays by means of a special colour or equivalent technique

b) Addition, Deletion and Modification of Points

One of the essential functional objectives of the software-based system shall be to provide means for fast, easy and simple on-site implementation of changes and modifications. These shall be accomplished by software utilizing the interactive facilities to be provided by the Contractor.

The on-site changes shall be made only by the authorized technical personnel after entering password security codes to avoid inadvertent tampering of system software. With the password entry and in accordance with the assigned priority level, the computer shall accept the request and indicate acceptance by means of a display on the interactive terminal and at the same time inquire concerning the nature of the required task, (i.e. whether it is addition, deletion or modification of point. By this interactive procedure between the man and the machine, the information, requesting the change, shall be transferred to, verified and implemented by the computer system. The exchange shall be terminated properly upon the completion of the required task by means of a special end-of-exchange coded message to inhibit any further access to the computer system.

The system shall provide a record of every message exchanged between man and machine along with the time and date information. This shall serve as a permanent, dated record of the implemented changes including point additions, deletions and modifications. Following incorporation of a change, the system shall automatically update all the pertinent index or reference tables associated with the printer, display monitors, mimic diagram, input/ output devices etc.

c) Performance Management system

The operator interface station shall provide facility for generation of station performance reports as per Cigre annual protocol 14- 97WG04) formats. The program shall be menu based on RDBMS package. The interactive facility shall be provided on VDU to enter data of various outages by the operator to generate these reports. This function along with maintenance management system and operator trainee facility could be integrated with station operation and control system or provided on standalone system.

d) Backup Alarm and Monitoring System

The backup alarm system shall be an inherently simple system handling only grouped major, minor and warning alarm inputs. These inputs shall be either from separate contacts on the same device as the one from where alarm inputs to the main alarm monitoring and reporting system are fed or from a separate device/location.

Operator shall have facility to know individual alarm by connecting interactive terminals to the control/protection system.

e) Detailed Requirements for Controls

i) General

Operator controls controlling the HVAC and HVDC systems shall operate on the Select/Selection Check back and Execute Command/Execute check back principle. The system shall only allow one control selection at a time. Selection shall only be possible from the designated control location.

Control selection cancellation shall occur if:

a)The selection cancel pushbutton is operated.

b)Control selection check back is invalid.

c)The control has been successfully input to the device control system (Execute Check back received).

d)The selection times out. (The period of selection time out for each type of control shall be determined at the design stage).

e)If an invalid control is attempted (e.g. operator attempts to trip a circuit breaker that is already open).

f)In the case of multiple input controls e.g. Tap-changer controls, the cancellation procedures shall be suitably modified.

g)If more than one selection at a time is attempted. (In this all the selections shall be cancelled).

In addition to the above cases, the selection cancellation feature shall be provided wherever the system control/ safety requirements make it necessary.

ii) Control Interfaces with the HVAC and HVDC Control and Protection Systems. All control interfaces shall be properly designed, isolated and protected. Provision shall be made at each control interface point for isolation of the control point and facilitating .

functional testing both in the direction of the controlled plant and looking back in to the Operator's Control and Monitoring system.
A full description of each control interface shall be given by the Bidder with the Bid. Facilities shall be provided to monitor analog set point(s) at all times. Loss of any analogue set point(s) shall not cause any change in the state of the controlled item of plant. The Bidder shall describe in the Bid how analogue set point controls are interfaced, monitored and operated. Facilities shall be provided to have automatic set point matching by the system where required.

iii) Control Logging
All operator control actions whether from the system or the respective local control panel shall be logged on the operations logger. The system shall automatically maintain database for counting tap changer operations, circuit breaker operations, hours of valve energization, Ampere-hours utilised by electrodes as cathode/ anode for maintaining equipment history.
The time of execution of the control action shall be printed out with a legend describing the control point activated. Logging of the selection of a control is not required, logging shall only occur at the time the control is executed.
iv) Operator Guidance and Training
Essential feature of computer based operator station shall be to provide operator guidance and expert systems. The expert system shall provide sufficient information to the operator during various emergencies and contingencies. Automatic sequences may be initiated during contingency conditions to prevent trip. Fault tracing procedures, Restoration procedure and emergency operations shall be indicated on operator console.
The operator training system shall also be available which shall guide operators about various controllers and their response during different system conditions. These shall be provided on simulator to enable station operators to understand HVDC system operations and trouble shooting of controls and protection system. The training to the operator should in no way interfere with normal controls systems during power flow on the HVDC system.

v) Priority Levels and Response Times
Operator inputs shall take priority over all other inputs (except from protections) to the control and monitoring system. Priority levels shall be assigned as follows:

- Operator initiated selection and control
- Alarm and status inputs
- Measurand inputs

All other types of inputs and operator requests may be accorded further lower priorities than those above, as long as the response of the system for control purposes is not slowed.
The Contractor shall give the expected response times of the system to all inputs. Figures shall be given for the complete system.

The response of the system to an operator control selection shall be between 1 and 2 seconds.

The response of the system to a control execution, i.e. time from execution command to execution check-back shall be given in the Bid. The response time shall not be greater than two seconds for in-station controls and five seconds for remote station controls including the time for transmission and checking of the control and check-back signals.

4.7.3.2 SUPPORT EQUIPMENTS FOR COMPUTER INFORMATION SYSTEM

.1 GENERAL

To meet the performance and functional objectives, the main control, monitoring and reporting system shall be based on microprocessor based systems, along with all necessary input/ output interfaces and peripheral display and output devices. The required functional and equipment flexibility and versatility shall be achieved by means of system software capability.

.2 SYSTEM CHANGEOVERS

The switchover from one system to another shall occur either as a consequence of detected malfunction(s) associated with the system or as a result of some deliberate action such as during scheduled maintenance. In the first case, the switchover shall be automatic; in the second case, it shall be initiated manually.
The switchover facility shall be designed to accept the
outputs from every interface associated with both systems A and B.
A manual switchover command shall over-ride an automatic switchover command. Switch-over from one system to another shall only be possible provided the system being switched to is operational as well as the switch-over facility itself is operational. In the absence of above conditions, the automatic/ manual switchover function shall be inhibited. Should this situation occur, it should be visually annunciated on the Display monitor, and at the processors.
In the event of failure to successfully switchover to the standby system, as a consequence of a protective function action, then such failure shall be annunciated through audible and visual alarms. The protection action shall proceed based on the detection of the primary system itself.

.3 CPU/DSP CAPACITY

Each CPU/DSP shall support all associated software for this application in an efficient manner with an optimum usage of its computation capacity. It shall provide a CPU/DSP-free time of at least 60% averaged over one minute while running the complete software of the operator interface including communication. The Bidder shall include in the Bid a detailed breakdown of intended usage of the CPU's/DSP’s duty cycle.

.4 MAIN MEMORY

All main memories for the system, including the status, sequential level over flow and text memories, shall be of non-volatile type. Memories shall use state of the art components.

.5 MASS MEMORIES

The mass memory shall comprise an integral part of the specified system. The size and capacities of these memories shall include 50% spare and unused capacity over and above the complete requirements.

The considerations of access and transfer times shall be based on the criteria of sufficiency and adequacy to meet the proper functional and operational requirements of the system for the specified application. When all software programs are in operation, no more than 50% of the duty cycle of the mass memory shall be utilized over any two-second interval of time.

Mass memory units, if offered as mass memory devices, shall be field-proven with a minimum MTBF of two years including associated controllers. Flexible (floppy) disc shall not be acceptable.

.6 REAL-TIME CLOCKS

Each system (A and B) shall have its independent high quality real-time clocks with a high order of stability and millisecond resolution capability. They shall be crystal-controlled or be equivalent in performance. The facilities and means to manually reset, advance and restart the clock shall include a visual display of real-time based on hours, minutes, and seconds. The clocks shall be capable of automatic time synchronization on a periodic basis, by means of a signal provided from the station master clock system .The external time synchronization function shall be assigned a high level of priority.

.7 STATION MASTER CLOCK

Each system shall be synchronized with the station master clock under present scope based on global positioning satellite. The station master clock along with all associated hardware like Antenaetc shall be in the scope of contractor.

The station master clock system shall produce output signals to synchronize real-time clocks provided in the following equipment:

OPERATOR'S CONTROL AND MONITORING SYSTEM A)

B) TRANSIENT FAULT RECORDERS

C) STANDARD TIME CLOCKS IN THE CONTROL ROOMS

D) DISTRIBUTED CONTROL SYSTEMS ON AC AS WELL DC SIDE

For further details on master clock Clause 2.d of Annexure Cyber security_Rev1 shall be referred.

.8 PROGRAMMING AND SOFTWARE MAINTENANCE EQUIPMENT The Contractor shall provide suitable equipment for programming and maintenance of the software associated with the system.

The equipment shall include all necessary items required for software maintenance including console/ monitors, keyboard, disc unit and printer, all necessary devices for program loading and all diagnostic programs. The software maintenance systems shall be so designed that corruption and damage to the software does not occur due to viruses or other such extraneous intrusions.

.9 WORKSTATION CONSOLE

Workstation console shall consist of a workstation driving one or more monitors, a single keyboard and a cursor positioning device/ mouse. The user shall be able to switch the keyboard and cursor-positioning device, as a unit, among all the monitors at a console via push buttons or other controls.
Two types of Workstation consoles are envisaged i.e. workstation console integrated with one LED colour monitor and workstation console integrated with two LED colour monitors.
Workstation console with single monitor is envisaged to be used as Development system for taking up developmental activities like database, displays & reports development. The bidder shall assess the suitability of workstation console for these requirements & if required higher end machines and/or additional servers may be included in the offer.
Workstation consoles with two monitors shall be used by the operators for control, monitoring and operation of power system. All workstation consoles shall support full-graphic displays.
The minimum hardware configuration of workstation console shall be:

- 16 GB Main memory
- 20 TB Solid state Drive (SSD)
- DVD ROM with R/RW drive
- 24inch LED colour monitors (single for all system except HMI, operator workstions and TFR monitoring PC which shall be dual monitors)
- Cordless Keyboard
- Cordless Mouse
- Speakers for audible alarms
- 10/100/1000Mbps dual Ethernet ports
- Port for connecting external/internal hard drive and juke Box/NAS storage

.10 KEYBOARDS

Keyboards for normal operational as well as maintenance purposes shall be included as part of the system with facility to switchover between the keyboards. Cordless optical mouse and keyboard shall be provided for BMS, Operator and Engineer's Workstations.

.11 PRINTERS

The industry standard laser Printers shall provide for hard-copy printouts on demand by the operator. Minimum of three industry standard laser jet printers shall be provided. At least one of these shall be a colour printer.

.12 LOCAL AREA NETWORK (LAN) AND DEVICE INTERFACES

Servers and peripheral devices are connected to each other on a Fibre optic based local area network (LAN), which allows sharing of resources without requiring any physical disconnections & reconnections of communication cable. Dual LAN shall be provided for the SCADA, control and protection system. LAN Cabling shall also be extended to conference room in the station control room for monitoring of entire HVDC system.

Each LAN shall have the following characteristics:
- Shall conform to the ISO 8802 or IEEE 802 series standards with advanced Layer 2 and Layer 3 features including IEEE 802.3 full duplex operation on all ports, IEEE 802.1p Priority Queuing to facilitate the passing of high speed tripping signals (GOOSE messages), IEEE 802.1Q V LAN to allow for segregation and grouping of IEDs into virtual LANs to isolate real time IEDs from data collection IEDs, IEEE 802.1w Rapid Spanning tree Protocol.
- Shall preclude LAN failure if a server, device, or their LAN interfaces fails.
- Shall allow reconfiguration of the LAN and the attached devices without disrupting operations
- Shall have minimum of sixteen (16) ports of 100Mbps per LAN switch.
- LAN switches shall have redundant power supplies

.13 SOFTWARE STRUCTURE

The software package shall be structured according to the SAS architecture and strictly divided in various levels. Necessary firewall shall be provided at suitable points in software to protect the system. Maintenance, modification or an extension of components of any feeder may not force a shutdown of the parts of the system, which are not affected by the system adaptation.

.14 OPERATOR CONTROL & MONITORING SOFTWARE

The operator control and monitoring software package for the station shall be independent of project specific hardware version and operating system. It shall further include tools for picture editing, engineering and system configuration. The system shall be easy to use, to maintain, and to adapt according to specific user requirements. Systems shall contain a library with standard functions and applications.

.15 SYSTEM SOFTWARE

The system software shall be structured in various levels. This software shall be placed in a non-volatile memory. The lowest level shall assure system performance and contain basic functions, which shall not be accessible by the application and maintenance engineer for modifications. The system shall support the generation of typical control macros and a process database for user specific data storage. In case of restoration of links after failure, the software along with hardware shall be capable of automatically synchronising with the remaining system without any manual interface. This shall be demonstrated by Contractor during integrated system test.

.16 PROGRAMMING SOFTWARE

All programming shall be the responsibility of the Contractor. All programmes purchased outside shall be subject to approval by the Employer/Engineer. Programmes shall be modular with each module performing a clearly defined task. Application programmes shall be written in an internationally recognized computer language such as C++ or any other language agreed to by the Employer.

The software shall generate and operate upon a universal database. All live data values shall be defined and updated only in the database. Programmes requiring live data values shall obtain the same from the database.

.17 NETWORK MANAGEMENT SYSTEM:

A) The Contractor shall provide network management system software for following management functions:

- CONFIGURATION MANAGEMENT
- FAULT MANAGEMENT
- PERFORMANCE MONITORING

This system shall be used for management of communication devices and other IEDs in the system. This NMS can be loaded in DR workstation and shall be easy to use, user friendly and menu based. The NMS shall monitor all the devices in the station and report if there is any fault in the monitored devices. The NMS shall

I) Maintain performance, resource usage, and error statistics for all managed links and devices and present this information via displays, periodic reports and on demand reports.

II) Maintain a graphical display of connectivity and device status.

III) Issue alarms when error conditions occurs

IV) Provide facility to add and delete addresses and links

V) The Contractor shall provide each software in two copies to load into the system in case of any problem related with Hardware/Communication etc.

B) INTERACTIVE PROGRAMMING

I) Addition, modification and deletion of points, point identification numbers and point description texts shall be designed to be easily and simply performed using the programming and software maintenance equipment.

ii) The software shall provide conversational capabilities for these functions in plain language output automatically on the interactive device printer to prompt and guide the programmer in performing this level of programming.

C) PROGRAM COPIES

The program shall be handed over with the system in a form that permits modifications and additions to be incorporated later by the Employer. This shall include, but not be limited to:

i) Two (2) proven copies of all final source programmes on external hard diskwith the interactive facilities provided).

II) Final source programs;

iii) Block diagram or flow chart to show relationships with other programs (To be provided on software maintenance terminal only);

.18 POWER FAILURE/ RESTART

In the case of a power failure, the computer system shall provide for an orderly shutdown and automatic restart, of the computer, upon restoration of the supply without need for manual intervention. The system shall be designed in such a way that alarms/ status changes entering shall be saved in the mass memory devices. Once the memory reserved for such events becomes full, then blocks or parts of the first arrived information shall be erased allowing fresh data to be stored. This would ensure that upon an accidental loss of power supply at any given time the latest alarms and status changes are not irretrievably lost.

A copy of all main memory resident programs and tables shall be retained in machine language on the mass memory device for use as back up in the event the operating copy of these programs in the main memory is destroyed or accidentally over-written.

.19 IEEE SWC TEST

a) The system shall be designed to operate without error or equipment failure during application of a transient test voltage applied to each point and power supply input terminal in both longitudinal and transverse modes. The transient test voltage shall be as specified in the ANSI C37.90.1 Guide for Surge Withstand Capability (SWC) Tests.

.20 GPS BASED TIME FACILITY

GPS based time facility, to be determined from Universal Coordinated Time (UTC) source, shall be provided for computer system. The time receiver shall include propagation delay compensation to provide an overall accuracy of 1.5 microseconds and shall also include an offset to permit correction to local time.
The time receiver shall detect the loss of signal from the UTC source. A loss-of-signal shall be sent to the computer systems and used as a telemetry failure indication. Upon loss of signal, the time facility shall revert to an internal time base. The internal time base shall have minimum stability of 1 ppm. Within five minutes of reacquisition of signal, the time shall return to within 1.5 microsecond of UTC.
The GPS system receiver unit shall have digital display for viewing UTC day of the year and time in the format DDD: HH:MM:SS where the hour display shall be in 00 to 23 hour format and date in MM: DD: YY format.
GPS system shall also be used to drive Contractor-supplied time and day indicators suitable for panel/ Wall mounting. The display for time shall be in the 24-hour, HH:MM:SS format. The display for the day shall be XXX format (MON through SUN).
Digital display for AC bus frequency in XX.XX format shall be provided.
Each digit of all the indicators shall be at least 7.5 cm in height and shall be bright enough. All required interface in this regard should be included in the scope of supply. For further details on master clock, Clause 2.d of Annexure Cyber security_Rev1 shall be referred

.21 PERIPHERALS

Both the display monitors and the functional keyboards/mouse shall be mounted on the control desk. The location of these units shall be well integrated with the overall design of the control desks. The unit shall be arranged so that they are easily removable and replaceable for maintenance.
The printers and interactive facilities shall be free-standing, pedestal-mounted units with facilities for quick manual substitution.

4.7.4 TRANSIENT FAULT RECORDERS

4.7.4.1 GENERAL

The transient fault recorders (TFR) shall continuously monitor the power system. These could be integrated with operator control and monitoring system or supplied as stand alone units. TFR shall be provided at the back to back converter station. The TFR may be provided in the form of central unit together with Data Acquisition Units (DAUs). Initiation by any one of the fault detecting sensors or external initiating contacts shall cause the fault recorder to record on all channels. The record shall comprise, pre-fault information, time of fault information and post fault information.

The Contractor shall determine the number of analog and event inputs required for each recorder and supply these number plus 40% spare channels. The TFR shall also have facility for harmonic analysis upto 50th harmonics of waveforms. **The proposed TFR shall have a minimum sampling frequency of 40 kHz for all the channels.**
Recorders shall be of solid-state modular construction microprocessor based and without moving parts. First in, first out (FIFO) printing logic shall be used. The necessary software for directly analyzing the records on the magnetic memory of the TFR shall also be supplied.
Facilities shall also be provided for data retrieval from TFR and analyse by means of a master station based on compatible PC having minimum configuration of 2.8 GHz clock speed, 20 TB SSD hard disc &16 GB RAM capacity, complete with 21 inch LED monitor, keyboard/ mouse etc and include laser printer with capability to print on A3 and A4 size paper. All necessary software package(s) along with facility to communicate between TFR & PC shall be provided by the Contractor.

The contractor shall provide a separate TFR for each block. The corresponding TFR of a particular block shall collect the required block level signals from both main & standby C&P systems simultaneously. Further, the station level signals shall be interfaced with both block TFRs and recording of main & standby station level signals shall be done simultaneously.

4.7.4.2 APPLICATION

Basically, for the HVDC system, a fault recorder system shall be arranged to monitor and record critical power system signals for the back to back converter station. To facilitate interpretation of the recordings, transient fault recorder at the station shall be time-synchronized from the station master clock system

INPUT SIGNALS

The input signals and starting sensors required for the HVDC system for commissioning and operation shall be determined by the Contractor. The input signals to fault recorder system shall include, but not be limited to, the following:

- Valve group firing pulse markers;
- Valve group ignition delay angle response;
- Valve group voltage;
- Block current order;
- DC power own Block
- AC bus voltage (3 phases);
- AC current to each valve group and transformer primary currents.
- DC Current
- DC voltage Converter transformer secondary voltage
- Valve winding voltage

The Triggering of TFR shall include, but not be limited to following inputs:

- Block-2 Block/ Deblock

- Block Commutation Fail
- Block Firing pulse loss
- Block last Breaker opened
- Block DC Prot Voltage level
- trig.
- Block DC Prot dv/dt trig.
- Block di/dt
- Block 30 minutes, 2 hours & 5 seconds overload
- operated AC Over voltage/ under voltage prot operated.
- Full voltage/ RVO
- Idc Limit by VDCOL

DC O/V, U/V

Each fault recorder shall be equipped with suitable input circuits and starting sensors for all of the input signals. The Contractor shall ensure that the characteristics of the input circuits and starting sensors are well matched to the characteristics of the signal sources.

4.7.4.3 ELECTRICAL CHARACTERISTICS

.1 MONITORING SYSTEMS

The recorder shall be a digital based type. Operation of the equipment shall be based on programs stored in non-volatile solid-state memory. Programs shall be stable and no inadvertent change of program(s) shall occur.

The recorder shall be equipped with a built-in post fault record-length timer, adjustable over a range of 0.5 to 10 seconds after the fault.

Normally open operation alarm contacts shall close while the fault recorder system is operating and be utilized as inputs to the alarm monitoring and reporting system.

A three digit, manually resetable operations counter shall be provided that indicates the number of faults or disturbances recorded.

The system shall be microprocessor based with no moving parts and equipped with sufficient solid state memory to record and store until printout, complete information on the event and analog inputs. The storage and printing shall be on a first in first out (FIFO) basis. The information shall be retained in the system until the complete record of the event being printed has been printed out. If printing of a record is stopped by printer fault or for some other reasons the record of that event shall be retained and printed out completely once the printer fault has been cleared. If another system disturbance occurs during one post-fault run time, the recorder shall also be able to record the same.

Facility for automatic dumping of information to a PC or an independent storage device (e.g. a disc drive) shall be provided. Upon occurrence of a fault the data shall be automatically transferred to the floppy disc/solid state non-volatile memory. It shall be possible to obtain printouts from the non-volatile memory/ floppy disc later.

Preserved fault data shall not get erased unless done manually. Erasing arrangement for manually erasing the data shall be provided.

The output shall be printed on plain paper in the A4/A3 format. The printout shall be clear and legible without the help of looking glass or any such device.

The recorded information shall include but not necessarily be limited to:

- Station Identification
- Identity of trigger source
- Record Identification for Analog, Event and Sensor traces
- Date/ Time: Year, Day, Hour, Minute, Second, Millisecond
- Analog traces
- Event traces
- Sensor traces
- Time marker trace which shall allow time interpolation of records to 2 ms.
- Start of record line.

.2 OPERATIONS

The fault recorder shall continuously monitor the power system. Initiation by fault detecting sensors or by other input contacts or pre-selected events shall cause the recorder to record the fault information. Operation of any one of the initiating sensors shall start the recording mechanism or otherwise cause all channels to record until the fault clears or the record-length timer setting is exceeded.
The transient fault recorder shall have facility for suitable interface for transmission of recorded analog and digital information to a remote station. This shall be demonstrated by the Contractor at site by using inter-station communication.

.3 INPUT CIRCUITRY

The input circuits for the recording channels shall be insulated for operation at potentials of 2000 Vrms between channels and between channel and ground. Each input recording channel shall be capable of operating from the output of 1A rms nominal secondaries of current transformers and capacitive voltage transformers with 63.5V rated secondary. Each channel shall be supplied with a selection of current shunts and voltage multipliers to provide a range of high and low current or voltage ranges which can be selected by straps or similar method. The recorder shall also be capable of operating from the supplied DCCT's and existing direct voltage devices. Any device required for processing of input signals in order to make them compatible to the equipment shall form an integral part of the supplied equipment. However such processing of input signals shall in no way distort its waveform. The equipment shall be carefully screened, shielded, earthed and protected as may be required for its safe functioning. It shall be possible to position the reference point of any of the analog channels to any position on the record. The individual traces shall be identified on the record by numbering them in the order they are connected at the input.
The current values of scaling parameters related to the various channels shall be printed on each printout to enable quick interpretation of the records.

.4 STARTING SENSORS

The initiating or detecting devices, which start the recording, shall be solid state and automatic self-resetting type.

Each sensor shall be equipped with an indicating lamp, viewable from the front of the cabinet, which operates when the sensor operates. The lamp shall remain 'on' until reset by the station operator. Failure to reset the lamp shall not affect subsequent operation of the sensor. Sensor settings shall be easily adjustable and easily accessible. One starting sensor for at least each of the following types of changes shall be provided.

Level Changes	Over current
	Over voltage
	Under voltage
Swing	Rate of change of nominal input
Frequency	Under frequency
	Over frequency

It shall be possible to adjust the response time of the sensors, in each case, to ensure the most rapid operation consistent with the characteristics of the analogue quantity being monitored.

It shall also be possible to initiate the fault recording, as required, by additional external relay contacts, either N.O. or N.C.

.5 PRE-FAULT PERIODS

The recording system shall accurately record power system transient disturbances with a pre-fault period, which shall be settable between 50 to 500 ms.

.6 MEMORIES

Sufficient memory shall be provided to prevent any loss of records under all normal operating circumstances. The Bidder/ Contractor shall provide a table relating the memory size provided, to the following:

Scan rate, Effective chart speed, Pre-fault storage time, Number of analog and event channels, Post fault storage time, Total storage time.

The memory capacity at the lowest scan rate and with the maximum number of channels equipped shall be sufficient to allow a total record storage time of at least 10 seconds.

.7 TIME

A means shall be provided to record on the chart the time of occurrence of each fault or disturbance to a resolution of 2 milliseconds or better. The time clock shall be synchronized with the station master clock signal but shall continue to operate from a crystal oscillator secondary standard with an accuracy of 10-5 or better. Time printout shall be a numerical printing showing the day of the year, hour, minute and second along the edge of the chart paper once each second during disturbance recording. A transverse line extending across the record shall indicate the start of the event record. By means of this scale and the numerical time print out it shall be possible to relate events by interpolation between 10 millisecond markers to an

accuracy of at least 2 milliseconds at the lowest scan rate. The time printout message shall also include a station and system identification message.
Facility shall exist to display the time in hour, minutes and seconds on the front of the panel.

.8 CALIBRATIONS

The recording system shall be so designed that each channel may be calibrated separately. Calibration shall be accomplished by applying the calibration level input in the test switches. Controls and switches shall be provided on the front panel to facilitate calibratin.

.9 RESOLUTIONS

a) Analog resolution
Analog to digital conversion shall be 12 bits (minimum). The amplitude of the recording shall be adjustable and magnification in fixed steps, of the recording, shall be provided.
b) Events Resolution
The event resolution at the lowest scan rate shall be two milliseconds or better.
c) Transient Response (analog channels)
The transient response delay of the analog input conditioning circuits to a step function input shall be less than 400 microseconds between 10% and 90% values of the step function with overshoot of the final value of the step function being not more than 2%.

.10 RECORDING QUALITY

Static trace width	1.5 mm maximum
Residual channel noise	0.1% of full scale maximum at 50 Hz or any harmonic thereof
Recording resolution	0.1% of full scale
Phase error between channels	Less than 5 degrees at 50Hz
Crosstalk	Lower than 50 dB (DC to 1500 Hz)

Scale alteration/ expansion facilities shall be provided.

.11 ALARM CIRCUITS AND INDICATORS

Alarm circuits shall be provided to indicate inability for automatic operation due to power failure, out of paper condition, incorrect switch positioning or other failure(s), which shall be prominently visible on the recorder panel. Each alarm circuit shall include a normally open contact which shall be integrated into the station alarm monitoring and reporting system.

.12 POWER REQUIREMENTS

The recording system shall be suitable for operation from the station battery supply. There shall be no loss of accuracy in the recording system for specified variations of DC input voltage.

4.7.4.4 FACTORY TESTS

Tests shall be performed at the factory on each transient fault recorder system that shall include, but not be limited to, the following:

.1 TEST OF INSULATION

All input and output terminals shall be tested in accordance with IEC 60255-5. All input channel circuits to recording channels, shall be tested in accordance with IEC 60255-5 (Series C).

.2 TRANSIENT IMMUNITY

All input and output terminals shall be tested in both longitudinal and transverse modes in accordance with ANSI Standard C37.90a (SWC Test) for transient voltage immunity.

.3 HIGH FREQUENCY DISTURBANCE TEST

The equipment shall be subjected to high frequency disturbance test in conformity with IEC-60255, Part IV.

.4 POWER ABNORMALITIES

The system shall be tested for functional performance within specified accuracies for variations in input power over the specified range.

.5 TEMPERATURES

If the TFR panel is proposed to be placed in a non-temperature controlled area, the system shall be tested for functional performance within guaranteed accuracies at an ambient temperature of 50ºC for 8 hours in accordance with IEC 60068-2-2. Functional tests shall be performed initially at ambient temperature, then when temperature stability is achieved and then again after eight hours.
The system shall be operational continuously during the test.
Else, TFR shall be tested at 30 ºC for functional performance requirements.

.6 SOFTWARE

The tests shall begin by loading the complete software into the system from the actual software copies to be supplied with the system. Loading from disc or other mass storage device shall not be acceptable for this test. The tests shall then proceed using the software as loaded into the system.
All diagnostic software routines supplied with the system shall be demonstrated on the system during the tests using the actual copies to be supplied with the system.

.7 FUNCTIONAL TESTS

The system shall be tested thoroughly for each and every input, output and function to show that the system is completely operational and performs within specified accuracies.

.8 ACCEPTANCE TESTS

The acceptance tests shall include power abnormalities and functional tests as described in the preceding section.

4.8 REMOTE CONTROL, MONITORING AND TELECONTROL SYSTEMS

4.8.1 A limited (as defined further) remote monitoring of the HVDC system from the Load dispatch centres in Southern region and Eastern regions shall be provided. The transmission mode between HVDC terminals and Load dispatch centres shall be through an optical fibre communication system provided by the Employer. Existing Fibre Cable from the Gantry structure to the communication equipment can be used by the Contractor.

Link	**Voice**		**Data/VOIP/VC**	
	Administrative	**Express**	**Asynchronous (300/600/1200 bps)**	**Synchronous (2 Mbps)**
NRLDC	✓	✓	✓ (2 nos.)	✓

The asynchronous data interface is required for communication between Remote Terminal Units (RTU) to be located at Vizag to Southern Regional Load Dispatch Centre (SRLDC). There shall be two nos. asynchronous data channels (i.e. one main channel and one stand-by channel) between RTU and the respective LDC. The asynchronous data channels shall be compatible with V.24/V.28 as per CCITT.

The communication between RTU (i.e. RCI) Serial interface ports from HVDC SCADA system at Vizag and respective LDC is provided by Employer. However RTU shall be in the scope of Contractor.

The Contractor shall establish the DTE (Data Terminal Equipment) to DCE connections at the station and integrate with the Employer provided communication link for establishing the end-to-end connectivity. Provision of all the requisite routers, cables, connectors and line drivers, if any, shall be in the scope of the Contractor. Providing necessary routers, cables, wiring, connector, telephone instrument, interfaces etc. and end-to-end connection shall be under the Contractor's scope.

For performing the remote control, monitoring and telemetering function at the LDC, the Contractor shall provide two serial ports at Vizag. Each serial port shall support the EIA RS 232C (CCITT V.24/V.28) asynchronous/synchronous interface capable of operating between 50 and 9600 bps. The communication protocol shall be as per IEC 60870-5-101 (hamming distance 4) at converter station. The Contractor shall demonstrate the required signals at the interface point in the converter station. The

system shall also include modems, if required for communication with the LDCs, which shall support communication data rates from 300 to 1200 bps.
OPGW Communication channel link between HVDC station & LDC for this purpose is provided by employer.

SECTION4: PERFORMANCE REQUIREMENTS

Further, the contractor shall comply with all requirements of Annexure – Communication and statutory requirements. The contractor shall note that the document can be updated from time to time and the latest version (available on POSOCO website) shall be complied with at the time of commissioning of the link.

4.9 Not Used

4.10 AC HARMONIC FILTERS

Existing AC Harmonic Filters to be utilized. The details will be provided to the successful bidder during detail engineering. The control system supplied by the Contractor shall not compromise the existing filters ratings.
Measurement for AC Harmonics currents of the converter shall be carried out for pre-refurbishment and post – refurbishment for same active power conditions with one block and two blocks in operation .

The measurement points for this AC harmonic measurements shall be on Vizag East and South buses.
Contractor shall perform filter rating verification study as part of contract, so as to establish that the refurbishment of HVDC under this scope does not compromise the equipment ratings of the AC filters in all respects.

4.11 INTERFERENCE AND AUDIBLE NOISE LEVELS

4.11.1 GENERAL

The Contractor shall take all the necessary precautions to ensure that there shall be no mal-operation, damage or danger to any equipment, system or personnel due to electromagnetic or electrostatic interference effects. The converter terminal(s) shall neither damage or cause mal-operation of the dc control and protection system. The Contractor shall take all the necessary precautions in the form of noise suppression techniques, shielding and filtering devices to prevent harmful interference which may be generated by the converter terminals to the following systems over the specified frequency ranges:

a) Power line carrier (PLC): 40 kHz to 500 KHz
b) Radio communication systems: 0.15 MHz to 300 MHz
c) Television systems: 30 MHz to 1000 MHz
d) VHF, UHF & microwave radio systems.

Any filtering required to mitigate interference to the specified levels shall be installed at the converter terminal itself unless an alternative arrangement is specifically selected by the Employer at the time of Contract award.
Refer Annexure Interference and Audible noise levels

4.11.2 RADIO INTERFERENCE (RI)

The Contractor shall take the necessary precautions in the form of valve hall and building shielding to meet his own requirements plus the following:

(a) With the converter operating at any of the specified operating modes and power levels and within the design range of firing angles, the radio interference level (RIL)from electromagnetic radiation generated by the converter station shall not exceed 100 microvolt/m under fair weather conditions outside the fence which are:

- 500 meters or more from the nearest bus connecting the valve to the converter transformers within the station and
- at a lateral distance of 30 m for the conductors of any out going ac line.

(b) This RIL criteria shall be achieved at all frequencies within the range of 0.15 MHz-to-300 MHz, and with the complete two 500 MW 12-pulse bridges operating at any dc power transfer level up to and including rated value. The design shall provide for quickly adding additional corrective measures, at no extra cost to the Employer, and in a way so as to not jeopardize reliable commercial operation, should the specified performance not be achieved in the actual installation.

c)The shielding shall be designed so that the specified radio interference levels shall not be exceeded assuming any earth resistivity between 10 and 1000 ohm-meter.

d)Measurements of actual RIL at each station shall be made by the Contractor, at points along the above defined contour and at other critical points. For transmission lines, measurement shall be made at a distance of about 1 Km from each station at the mid point of a span.

Measurements shall be made with the ac switchyard and ac transmission lines energized and the HVDC system in operation.

Measuring instruments shall comply with the American National Standard Institute Specifications for Electromagnetic Noise and Field Strength Instrumentation 10 kHz to 1 GHz, ANSI C63.2 (1 by 160 ms charge & discharge times, 9 kHz bandwidth). The method of measurement shall comply with IEC Standards 61000-4-6 and 61000-4-3 in the frequency range 150 kHz to 1000 MHz.
Measurements shall be made at a quasi-peak setting and shall include at least three complete frequency scans at each selected location. The RIL at a particular frequency and location shall be considered to be the average value of all measurements taken at that frequency and location.

The measuring procedure shall be submitted to the Employer for approval prior to measurements being made and a final report shall be submitted after completion of all measurements.

4.11.3 400 KV AC EQUIPMENT

Maximum radio interference voltage for frequency between 0.5 MHz to 2 MHz at 1.1 times of maximum DC voltage for DC system, 320 kV RMS for 400 kV system and 156 kV RMS for 220 kV system and 92 kV RMS for 132 kV system shall be 2500, 1000, 1000 and 500 micro Volt respectively.

4.11.4 TELEVISION INTERFERENCE (TVI)

The Television Interference Level (TVIL) generated by "gap type" or "defect" discharges shall not exceed 10 micro volts/m at the locations/contour line specified above in Clause 4.11.2.

The measurements shall be made by the Contractor when the installations are complete and are in operation, in accordance with the measurement procedures defined for signals in IEC Standard 61000-4-3 in the frequency range 80 to 1000 MHz .Instruments in accordance with ANSI C63.3 shall be used. The measuring antenna shall be at a height of 6 m or more above ground.

The procedures shall be submitted to the Employer for approval prior to measurements being made and a final report shall be submitted after completion of all measurements.

4.11.5 INTERFERENCE WITH POWER-LINE CARRIER SYSTEMS

4.11.5.1 General

The Contractor shall take the necessary precautions in the form of noise suppression techniques and filtering devices to prevent harmful interference from the converter station including interference from the dynamic reactive compensation , if these are provided, to power-line carrier (PLC) systems operating on the HVAC transmission line networks connected to converter station
The frequency spectra to be protected are:
System Frequency Spectrum Power-line carrier 40 kHz to 500 kHz

The Contractor shall provide information on the noise spectrum at the termination of the HVDC converter station in the frequency range 40 kHz to 500 kHz.

Information on existing and planned power-line carrier systems shall be given to the Contractor by the Employer.

4.11.5.2 INTERFERENCE STUDY

During the detailed design stage, the Contractor shall perform a detailed interference study, based on final data to be submitted at that time by the Employer, to determine the extent and severity of possible PLC and open-wire carrier interference from the HVDC system and provide details of necessary carrier frequency and/or other mitigating measures necessary to avoid harmful interference. The interference study calculations shall be submitted to the Employer and shall include, but shall not be limited to, the following:

a) Probable normal carrier frequency noise levels, plus prediction of the frequency of occurrence and duration of guaranteed maximum carrier frequency noise levels on the ac and dc side of the converter valves.
b) Sensitivity to interference from the HVDC facility to each PLC and open-wire carrier system. Predicted dB decrease in normal and worst case signal-to-noise ratios for each PLC and open-wire carrier system due to interference from the HVDC system, and associated dynamic compensation, if any.
c) Limit values for carrier frequency noise on the HVAC busses that are necessary to avoid harmful interference to the carrier systems studied.
d) Detailed designs and noise reduction performance calculations for additional carrier frequency filtering required to meet the limits derived in (c) above.
e) Carrier-frequency mutual coupling loss characteristics between the various transmission lines.
f) Carrier-frequency insertion loss characteristics for converter station equipment such as converter transformers, smoothing reactors and surge capacitors.
g) Carrier-frequency insertion loss characteristics and detailed designs for carrier frequency filters and/or the other mitigating equipment adopted to meet specified interference limits.

4.11.5.3 TESTS

A test programme describing the method to make measurements of actual carrier noise levels produced by the converter terminals shall be submitted by the Contractor for the approval of Employer. These measurements shall be used to demonstrate compliance with the above requirements.

The measurements of actual noise levels in the carrier-frequency spectrum due to operation of the converter station and at other locations in accordance the test programme shall be performed by the Contractor.

4.11.6 INTERFERENCE WITH CONTROL SYSTEM AND OTHER COMMUNICATION SYSTEMS

4.11.6.1 GENERAL

The Contractor shall take the necessary precautions in the form of noise suppression techniques, shielding and filtering devices to prevent harmful interference from the converter station to any of the control systems and other communication systems such as micro-wave or HF, VHF, and UHF radio systems installed at site.

4.11.6.2 DESIGN CRITERIA

In order to meet the above requirements in the converter building, the Contractor shall submit calculations to the Employer including, but not limited to, the following:

a)The predicted radiated and conducted noise levels from the converter valves in the frequency spectra of concern inside the valve halls.

b)The allowable noise levels in the various areas of the converter building, including control room and other identifiable communications rooms in the HVDC station, which shall meet the station interference criteria for communication and control systems.

c)The type of noise interference mitigation measures and their performance details which the Contractor shall provide as part of the scope of supply to reduce the sensitivity to interference of Contractor-supplied control and other equipment.

d)The type of screening/shielding necessary and expected insertion loss performance for valve halls and any other areas in the converter building which the Contractor considers is necessary to reduce the noise levels in (a) above to the levels in (b) above.

The Contractor shall guarantee that the interference to communications and control systems shall not exceed the specified interference limits.

4.11.6.3 INTERFERENCE LIMITS

a)No worse than 1.5 dB decrease in signal-to-noise ratio in the microwave communication system for any voice channel, voice channel slot or group channel slot in the microwave radio system.

b)No measurable degradation in data circuit bit error rate or telephone circuit signalling on any circuit in the microwave communication system.

c)No worse than 3 dB decrease in signal-to-noise ratio measured at voice frequency on the UHF or VHF radio systems.

4.11.6.4 TESTS

The Contractor shall perform measurements of actual noise levels, in the frequency spectra of concern, produced due to operation of the converter station and of actual interference to communications and control equipment at site in accordance with a test program prepared by the Contractor and approved by the Employer.

4.11.7 AUDIBLE NOISE:

The Contractor shall limit the audible noise for various areas of the converter station and buildings in his scope of work to the following values and demonstrate by calculation and site measurement that the specified levels shall not be exceeded

Mechanical Equipment Indoor areas having long term access (measured at 2 meter distance) : 75 dBA

Equipment in outdoor areas (measured at 15 meter distance) : 75dBA

4.12 ENGINEERING STUDIES REQUIREMENTS

4.12.1 GENERAL

The Contractor shall submit all reports on the system studies, engineering and the design of the Works and shall satisfy the Employer as to the adequacy of the studies to be carried out in accordance with the Contract.

The Contractor shall carry out comprehensive studies for the present scope of the project. The Contractor shall perform all studies according to the schedule established for the Contract. The Employer shall have the right to observe and participate in the studies performed as part of the Contract and shall have access to all data necessary for a complete understanding of the purpose & procedure of such studies as well as the validity of the results. The Employer shall, from time to time, notify in advance to the Contractor which of the aforesaid studies he wishes to observe and participate in and the Contractor shall give the Employer at least thirty days prior notice before commencement of the above said studies. The results of the preliminary design performed for the preparation of the proposal shall be included in the Contractor’s bid. However, all studies would be repeated during the detailed engineering of the project conforming to the technical specification requirements and all equipment would be provided and rated as per final study result. Some of the studies to be performed during the progress of the Works shall be performed by the Contractor in consultation and/or with the participation of the Employer. Regarding participation of Employer in various studies, a firm schedule for every such study shall be agreed prior to start of the engineering work.

The study reports shall include, but not be limited to the following:

a)Study objectives
b)Initial conditions, data and assumptions
c)Codes, standards and criteria used in the studies
d)Description of means and methods used in the studies
e)Computer models and data used in the studies to represent the Contractor's HVDC equipment and the Employer's equipment
f) Summary of study results
g)Conclusions

Items a) through e) above shall be submitted to the Employer for review and comment before the studies start.

The digital model used shall be valid for a frequency range from 0.0Hz (steady-state) up to high frequencies (step change).
The software for the digital model shall include:

- Transfer function block diagrams (showing the performance) along with the parameters
- Input and output variables of each transfer function block (showing the performance) along with their standardized system.
- Flow charts / logic diagrams of the entire control features

The Contractor shall use proven software/hardware tools in the system studies for this HVDC project. The Employer will only accept study results generated with tools approved by Employer. If the Contractor wishes to utilize special tools, including special computer programs, Contractor shall submit the same to the Employer for his review and approval.

h)The conditions, data and equivalent circuits given in this Specification shall be used for all preliminary studies. After the Award of the Contract, the Employer will provide data which shall be used by the Contractor in doing studies specified in this section. The Contractor shall have his database approved by the Employer prior to commencement of studies during post award detailed engineering. The Contractor shall make available to the Employer all his data files on external hard disk. He shall also furnish base case data file(s) for the studies carried out and other files as and when requested by the Employer.

The Employer shall be able to open these files or files on external hard disk or on their own PC .

The power system model shall be used if it is possible for the particular study item. For some study items, where it may be very difficult or unnecessary to use the whole system model, equivalent models can be utilized subject to the Employer's approval.

4.12.2 STUDIES BY THE CONTRACTOR

The Contractor shall perform studies to confirm the ratings of all equipment to be supplied for the project. If required, the Contractor can go ahead with manufacturing before carrying out the detailed studies at his own risk and cost. These studies shall include, but not be limited to the following:

i) Main circuit calculation
ii) Thermal Rating Study for Key Equipment
iii) Studies for Reactive Power Compensation and Balance
iv) Temporary Over voltage
v) Studies on Overvoltage Protection and Insulation Co-ordination
vi) Transient Current Requirement Study
vii) PLC/RI Performance
viii)Reliability and Availability predictions
ix) Loss Study

x) Sub-synchronous resonance / oscillation.
xi) Studies of DC Current Flowing through Windings of Converter Transformers
xii) Load Flow and Stability Study
xiii) Terminal faults, fault recovery, control coordination, commutation failure and its recovery etc.
xiv) Filter rating verification study
xv) Transient Recovery Voltage study for AC Breakers of HVDC Vizag
xvi) Low order harmonic filter resonance study

4.12.3 Studies for the Control, Protection and Communication Systems

The Contractor shall perform all system studies for determining the performance of control and protection equipment, design studies on software/hardware for control and protection system, development studies, key techniques study, commissioning and acceptance test study, etc., and submit study and design reports to the Employer.

The Contractor's study reports shall include the following study results:

i) Dynamic Performance Study
ii) Hierarchical Structure of the Control and Protection
iii) Redundancy of the Control and Protection Systems
iv) DC Power and Current Control Modes and Features
v) Switching Sequences and interlocking
vi) AC & DC System Protections

For each protection, the report shall include the following:

a) Purpose of the protection
b) Principle of protection operation
c) Required accuracy of measuring signals
d) Fault detection and coordination between the DC controls and the protection and AC protection.
e) Consequences of protection operation, such as DC control and sequence control initiated by the converter
f) Redundancy of protection and operation of backup protection
g) Detailed calculations of the protection settings together with limiting fault cases and/or criteria that determine these settings.
h) Description of the applicable protection in case of loss of telecommunication.

vii) Reactive Power Control

The study shall include at least the following:
a) Reactive power control principles for converter operation during steady state and transient conditions
b) Reference variable control criteria
c) Criteria for switching of reactive power subbanks

d)Coordination with any DC converter reactive control capability if supplied

e)Operator operation, including control and monitoring features

f)Equipment description , emphasizing reliability/availability and maintenance features.

g)Validity checking of signals

h)Switchover and control feature between AC voltage/reactive power controls

The report shall include the studies of the following control modes with the AC network condition on both sides of the Block and actual performance of converter equipment and possible fault condition being taken into account:

a) Power ramp down

b)Power ramp up

c)Damping of subsynchronous oscillations

d)Abnormal AC voltage and frequency control

e)Supplementary modulation signals

Viii)System Study for interaction of HVDC Systems in Indian grid.

ix)Commutation failure performance study
x) Runback control
xi) Damping control
Xii) Station control and SCADA system
xiii) Control for converter Transformer Tap changer xiv) Hardware design
xv)Harmonic measurement:

xvii)Commutation failure performance study

4.12.4Statuary requirements

Refer Annexure: Communication and statutory requirement for the statuary requirements or latest CEA/ Grid India guidelines in their website.