

6.0 GENERAL

The Contractor shall provide all equipment necessary to meet the operational and performance requirements of the Specification as per present scope. In this Section (6) of the Specification technical requirements for various major equipment have been specified.

The equipment shall be designed to operate in the environmental and system conditions as specified in Section 2 of this Specification.

The equipment shall comply with the relevant standards as defined in Section 3, Section 6 and elsewhere. They shall satisfy the General Technical Requirements specified in Section 3 and elsewhere unless otherwise specified in Section 6.

It is not the intent to specify completely herein all details of the design and construction of equipment. However, the equipment shall conform in all respects to high standards of engineering, design and workmanship and shall be capable of performing, in continuous, commercial operation in a manner acceptable to the Employer, who shall interpret the meanings of drawings and Specification and shall have the power to reject any work or material which, in his judgment, is not in accordance therewith. The equipment shall be complete with all components necessary for their effective and trouble free operation and such components shall be deemed to be within the scope of the Contractor's supply irrespective of whether those are specifically brought out in this Specification and/or the Contract or not.

The Contractor shall carry out a comprehensive inspection and testing programme during manufacture of the equipment. An indication of inspection/ testing envisaged by the Employer is given in subsequent clauses. This is however not intended to form a comprehensive programme as it is the Contractor's responsibility to draw up and carry out such a programme in the form of detailed quality plan duly approved by the Employer for necessary implementation.

6.1 THYRISTOR VALVES AND ASSOCIATED EQUIPMENT

6.1.1 DEFINITIONS

1. A 'Valve' is all the components, external to the main assembly which forms one of the 6 arms of a 6 pulse Graetz converter bridge.
2. A 'multiple valve unit' is an assembly of a number of valves mounted into a single structure (these include components mounted on the valve structure, e.g., saturable reactor, surge arrester) which may be considered part of the valve.
3. A 'valve module' is the smallest assembly, comprising a number of thyristor levels, voltage grading and damping components, valve

reactors, etc. from which the valve is built up and which exhibits the same electrical properties as the complete valve, but only a portion of the full voltage capability of the valve.

'Tier Assembly' is the assembly of thyristors mounted in pairs in clamped sub- assemblies, each sub assembly having integral series reactor, damping resistor support & cooling surfaces. Valve is built up using tier assemblies.

If the Bidder have 'Tier Assembly' concept in building up of valves then tests referring to modules in subsequent sections shall be conducted on Tier Assembly.

4. A 'thyristor level' comprises a single thyristor, control, protection, monitoring, auxiliary power and voltage grading components which make up a single voltage level within the valve.
5. The 'redundancy' is the number of additional thyristor levels which are installed on a valve above the number which are necessary to provide a guarantee that the valve shall withstand the various specified test voltages.
6. 'Complete fault suppression capability' is defined as the ability of the valve to withstand one asymmetrical loop of the highest short-circuit over current it shall experience due to any fault and maintain full blocking capability on immediate reapplication of the maximum design fundamental frequency over voltage which can occur simultaneously with the highest value of short circuit over current, for which the valve remains conducting without damage to the valve or permanent change in valve characteristics with the valve in the following condition prior to the fault :
 - i) all the redundancy is used up
 - ii) cooling water at the maximum temperature consistent with iii) below
 - iii) the thyristor junction temperature is the maximum it shall reach during the short-time overload condition specified in Clause 4.1 after a period of operating at the nominal rating.

The junction temperature shall not be achieved by external heating of Thyristor Valve Modules during testing .

7. The 'Redundant Thyristor The
'Redundant Thyristor Factor'

$$(fr) fr = Nt / (Nt - Nr)$$

N t = total number of thyristor levels in the valve

N r = the redundancy (as defined above) in the valve

8. Valve for type testing

For those tests where it is specified that the test shall be on a

complete valve, it is intended that the valve shall be erected complete with all ancillary components as far as possible. In particular, the thyristor cooling shall reasonably represent the service conditions, as far as is necessary for the test in question.

9. Modules for type testing

For those tests where it is specified that the test may be performed upon a module, the module tested shall be:

- a valve module, or
- a part of a valve module or
- more than one valve module

in a connection appropriate to the requirements and taking full account of the particular design characteristics of the valve.

6.1.2 GENERAL REQUIREMENTS

1. In line with the existing arrangement, new thyristor valves shall also be Floor mounted quadruple valve. The valve shall be designed and rated to meet the performance requirements described in Section 4 and as described below. The valves shall be of the indoor air insulated type. They shall be of modular design for ease of maintenance. The proposed thyristor shall be of a type in commercial production with fully proven characteristics. The Bidder shall indicate in the bid regarding significant departures from previous designs of valves in service in HVDC applications.
2. The valves shall be cooled by water. Best engineering methods available shall be employed to ensure that no water leak can occur in service and is minimized during maintenance activities. The number of connections which have to be opened to change modules or components shall be minimized and the replacement of thyristor shall be of the quick-release type if replacement of thyristors is required. If a leak should occur, the operational efficiency of the valve shall in no way be impaired, and means of disposing of, and cleaning, of such water leakage shall be provided. An alarm shall be initiated in the event of such a leak. In the event of catastrophic leak, the converter shall be taken out of service automatically to minimize damage to the plant. The corrosion of any material surfaces in contact with the cooling water shall be minimized, and the rate of corrosion shall not reduce design life of the plant i.e. at least forty years. The Employer/Consultant shall carry out design review of the Cooling system Design during detailed engineering. The Contractors shall furnish details of the Cooling system components, design philosophy, design criteria and all relevant details as may be sought by the Employer or his Consultant during design review.
3. The converter design shall take into account the effect of any additional leakage currents which may occur in the event of a failure of a thyristor level. Any plastic components shall be of a type which is not degraded by corona discharges. If such material is used, the Contractor shall satisfy the Employer that there cannot be any corona discharge in the

vicinity of the plastic components.

4. The valve shall be designed and protected during operating conditions for various over voltage and over current stresses to which it may be subjected to due to faults occurring in various parts of the station, including those described in Section 4 of this Specification.
5. Status of each thyristor level on the valve while the equipment is in service shall be monitored, and the Contractor shall demonstrate the reliability of the monitoring equipment.
6. The Bidder shall offer equipment which monitors on line the individual thyristors continuously and annunciate individual thyristor failure in the control room and shall also initiate alarms in case of failure of redundant thyristors levels The Bidder is to propose the number of thyristor failures at which a trip of the converter shall be initiated. Where protective firing is provided, the valve shall be designed to allow protective firing of thyristor levels. It shall be possible to detect by the monitoring equipment the turn on of the individual thyristor levels due to protective firing. The protective firing shall not operate for inverter commutation transients occurring during maximum temporary over voltage due to load rejection e.g. following ac system fault and shall not effect subsequent recovery of the dc system.
7. All power thyristors shall carry an individual serial number. A cross reference system shall provide quick access to the test data for any thyristor and to the location of any thyristor within the valve structures.
8. The Contractor shall provide thyristor test equipment complete with all required accessories at site, for maintenance and fault diagnostics.
9. The Contractor shall ensure that while designing the structure for supporting the MVUs (Multiple Valve Unit), sufficient space between valve sections is provided to reduce the risk of spread of fire. The Contractor shall in view of the same reason design for the placement of elements in the grading circuit in an appropriate fashion. The material which shall be used as a base for holding the grading circuits, as barriers between units within a valve section or between two tiers of valve section and any other combustible material in a MVU shall be chosen to the complete satisfaction of the Employer. No oil immersed part is permitted to be used inside the valve as well as valve hall. The electronic components located within the valve shall be designed to eliminate overheat and arcing. Only components of low flammability, high reliability and adequate ratings in margins can be used. The thyristor control unit should be housed and isolated completely from other parts inside the valve by the non-combustible material. Fire barriers of non-combustible material between the adjoining materials or sections of the fibre optic channel or other measures taken in order to eliminate lateral or vertical propagation of fire through adjoining plastic material or fibre optic channels shall be installed. The fire barriers should be in proper arrangement to avoid overheats of parts inside valve.
10. All thyristor including spare thyristors shall be identical and interchangeable within the back to back converter station.

6.1.3 MAINTENANCE

- .1 The valve shall be designed so that it is easy to clean and change modules or components in the valve assembly. It shall be possible to carry out replacement of one module or components within two hour from shutdown to start-up excluding time for switching procedures, but including the time required for identification of the faulty module or component.
- .2 The principal maintenance intervals shall not be less than twelve months. The Bidder shall state the length of period and number of man hours required for the principal maintenance. Short maintenance period (not exceeding four hours) to change modules or components shall be permissible for one 12-pulse converter unit at every twelve months interval.
- .3 Routine inspection and maintenance shall be possible for grading electrode. The corrosion or deposit of material of electrode shall not be acceptable. The failure of electrode shall not result in water leak within the valve. The life expectancy of the grading electrode shall not be less than 20 years.

6.1.4 VALVE TRANSIENT OVERVOLTAGE CAPABILITY

- .1 The valve transient over voltage capability shall be:
 - 15% margin over the arrester protective level for switching surges
 - 15% margin over the arrester protective level for lightning surges
 - 20% margin over the arrester protective level for steep-front surges as determined during studies by the Contractor in line with IEC- 60071-11 and IEC-60071-12.
- .2 Where the valve has been provided with protective firing for over voltages in the forward direction it shall be based on the following conditions:
 - The valve arrester shall be the main valve protection against switching over voltages and lightning over voltages.
 - The protective firing shall not be the main valve protection for switching and lightning over voltages.
Protective firing being applied only in the event of large uneven voltage distribution within the valve or high dv/dt in the forward direction due to component or insulation failure
 - the minimum protective firing threshold shall be at least 5% over maximum valve arrestor protective level for switching over voltages. This shall be verified during Valve testing. Further,

protective firing action shall not cause the valve to turn on under dynamic over voltage conditions as defined in Section 4 for which control of the valve is required to be maintained.

- The protective firing shall not operate for inverter commutation transients occurring during maximum temporary over voltage; e.g. following ac system fault and shall not effect subsequent recovery of the dc system.

Bidder shall ensure that protective Firing Shall not occur during lightning strike on connected DC and AC side. This condition shall not be applicable during fault clearing actions at HVDC terminal.

6.1.5 REDUNDANCY

A number of extra thyristor voltage levels shall be included in each valve to allow for failure of individual components during the twelve-month maintenance cycle. Failure of the thyristor level means failure of a thyristor or any associated component in the valve, which functionally reduces the number of thyristor levels in the valve.

- .1 The number of redundant thyristors shall be such that the redundancy as defined is exhausted in not more than one valve of the 500 MW, 12-pulse bridges during the operating period between the scheduled maintenance, assuming no failed thyristors at the beginning of the period and continuous operation without replacement of any thyristors that fail during the period. The redundancy shall not be less than 3.0% of the total number of thyristors in the valve.
- .2 The calculation of the number of failures of thyristors shall be based on guaranteed failure rate of thyristors and associated elements. The Bidder shall state the total number of thyristor levels in a valve.

6.1.6 VALVE TRANSIENT OVERCURRENT CAPABILITY

With respect to transient over currents due to faults, the valve shall have the following Capabilities:

- .1 Complete fault suppression capability as defined in Clause 6.1.1.6 of the Specification.
- .2 Carrying three complete asymmetrical loops of the highest short circuit over current the valve shall experience due to any fault without requiring to block any voltage in the forward direction but capable of withstanding, between short-circuit current loops, an ac voltage in the reverse direction corresponding to a recovery voltage equal to the maximum dynamic fundamental frequency over voltage, which can occur simultaneously with the highest value of short-circuit over current, for which the valves remain conducting. The ratio between the maximum valve short circuit current and the thyristor surge current capability shall be stated

during detailed engineering.

- .3 After carrying full rated current for 200 ms or any other time and magnitude as verified from studies in bypass operation, the valve shall be able to withstand a positive polarity switching impulse voltage of peak value up to the protective firing voltage level of the valve, occurring in the recovery period of an inverter valve which is recovering from a near commutation failure condition. The Contractor shall provide calculations to justify that thyristor junction temperature during bypass operation shall be less or not onerous than the conditions specified for complete fault suppression capability as defined in clause 6.1.1.6.
- .4 For these severe faults, the bidder shall state the time for the converter protection to initiate a trip signal and the time for the AC circuit breaker to clear the fault.
- .5 For calculation of valve fault currents, consideration shall be given, but not limited, to the following :
 - a fault across another valve
 - fault across a bridge
 - neutral to ground fault of a wye-connected transformer with fault on the valve winding side
- .6 These calculations supported by cycle-by-cycle time domain simulations (PSCAD type) and details of the cases considered, the assumptions made, and the method of calculation used in determining the maximum over current used for dimensioning the valve for its transient over current capability, shall be given in the Detailed Engineering.
- .7 Valve designs which do not allow for the faults mentioned above or use over current diverters shall not be acceptable.
- .8 The bidder to provide the short circuit current capability of thyristor valve for a flashover across the valve, taking into consideration, the relevant parameters like DOV, system impedance, Converter Transformer reactance, firing angle and tap position etc.

6.1.7 VALVE CONTROL AND PROTECTION

- .1 The Light guides connecting the valve electronics to the valve based electronics shall be arranged so that the light guides may be easily disconnected and removed. The light guides shall be protected from mechanical damages or abrasion once installed. The Light Guides shall be suitable for operation under high DC field environment.
- .2 The valves and associated protection shall be designed to tolerate complete loss of auxiliary power without valve damage. If a transfer scheme is required in the power supply to the valves, then the valve controls and protection shall be capable of recovering transmission within a total interruption time not greater than the permissible

temporary blocking interval.

6.1.8 Not used

6.1.9 TESTING

6.1.9.1 GENERAL

- .1 The tests on the thyristor valves, which are to include but not be limited to those in this item, shall be performed as per the test program and test specification to be submitted for the approval of the Employer prior to commencement of test. Full details of the test results shall be submitted to the Employer for approval.
- .2 The Bidder/Contractor shall submit a test program with test levels and procedures.
- .3 Correction factor shall be applied to test voltages, wherever applicable, based on the data provided for the project site.
- .4 During partial discharge measurement, the criteria for successful PD measurement for ac and dc tests shall be as per IEC 60700-1.
- .5 Wherein not explicitly stated or intended otherwise in the technical specification, testing of the thyristor valves shall be as per IEC 60700-1.
- .6 A hot valve is defined to be one with the junction temperature of its thyristors equal to the maximum permissible steady- state temperature. This will generally be obtained at the maximum current rating (including overload capability) and the corresponding maximum permissible temperature of the cooling medium. The hot valve condition can be achieved by
 - (i) combination of current and increasing cooling media temperature
 - or
 - (ii) By increasing only the cooling media temperature subject to employer's approval.

The applicable tests shall be carried out in the complete valve.

7. Minimum no. of shots for lightning and switching impulse test of dielectric test for MVU , Valve and Valve base shall be 5(five) of each polarity

6.1.9.2 Classification of Test.

- .1 MAJOR CLASSIFICATION OF TESTS IS:
 - i) Tests on a multiple valve unit (MVU)
 - ii) Tests on a valve
 - iii) Tests on valve modules
 - iv) Tests on a valve base
 - v) Tests on individual valve components

- .2 A further classification of the tests is:
 - i) Type tests, which verify that the valve design shall meet the specified requirements
 - ii) Routine tests : production tests carried out on all valve modules or components

6.1.9.3 Summary of Tests

6.1.9.3.1 TYPE TESTS

- .1 Tests on Multiple Valve Unit (MVU):
 - i) DC voltage test to earth.
 - ii) AC voltage test. (Only applicable if AC Voltage is applied on MVU Terminals during operating conditions)
 - iii) Switching impulse withstand voltage test
 - iv) Lightning impulse withstand voltage test
 - v) Steep-Front impulse voltage test. (Only applicable if Steep Front Impulse Voltage is applied on MVU Terminals during operating conditions)

- .2 **Voltage Tests on Valve:**
 - i) DC withstand voltage test
 - ii) Wet dc withstand voltage test
 - iii) AC withstand voltage test
 - iv) Switching impulse withstand voltage test
 - v) Wet switching impulse withstand voltage test
 - vi) Lightning impulse withstand voltage test
 - vii) Steep-front impulse withstand voltage test
 - viii) Non-periodic firing test

- .3 **Operational Tests on Valve modules:**
 - i) Maximum continuous operating duty tests
 - ii) Maximum temporary operating duty tests
 - iii) Minimum alternating voltage tests
 - iv) Temporary under voltage tests
 - v) Intermittent direct current test
 - vi) Valve losses test
 - vii) Transient forward voltage during thyristor recovery period
 - viii) Short-circuit current without subsequent blocking test
 - ix) Short-Circuit current with subsequent blocking test.

- .4 **Voltage Tests on Valve Base**
 - i) DC withstand voltage test

- ii) AC withstand voltage test
- iii) Switching impulse withstand voltage test
- iv) Lightning impulse withstand voltage test
- v) Steep front Impulse test (Only applicable if Steep Front Impulse Voltage is applied on MVU Terminals during operating conditions)

6.1.9.3.2 ROUTINE TESTS

- .1 Connection check
- .2 Voltage grading circuit test
- .3 Check of auxiliaries
- .4 Firing check
- .5 Voltage withstand check
- .6 Pressure test at an overpressure of 1.5 pu of the design pressure.
- .7 Tests on individual valve components

6.1.9.4 Check for Degradation of Components of Multiple Valve Units, Valves, or Modules

- Prior to the start of the type tests, multiple valve units, valves, and modules (referred to as "test objects" in future), shall be demonstrated to pass the routine test procedure described below, together with any other commissioning checks that may be required to demonstrate that the equipment is initially in the correct working condition.
- Prior to the commencement of testing the Contractor shall define the maximum permissible change in snubber / damping circuit impedance for which the valve has been designed, and justify this value to the satisfaction of the Employer. In the event of a change in impedance greater than this value the associated thyristor level shall be considered to have failed.
- Check of the grading network impedance of each thyristor level at low and high frequency. During the last test of the test sequence, both in phase and quadrature components are checked.
- Check of the gate unit power supply charging.
- Check of thyristor gating in response to optical signals.
- The function of the monitoring circuits for the thyristor control unit is checked. Check of the optical data back system.
- Check of electronic dV/dt protection.
- Power frequency withstand test of each thyristor level.
- Switching impulse test in both forward and reverse

direction. Voltage level for protective firing is also checked.

- Voltage divider impedance check
- After each individual test every single thyristor shall be checked for short-circuit with the monitoring system. At the completion of the type test programme, all the test objects shall undergo a repeat of the above routine test procedure. Thyristor level short circuit occurring during the repeat routine tests shall be counted as part of the criteria for acceptance.

If faults or degradation not leading to a thyristor short circuit are discovered during the type tests, then the number and distribution of faults shall be assessed by the Employer and the manufacturer to determine whether systematic or random nature failures have occurred.

6.1.9.5 Test Circuits

A test circuit shall be such as to adequately test the performance of the

valve under realistic worst case stress conditions and shall demonstrate in a simple and conclusive manner the capability of the valve. All test circuits and test procedures shall be approved by the Employer/Engineer.

6.1.9.6 Criteria for Successful Type Testing

.1 The criteria stated here applies to the tests given below:

| Type Test | To be Performed On | Sub-Item No. |
|--|-----------------------|--------------|
| DC voltage test to earth. | 1 Multiple Valve Unit | 6.1.9.7(a) |
| AC voltage test | 1 Multiple Valve Unit | 6.1.9.7(b) |
| Switching Impulse Withstand Voltage Test | 1 Multiple Valve Unit | 6.1.9.7(c) |
| Lightning Impulse Withstand Voltage Test | 1 Multiple Valve Unit | 6.1.9.7(d) |
| Steep Front Impulse Voltage Withstand Test | 1 Multiple Valve Unit | 6.1.9.7(e) |
| DC Voltage Withstand Test | 1 Valve Unit | 6.1.9.8(a) |
| Wet DC Voltage | 1 Valve Unit | 6.1.9.8(b) |

| | | |
|---|--------------|------------------|
| Withstand Test | | |
| AC Voltage Withstand Test | 1 Valve Unit | 6.1.9.8(c) |
| Switching Impulse Withstand Voltage Test | 1 Valve Unit | 6.1.9.8(d) |
| Wet Switching Impulse Withstand Voltage Test | 1 Valve Unit | 6.1.9.8(e) |
| Lightning Impulse Withstand Voltage Test | 1 Valve Unit | 6.1.9.8(f) |
| Steep Front Impulse Withstand Voltage Test | 1 Valve Unit | 6.1.9.8(g) |
| Non Periodic Firing Test | 1 Valve Unit | 6.1.9.8(h) |
| Periodic firing & Extinction tests | N.Modules | 6.1.9.9.1 |
| Current Sharing Test | N. Modules | 6.1.9.9.3 |
| Transient forward voltage test during recovery period. | N. Modules | 6.1.9.9.4 |
| Short Circuit Current Without Subsequent blocking | N. Modules | 6.1.9.9.5 |
| Short Circuit Test With Subsequent Blocking | N. Modules | <u>6.1.9.9.6</u> |
| Test for valve insensitivity to electromagnetic disturbance | N. Modules | <u>6.1.9.9.7</u> |
| Testing of special features | N. Modules | 6.1.9.9.8 |

.2 A type test for these purposes is each particular test on a valve or multiple valve unit and for the 'N' test on the valve module type test, where 'N' is the total number of valve modules required for one complete valve.

- .3 The order in which the "Voltage Tests on Valve" and "Operational Tests on Valve modules" shall be performed shall be discussed and agreed with the Employer. However, as far as possible the following sequence shall be adopted.

First : "Voltage Tests on Valve"

Second : "Operational Tests on Valve Modules"

Third : "Production Sample tests - Tests on valve modules (refer to clause 6.1.9.10)

- .4 The same valve modules shall be used for the test of clause 6.1.9.3.1.1, clause 6.1.9.3.1.2 and in the first 'N' modules for the tests of clause 6.1.9.3.1.3.
- .5 The results of the check for degradation of components of test objects (refer to Clause 6.1.9.4) shall be used in applying the criteria of successful type testing. The criteria for successful type testing shall be as per IEC 60700-1 clause 4.4.1.

6.1.9.7 Tests on Multiple Valve Units (MVU)

- .1 If the valve arresters are normally mounted on the MVU, the valve arrester housing only should be installed for the tests. In case the arrester housing is not tested during the MVU tests, the same shall be tested separately. The MVU need not be installed fully with complete valve modules (i.e., complete with thyristors, grading circuits, valve reactors, compensating capacitors, etc.). The MVU may contain some complete valve modules, with the rest of the valve modules simulated by their grading circuits, where the simulation of the grading circuits shall be such as to ensure the voltage distribution during the tests to be equal to that with all complete valve modules installed. The number of complete valve modules in an MVU used as a test object shall not be less than the total number of complete valve modules in a valve.

- .2 The components in the module shall be randomly selected from the lot manufactured. The Bidder shall state the maximum component diversity permitted in the design of the valve modules and the valve. The Employer/Engineer shall select the valve modules for the tests.

It is recognized that at the time of the type test, only a few modules are available. However, the minimum number of modules available for the selection should not be less than twice the number of modules in a valve.

The MVU shall include all cooling equipment and control equipment interconnecting the modules and the components at ground potential. The tests shall be performed with the redundant thyristor levels of one valve of the MVU shorted out. The location of the thyristor levels to be shorted out shall be chosen by the Engineer.

- .3 The test are extended to verify the design of the MVU regarding dc corona extinction voltage levels and also to verify the MVU

design regarding steep front, lightning and switching impulse voltage withstand levels as related to its insulation coordination. Grounded shields shall be suitably arranged around the valve structure to simulate effects of nearby building steel grounding rods and any other structure which influences the stray capacitance to ground of the test structure. The ground plane should reflect realistic stray capacitance distribution during dielectric tests.

- .4 The tests on the MVUs specified in this section shall be conducted with voltages of both polarities, where applicable.

The test on the MVU specified in this section shall be carried out with the highest voltage valve (with respect to ground) shorted out.

All thyristors and other components of the multiple valve unit shall be checked before and after each test sequence. The test shall be considered successful if the valve meets the criteria for successful type testing (see Clause 6.1.9.6).

A) MVU DC VOLTAGE TEST TO EARTH

The test shall be performed as per IEC 60700-1.

B) MVU AC VOLTAGE TESTS.

The test shall be performed as per IEC 60700-1.

C) SWITCHING IMPULSE WITHSTAND VOLTAGE TEST

The test shall be performed as per IEC 60700-1. Forced firing in the forward direction shall not be permitted.

D) LIGHTNING IMPULSE WITHSTAND VOLTAGE TEST

The test shall be performed as per IEC 60700-1.

E) STEEP-FRONT IMPULSE VOLTAGE TEST

Peak voltage: The guaranteed steep-front impulse voltage withstands capability of the MVU.

Wave shape: The test wave front should be as calculated in the Insulation Coordination report.

- .1 Test conditions shall be the same as for switching impulse withstand voltage test 6.1.9.7 (c).
- .2 Atmospheric correction factors shall be applied.

6.1.9.8 Withstand Voltage Test on Valves

- .1 These tests are intended to verify the design of the valve with regard to its voltage related characteristics for various types of over voltages (DC, power frequency AC, switching impulse, lightning impulse and steep-front impulse over voltages). The tests shall demonstrate that:
 - a) Sufficient internal insulation has been provided to enable the valve to withstand the specified over voltages and to test the

effectiveness of any internal over voltage protective circuits.

- b) Partial discharges shall not occur under normal conditions and any such discharges under high over voltage conditions are within defined limits specified for each test.
 - c) The internal grading and damping circuits have sufficient power rating.
 - d) The voltage distribution along the thyristor string under various types of over voltages, including steep-front impulse voltages, are such that voltages imposed on various components of the valve are within their voltage withstand capabilities.
 - e) The gating circuits are immune to interference due to impulse over voltages and function correctly.
 - f) The valve can be fired from high overvoltage conditions without damage, and firing of the string of thyristors is effectively simultaneous so as not to cause undue overvoltages on the last fired thyristor.
- .2 The complete valve assembly, with redundant thyristor levels short-circuited and the surge arresters disconnected shall be subjected to the tests. However, where a valve arrester is normally mounted on the valve, the arrester housing only shall be mounted on the valve. In case the arrester housing is not part of Valve test, the same shall be subjected to tests separately. The location of the thyristors to be short-circuited during tests to account for removal of redundant thyristors shall be selected by the Employer/Engineer.
- .3 Alternatively, if the Bidder can demonstrate that the stresses are the same as short-circuiting the redundant thyristors, the test may be performed with the redundant thyristors in place but with the test voltage equal to the guaranteed withstand voltage raised by the redundancy factor.
- .4 The Employer shall select the valve modules to be installed in the valve to be tested. The minimum number of modules available for the selection should not be less than twice the number of modules in a valve.
- .5 The complete valve shall be mounted, including all peripherals required for operation of the valve, e.g., reactors, so that all in-service conditions corresponding to the valve locations are correctly simulated. The valve electronic shall be energized during the tests, where specified.

All thyristors and other components of the valve shall be checked before and after each test sequence. The test shall be considered successful if the valve meets the criteria for successful type testing (see Clause 6.1.9.6).

- a) DC Withstand Voltage Test

The test shall be performed as per IEC 60700-1.

- b) Wet DC Withstand Voltage Test

With the same condition as for the wet switching surge test (e) below, a voltage of 1.3 Ud for one minute followed by 1.0 Ud for five minutes shall be applied across the valve terminals for five minutes.

- c) AC Withstand Voltage Test
The test shall be performed as per IEC 60700-1.
- d) Switching Impulse Withstand Voltage Test
The test shall be performed as per IEC 60700-1 with reference to clause 8.3.3 and a test safety factor of 1.15.
- e) Wet Switching Surge Test
The switching surge test shall be repeated on the valve with a water leak on one of the top modules of the valve stack. The water leakage shall be maintained at least one hour prior to testing and shall be continued during testing. The rate of water leakage shall be the maximum that would not be detected by automatic supervisory equipment and is a continuous drip, short of being a continuous stream. The conductivity of the water shall be 5% higher than the maximum conductivity which would initiate a high conductivity alarm.
- f) Lightning Impulse Withstand Voltage Test
The test shall be performed on hot valve conditions in line with 6.1.9.1.6 and as per IEC 60700-1 with reference to clause 8.3.3 and a test safety factor of 1.15.
The lightning impulse test in forward direction shall be carried out with the valve electronics energized. Where forced firing on the forward direction is provided to self protect the valve, this mechanism shall be demonstrated during the test. It shall be demonstrated that the valve protective firing action threshold is in accordance with the conditions stated in clause 6.1.4. The forward protective firing level of valve shall be validated during type test.
- g) Steep Front Impulse Withstand Voltage Test
The test shall be performed on hot valve conditions in line with 6.1.9.1.6 and as per IEC 60700-1 with reference to clause 8.3.3 and a test safety factor of 1.2. The forward protective firing level of valve shall be validated during type test.
- h) Valve Non-Periodic Firing Test
The test shall be performed as per IEC 60700-1.
- .6 Tests for Valve insensitivity to electromagnetic interference (EMI).

6.1.9.9 Operational Tests.

- .1 These tests are intended to verify the design of the valve with

regard to its performance under normal operating conditions, abnormal operating conditions and transient fault conditions.

.2 Valve modules shall be used for all operational tests. The tests shall demonstrate that:

.1 The valve functions properly (i.e., no commutation failures, correct voltage and current wave-forms, correct operation of all internal circuits) under the various specified test conditions;

.2 The turn-on and turn-off voltage and current stresses are within the capabilities of the thyristors and other internal circuits;

.3 the cooling provided is adequate and no component is overheated, even under the worst temperature and operating conditions;

.4 valve losses are within specified limits;

.5 The fault suppression capability of the thyristors for the worst fault condition is adequate.

.6 The tests described under Clauses 6.1.9.9.1, and 6.1.9.9.2 shall be performed on a circuit using 12 valve functions, each valve function consisting of at least 5 or more thyristor levels under test, (The test samples shall be randomly selected from the lot manufactured) connected in a back-to-back arrangement of 2 six-pulse bridges, one operating in rectifier mode and the other operating in inverter mode. The tests shall be performed on the modules subjected to the dielectric valve test. In order to cover all thyristor levels in the "N" modules to be tested, the tests have to be performed as two series of tests.

For the operational tests where a test circuit with a back-to-back arrangement of 2 six pulse bridges has been specified; alternative synthetic test circuits, if it can be demonstrated that the alternative circuits are as rigorous as the designated test circuit with regard to the objectives of the tests, can be used.

.3 In order to get correct voltage wave-forms and stresses as obtained in service, the total stray capacitance associated with the valve and the impedances contributing to the commutation reactance shall be properly represented in the test circuit. The test circuit shall be of proven design. It shall be demonstrated, subject to the approval of the Employer, that the test circuit produces stresses equivalent to those pertaining to service conditions. The coolant shall be in a condition representative of service condition with flow and temperature set to most unfavourable values appropriate to the test in question. If the temperature of the cooling medium is different for different modules within the valve, the highest temperature obtained shall be used.

.4 For operational tests, redundant thyristor levels shall not be short circuited. The test voltages used shall be adjusted by means of a scaling factor, k_n ,

$$k_n = N_{tut} / (N_t - N_r);$$

Where, N_{tut} = number of series thyristor levels in the test object

Nt = number of series thyristor levels in the valve
Nr = total number of redundant series thyristor levels
in the valve

- .5 Operational tests performed shall represent the worst operating conditions that can occur in service under various operating modes like continuous overload, short duration overload and reduce voltage operation.

6.1.9.9.1 **PERIODIC FIRING AND EXTINCTION TESTS**

The principal objectives of the tests are: To check the adequacy of the thyristor levels and associated electrical circuits in a valve with regard to current, voltage and temperature stresses at turn-on and turn-off under the worst repetitive stress conditions. To demonstrate correct performance of the valve at minimum repetitive voltage, coincident with minimum delay and extinction angles, at maximum temperature.

The tests shall verify the design of the modules by demonstrating the correct operation of the modules under the worst operating conditions without loss or degradation of the thyristors or auxiliary components and to check the temperature rise of the cooling media with the information given in the Schedule of Technical Information. The tests shall be performed on 'N' modules and shall be conducted on the test circuit with a back-to-back arrangement of 2 six-pulse bridges described above.

The tests shall be carried out at 1.05 x rated current and 1.10 x rated voltage. The tests shall be conducted at a maximum delay angles corresponding to normal voltage operation and for reduced voltage operation modes.

All necessary observations of voltages, currents, firing angles, temperatures and flow of cooling water shall be made to satisfy the objective of the test.

To obtain voltage and current stresses representative of service conditions, the test circuit shall have proper representation of total stray capacitance associated with the valve and the inductances contributing to the commutating reactance.

During the tests, the temperature rise of the most critical heat producing components and their adjacent mounting surfaces shall be monitored to verify that the maximum temperatures reached are within limits permitted by the design. Temperatures of the hot spots of the following components of valve modules shall be monitored:

- i) Heat sink as close to thyristor case as possible
- ii) Damping resistor case
- iii) Valve reactor

The temperature shall be monitored on at least 12 number of each component, one from each valve module.

1. Maximum continuous operating duty tests

The test shall be performed as per IEC 60700-1. with a test

safety factor of 1.10 for the test voltage.

2. Maximum temporary operating duty test (a = 90)

The test shall be performed as per IEC 60700-1 with a test safety factor of 1.10 for the test voltage.

3. Minimum Alternating Voltage Tests

The test shall be performed as per IEC 60700-1 with a test safety factor of 0.80 for the test voltage.

4. Temporary under voltage Test

The valve shall be tested, for 2 seconds, at transient μ min, coincident with a test voltage:

$$U_{tpv} = U_{vON} * (n_t / n_v) * k_u * 0.95 ; \text{ where,}$$

U_{vON} =nominal value of valve no load phase to phase voltage

k_u = 0.3 (temporary under voltage factor (fundamental frequency) for which the converters shall remain controllable).

It shall be demonstrated that valve remains controllable over the full duration of the temporary under voltage.

5. Intermittent Direct Current Test

.1 This test is to demonstrate the proper functioning of the valve firing system and integrity of the valve when the direct current is intermittent. The test shall be carried out on 'N' valve modules. The test circuit used for this test shall be the 2 x six-pulse bridge back-to- back circuit described above.

.2 The test shall be performed with the valve coolant at its maximum temperature. The stresses arising from intermittent direct current operation for two operating conditions shall be reproduced:

a) a = 90⁰ operation with maximum a.c. voltage (clause 6.1.9.9.1 – Maximum temporary operating duty test (a=90⁰)

b) rectifier amin operation with minimum ac voltage (clause 6.1.9.9.3.1 – Minimum Alternating Voltage Tests)

.3 The duration of test shall be at least 2 minutes or twice the normal permitted time in service for operation with intermittent direct current under the specified conditions, whichever is more.

Note: Test duration shorter than 2 minutes may be acceptable, subject to the approval of Employer, if the Contractor demonstrates that the prescribed test duration is unnecessarily long relative to the protective scheme of the valve. However such a protective scheme shall not impose operational restrictions.

.4 The test shall demonstrate safe turn-on of the thyristors, in

accordance with the design, at the requisite number of firings per cycle. The behaviour of the valve (sections) shall also be explored with an adjustable intermittent direct current in which duration of the periods of zero current can be varied from zero to a value which is long compared with the turn-off time of the thyristor.

6.1.9.9.2 VALVE LOSSES TEST

Valve losses shall be determined from a combination of tests and calculations; thyristor losses shall be determined by measuring the forward voltage drops of all thyristors.

6.1.9.9.3 TESTS WITH TRANSIENT FORWARD VOLTAGE DURING THE RECOVERY PERIOD

The test shall be performed as per IEC 60700-1.

6.1.9.9.4 SHORT-CIRCUIT CURRENT WITHOUT SUBSEQUENT BLOCKING TEST

The test shall be performed as per IEC 60700-1.

6.1.9.9.5 Short-Circuit Current with Subsequent Blocking Test

The test shall be performed as per IEC 60700-1.

6.1.9.9.6 TESTS FOR VALVE INSENSITIVITY TO ELECTROMAGNETIC DISTURBANCE

The test shall be performed as per IEC 60700-1.

6.1.9.9.7 TESTING OF SPECIAL FEATURES AND SPECIAL TEST ON DIRECT LIGHT FIRED VALVE.

The bidder shall bring out in his bid the special features of the valve offered, and tests proposed to verify the design and performance of special features of the valve. Those features which can be performed as part of other tests shall be accordingly demonstrated. Features which require special tests shall be agreed between bidder/supplier and Employer. The supplier shall give due consideration, where appropriate, in the type test programme, to the performance of special tests to verify critical aspects of the fault tolerance capability of the valve.

6.1.9.9.8 Long-term Aging test.

I) Long-term Aging test on PEX /Equivalent plastic material used within Valve.

Such test shall involve pressure and temperature cycling. The supplier shall provide an ageing test protocol for approval of the Employer,

Or,

Ageing test certificate / report of test performed on the PEX /Equivalent plastic material used within Valve subject to the approval of the Employer

II) The supplier shall propose an ageing test on light guide sheath material. Such test should include valve hall environment.

Or,

Ageing test certificate / report of test performed on the light guide sheath material subject to the approval of the Employer

6.1.9.10 Production Sample tests:

The Contractor shall repeat the tests mentioned in clauses 6.1.9.9.1 and 6.1.9.9.5 excluding the following test –

- Minimum Alternating Voltage test
- Temporary Under Voltage Test
- Intermittent Current Test

on 1 % of the sample of the total number of modules being supplied.

The Contractor may perform the tests on samples nominated by the Employer in one test session. However, the risk involved in rejection of one or any production batch shall entirely be that of the Contractor.

Criteria for successful production sample test:

- a) No thyristor-level degradation may occur during the test. Degradation due to consequence damages shall not be counted (e.g. degradation due to test circuit failures and similar events).
- b) If criterion not met, complete sample test shall be repeated with the failed components replaced. At this test no thyristor level degradation may occur.
- c) If criterion a) and b) are not met, an investigation shall be performed and it shall be proven to the satisfaction of the Employer that the degradation are of random nature before any further testing is carried out.

6.1.9.11 Routine Tests on Modules

The Contractor shall submit a detailed description of the procedure of carrying out each of the tests listed below:

- a) Connection Check

To check that all main current - carrying connections have been correctly made.

b) Voltage Grading Circuit Check

To check the grading circuit parameters and thereby ensure that the voltage division between the series-connected thyristors shall be correct for applied voltages from dc to impulse wave shapes.

c) Check of Auxiliaries

To check that the auxiliaries on each valve module associated with each valve module and the auxiliaries common to the complete valve function correctly.

d) Firing Check

To check that all of the thyristors in the valve module turn on correctly in response to a firing signal to the module.

e) Voltage Withstand Check

- .1 To check that the valve module can withstand the voltage corresponding to the maximum specified for the valve.
- .2 A partial discharge measurement shall be used to check correct assembly of modules.

f) Pressure Test (if applicable only)

To check that there is no water leaks.

g) Tests on Individual Valve components

- .1 All components on the valve shall be subjected to testing, inspection and quality assessment.
- .2 Those components such as thyristors, which have testing procedures recommended by IEC (or other internationally acceptable standard), shall be subjected to those test procedures and reports issued.
- .3 The Bidder shall submit in the Bid a description of the procedures to be adopted for quality assessment of the components and the completed production modules.

6.1.9.12 Dielectric Tests on Valve Base

The tests specified in this subsection apply to that part of a valve which constitutes the valve base. The tests are intended to verify the electrical design of the valve base (including ducts or pipes for the cooling medium, light guides etc. within the valve base) for various types of over voltages (dc, switching impulse and lightning impulse voltages). The tests should demonstrate that:

- Sufficient internal insulation has been provided to enable the valve base to withstand the specified test voltages.
- Partial discharges shall not occur under normal conditions and any such discharges under high over voltage conditions are within safe limits, to be defined for each particular design.

For all tests on a valve base given in this subsection, the highest voltage and the lowest voltage dc terminals of a multiple valve unit

(or a valve, as the case may be) shall be connected together and the test voltage then applied between the connected main dc terminals of the unit and ground.

Atmospheric correction factor as per IEC 60700-1 shall be applied.

.2 VALVE BASE DC VOLTAGE TEST

The test shall be performed as per IEC 60700-1.

.3 VALVE BASE AC VOLTAGE TEST

The test shall be performed as per IEC 60700-1.

.4 VALVE BASE SWITCHING IMPULSE TEST

The test shall be performed as per IEC 60700-1.

.5 VALVE BASE LIGHTNING IMPULSE TEST

The test shall be performed as per IEC 60700-1.

6.1.9.13 Test on Valve Support Insulator

Wet switching impulse and Wet DC Test shall be conducted on valve support insulators on the MVU with cooling pipes and fibre optic in place. The value of test voltage and method of testing shall be submitted by bidder for employers approval

6.2 Not applicable

6.3 SURGE ARRESTERS

6.3.1 GENERAL

The Contractor shall supply the dc and ac surge arresters necessary for the protection of the equipment associated with each converter station as per present scope in accordance with the requirements specified in Section 4 of this Specification.

All arresters shall be of hermetically sealed units, self-supporting construction and generally suitable for mounting on tubular support structures in the AC & DC yard /Valve Hall as per present scope. Arresters without insulator housing shall be acceptable provided they are installed in a controlled environment. However, such design should have been in satisfactory operation in a similar environment for at least two years on the date of bid opening.

All arresters shall be of the gapless metal oxide type with no series spark gaps.

6.3.2 DUTY REQUIREMENTS

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

The arresters shall be rated and tested such that they are able to discharge a specified maximum energy due to the application of temporary voltages of form and magnitude which can occur in service as determined by insulation coordination studies to be carried out by the Contractor, without coming into the temperature region where thermal runaway could result upon subsequent application of maximum transient and steady state voltage conditions.

Particular attention shall be given to the high discharge currents which some of the arresters may experience in service due to the requirements to discharge the energy of the ac filters, shunt capacitors and reactive compensating equipment or in other circumstances.

The design of the arresters shall take into account and shall maximize the degree of current sharing between complete arresters. Similarly the design shall also take into account and shall maximize the degree of current sharing between parallel columns of the same arrester.

The reference current of the arresters shall be high enough to eliminate the influence of grading and stray capacitance on the measured reference voltage. The Bidder/Contractor shall furnish the values and supporting calculations along with the Bid.

All AC and DC Surge Arresters shall have composite housing except for as allowed in clause 6.3.1.

6.3.3 CONSTRUCTIONAL FEATURES

The features and constructional details of arresters shall be in accordance with the requirement stipulated hereunder.

The non-linear blocks shall be of sintered metal oxide material. These shall be provided in such a way as to obtain robust construction, with excellent mechanical and electrical properties even after repeated operations.

The arresters shall be designed to withstand a certain degree of contamination. Site pollution shall be considered as class III- Heavy as per IEC 60815.

Seals shall be provided in such a way that these are always effectively maintained even when discharging rated lightning current.

The housing shall be so coordinated that external flashover shall not occur due to application of any impulse or switching surge voltage upto the maximum design value for the arrester.

The end fittings shall be made of non-magnetic and corrosion proof material.

Internal components shall be designed to minimize internal corona and also to ensure minimal capacitive coupling with any conducting layer of pollutant on the outside of the porcelain housing. Organic

materials are not permitted as this may influence the reliability of the arrester.

The heat treatment cycle details alongwith necessary quality checks used for individual blocks along with insulation layer formed across each block shall be furnished by the Bidder/Contractor. Metalizing coating thickness for reduced resistance between adjacent discs shall be furnished alongwith procedure for checking the same. Details of thermal stability test for uniform distribution of current on individual disc shall also be furnished.

Pressure relief class shall be as per Table VII of IS-3070 or equivalent.

6.3.4 FITTINGS AND ACCESSORIES

Arresters shall be complete with insulating base having provision for bolting to flat surface of structure.

Self contained discharge counters, suitably enclosed for outdoor use and requiring no auxiliary or battery supply for operation shall be provided for each single pole/ phase unit. Suitable leakage current meters for the arresters with no key interlocking system during operation should also be supplied within the same enclosure (Not applicable for Valve Hall). The reading of the ammeter and counters shall be visible through an inspection glass panel. The terminals shall be robust and of adequate size and shall be so located that in coming and outgoing connections are made with minimum possible bends.

Discharge counters shall be mounted on support structure of the arrester.

Grading/corona rings shall be provided on each complete arrester unit, as required.

6.3.5 TESTS

The arresters shall be tested to verify all specified protection and duty cycles as determined by studies carried out by the contractor. The tests shall be carried out as per IEC 60099-4 and IEC 60099-9.

6.4 Not applicable

6.5 Not applicable

6.6 PLC HARMONIC FILTERS EQUIPMENT

6.6.1 GENERAL

The Contractor shall provide PLC filters required to meet harmonic requirements specified in Section 4.11

For the purposes of this Specification any conventional linear shunt capacitors, reactors and resistors shall be considered included as part

of the PLC filter,

The Contractor shall demonstrate to the satisfaction of the Employer that the equipment to be installed for high frequency filtering meets the requirements of this Specification before any equipment is put into service.

The Employer shall, at his discretion, have the right to reject any component which fails to meet this Specification or which does not meet the limits of tolerance established by the Contractor and used in the calculations demonstrating that the ac harmonic filter shall meet the performance requirements given in Section 4.

The Contractor shall specify the values and tolerances for capacitance, power factor, dielectric losses, rated voltage, the frequency coefficient and the temperature coefficient. The values and tolerances of inductance and resistance for reactors and resistors shall also be included.

High Frequency filters shall be designed for applicable high frequency stress.

6.6.2 GENERAL REQUIREMENTS

6.6.2.1 HARMONIC FILTERS

The ac filters shall be made up of capacitors, reactors and, if necessary, resistors conforming to the requirements as described herein. All filter components shall be screened, wherever possible, to prevent entry of birds, reptiles and rodents. At the discretion of the Employer the filter equipment may be mounted at ground level as described in section 5.

The ac filter shall use as high a proportion of identical interchangeable components as possible in order to simplify maintenance and stocking of spare parts, in particular tuned arm inductors (if used).

The individual ac filter branches shall, wherever possible, be designed so that common spares may be used.

6.6.3 C

CAPACITORS

AC filter capacitors shall be designed and tested in line with applicable parts of IEC 60871-1. The capacitor units shall be of internal fuse, fuse-less or self-healing design.

Rated voltage for a. c. filter capacitors shall at minimum be determined as

$$U_k + \sqrt{\sum_{\substack{h=1 \\ h \neq k}} U_h^2}$$

Where k denotes the maximum individual harmonic voltage across the capacitor bank.

6.6.3.1

DEFINITIONS

For the purposes of this clause the following definitions shall be applicable:

a) Capacitor Element

The single wound section comprising aluminium foil and kraft paper and/or plastic film as appropriate.

b) Capacitor Unit or Capacitor Can

The stainless steel case complete with bushing(s), internal discharge and grading resistors, capacitor elements connected in series and parallel, internal connections and, if used, element fuses.

c) Series Group

All capacitor units connected in parallel at any one voltage level.

d) Capacitor Rack

The steel framework supporting one or more series groups including interconnection bus work and insulators as required.

e) Capacitor Stack

One or more capacitor racks supported on one set of base insulators including inter-rack insulators and rack to rack connections.

f) Capacitor Bank

The three phase set of capacitor units which may be represented as a single lumped capacitor in a single line diagram and which comprises one or more capacitor stacks and is complete with all interconnections and protective and monitoring devices.

6.6.3.2

CAPACITOR UNIT FAILURE DETECTION

The Contractor shall provide at least three stages of capacitor unit or element failure detection.

The first stage shall generate an alarm and the filter branch shall continue in service. It may be assumed that the branch shall be disconnected for maintenance within two weeks.

The second stage shall generate a separate alarm and a delayed trip signal which shall disconnect the branch after two hours.

The third stage shall cause an immediate disconnection of the branch.

The first stage unit failure alarm shall be set at not less than the number of units corresponding to:

1) 0.5% of the total number of element in the applicable filter

capacitor unit; or

2) One capacitor element, whichever is the greatest.

Equipment shall be provided to detect, while de-energised, the number of failed elements in the filter capacitor bank or any part thereof. The first stage element failure alarm shall be set to limit the expected frequency of operation of this alarm to one per bank per year.

The second stage alarm level shall be set such that the expected frequency of operation of this alarm shall not be less than twice the element failures corresponding to the first level alarm.

The third stage (trip) level shall be set to avoid avalanche failure of filter capacitor units but shall not be at loss of fewer elements or units than required to generate the second stage alarm.

6.6.3.2.1 *Banks*

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

6.6.3.2.2 *Stacks*

Unless specified otherwise, each capacitor stack shall be mounted on a support structure and insulators to allow safe access for personnel in the station to the capacitor area for visual inspection of the capacitors with the banks energised. The stacks shall be free of audible vibration.

All structural members shall be electrically connected to the station ground mat and shall be of galvanised structural steel.

6.6.3.2.3 *Racks*

The capacitor racks shall be supplied complete with all capacitor units, rails, insulators, and connections and shall be equipped with lifting eyes to facilitate easy assembly into the stacks. The racks shall be constructed of galvanised structural steel. No drilling shall be permitted after galvanising. Each rack shall be clearly labelled with the weight of the fully equipped rack, the phase and bank of which it forms a part. The maximum and minimum capacitor unit capacitance's which may be substituted into the rack as spares shall be suitably identified. Suitable warning labels shall be affixed.

All structural members shall be electrically connected to each other in

order to ensure adequate grounding of the rack during maintenance. The rack shall be provided with adequate connections for grounding. Steel rack components shall not be used as an electrical bus.

6.6.3.2.4 *Units*

The capacitor units shall be supplied with stainless steel cases and shall be designed to allow for expansion and contraction due to all ambient and loading conditions expected during the life of the unit including short term and transient conditions.

Each capacitor unit shall be mounted so that it can be easily removed from the rack and replaced without removing other units or disassembling any portion of the rack.

Each capacitor unit shall be furnished with lifting eyes or similar provision for lifting the unit to and from the rack.

The dielectric fluid used within the capacitor unit shall be environmentally safe and biodegradable. It shall be as little toxic and corrosive as possible. PCB type fluid is not acceptable. The capacitor elements shall be vacuum dried inside the case prior to impregnation with the dielectric fluid. After impregnation the capacitor unit shall be sealed immediately upon removal from the impregnant reservoir.

The current, voltage and kVA rating of the capacitor units as well as the capacitance shall be derived from the bank rating as determined by the Contractor and shall be given on the capacitor unit nameplate.

The capacitor unit rating plate will be according to IEC 60871-1

6.6.3.2.5 *Insulators*

All rack and bus insulators as well as the insulators used to insulate each stack of capacitor racks from ground shall be pin cap or post type.

The minimum nominal voltage rating shall be 15 kV, and the low frequency wet withstand voltage rating of all insulators used to insulate within or between the capacitor racks of a stack shall not be less than three times the actual voltage stress across the insulators.

If the bank is furnished with graded insulation the minimum rated voltage of the insulators shall be 15 kV.

6.6.3.3 DESIGN REQUIREMENTS

The capacitors shall, except as otherwise specify, be designed and rated in accordance with the latest issue of IEC-60871. The capacitors shall be tested as per the above standards by the ambient

temperatures mentioned in these standards. The Contractor shall, however, forward for the Employer's approval extrapolated values and documentation for the reference temperature of 30°C, equal to the annual mean dry bulb temperature. The capacitors shall be suitable for outdoor installation.

6.6.3.4 TESTS ON CAPACITOR UNITS

The tests shall be generally in accordance with the latest issue of IEC publication 60871 except as otherwise specified below. Additional tests as applicable for high frequency filter applications shall be carried out. Failure of any unit to meet any test requirement shall constitute grounds for the Employer to reject the unit, all units in the batch, or all units of the type as appropriate to the form of test in which the failure occurred.

The following definitions to the tests shall apply:

- a) The rated voltage U_r of an AC filter capacitor bank shall be defined as:

$$U_r = U_h + \sqrt{\sum_{100} U^2}$$

Where

U_h = Fundamental frequency rms voltage (or the greatest individual harmonic voltage)

U_n = Nth harmonic frequency rms voltage ($n \neq 1$ or the individual harmonic order with the greatest voltage)

Which can appear across the capacitor bank for steady state under the most onerous conditions of the ac bus voltage, dc load and filter detuning.

Calculations establishing the conformity of the design to the guaranteed availability shall be furnished by the contractor to the Employer **for approval**.

For low voltage ac filter capacitors, the rated peak voltage shall be highest value of $USIWL / (4 * S)$ or $(1.1 * V_b * \sqrt{2}) / (S)$.

V_b : Rated Voltage as defined at 6.6.3.4 a)

USIWL: Switching withstand level of the LV Capacitor

S: Number of series connected Capacitor Units in Bank

- b) The rated harmonic frequency is defined as the frequency at which the impedance of the filter branch is lowest.
- c) Failure of any element shall be considered as failure of the unit to withstand any voltage test. In other tests, any parameter falling outside the design limits as specified by the Contractor and approved by the Employer shall constitute a failure of the unit to pass the test.

Tests to be performed by the Contractor shall include, but not be limited to the following:

6.6.3.4.1 *Type Tests*

The type tests shall be performed on at least two capacitor units of each type with further provisions that :

i) In case of capacitor units are being manufactured at different plants, capacitor units from each plant shall be type tested.

ii) If the design has been changed by the Supplier in any way during the course of manufacture, the Employer shall have the right to have the type tests repeated on the new design at no extra cost.

iii) A type test shall be deemed to have been passed if all the selected units pass the tests individually unless otherwise specified in a test.

iv) The type tests required shall be as per IEC 60871. However Thermal Stability Test shall be performed on capacitor type with highest kVAR per cubic unit of tank volume

6.6.3.4.2 *Routine Tests*

Routine tests shall be performed on every unit in line with IEC-60871.

6.6.3.5 SPARES REQUIREMENT

The Contractor shall supply spare capacitor units of each type and rating. At least 1% (but a minimum two units) of the total number of units of that type used in capacitor banks, filters and SVCs (if used) shall be supplied. However, at least one unit of each tolerance class of each type shall be supplied at each station unless any spare unit can be used to replace any failed unit of the same type irrespective of tolerance class.

6.6.4 REACTORS

6.6.4.1 GENERAL REQUIREMENTS

Reactors for ac harmonic filter branches, including other reactors such as current limiting reactors on shunt capacitor sub-banks etc. for reactive power control shall generally be constructed and tested in accordance with the latest issue of IEC-60076-6 as appropriate to the type of reactor provided. The Contractor shall specify, subject to the approval of the Employer, the acceptance limits applicable to all tested parameters. These limits shall not be less restrictive than the assumptions used in calculating the reactor rating as defined in Section 4. Only dry type reactors shall be provided. They shall be mounted such that there is negligible mutual coupling between phases or between filter branches and adequate precautions shall be taken to prevent overheating of any magnetic material located in the magnetic field of the reactor.

The reactors shall be suitable for outdoor installation and shall not

contain any moving parts. They may be equipped with off- load taps or adjustable links to allow accurate filter branch tuning during initial commissioning of the filters only

The reactors shall be provided with lifting eyes to facilitate rapid erection and replacement. The name plate provided on the reactors shall be at such a height that a person standing on the ground can conveniently read it.

The reactors shall be constructed with sufficient strength to withstand, without damage or loss of life, the mechanical forces both while in service and during erection.

6.6.4.2 TESTS ON REACTORS

The reactors of each type and rating shall be subjected to type and routine tests in accordance with the relevant standards and, in addition, to the tests described herein:

In the case of reactors which are forced cooled or have oil circulation pumps, all tests shall be performed with one pump and one cooler out of service.

For the purposes of tests the following definitions, in addition to those given in the relevant standards, shall be applicable;

- a) The rated harmonic frequency shall be the frequency at which the branch impedance is minimum.
- b) The rated voltage shall be the peak value of the arithmetic sum of 50 Hz and all harmonic voltages calculated in accordance with Section 4 which can occur across the reactor for a period in excess of 10 minutes under the most onerous conditions of ac bus voltage, dc load, and filter detuning.
- c) The rated current shall be that 50 Hz current which shall produce the same losses as the most onerous combination of 50 Hz and harmonic currents, for the loading conditions as in b) above, and using the results of type tests to calculate the total losses.

For multi coil reactors, tests shall be performed on one coil, as relevant. Tests performed on reactors shall include, but not be limited to, the following:

6.6.4.2.1 Type Tests

Type tests shall be conducted on one reactor of each type and rating in the sequence given below.

a) Temperature Rise Test

A heat run test under conditions similar to the actual site installation shall be made in order to demonstrate that the thermal stability and design temperatures are not exceeded. The losses caused by each of the major current components shall be calculated for the warm reactor. The currents shall be those calculated for rating purposes.

The losses for the reactor shall be summed and a test current at fundamental frequency giving equal losses in the warm reactor shall

be calculated. The Contractor shall support, by measurements, the inductance versus frequency relationship needed for the calculations. The equivalent 50 Hz test current shall be calculated by the following formula

$$I_t^2 \cdot R_F = I_F^2 \cdot R_F + \sum_{n=2}^{n=10} I_{Hn}^2 \cdot R_{Hn}$$

Where,

I_t = equivalent test current (50 Hz)

I_F = maximum continuous fundamental current (50 Hz) I_{Hn} = maximum continuous nth harmonic current

R_F = loss resistance at fundamental frequency corrected to maximum working temperature

R_{Hn} = loss resistance at nth harmonic frequency, corrected to maximum working temperature.

The resistance values, R_{Hn} , used in the formula, shall be verified by measurements.

The duration of the test shall be the time required for the temperature to reach steady state conditions but in any case not less than 2 hours.

The temperature of all the components shall be measured at the end of the test and shall be corrected to maximum ambient temperature. It shall be demonstrated that no part of the reactors including support, support insulators or connections shall be above the maximum continuous operating temperature as applicable for the class of insulation used.

b) Measurement of Variation of Inductance and Resistance with Frequency. The variation of inductance and resistance with frequency shall be measured at nominal tap and a convenient ambient temperature over the range from dc to 3 kHz.

c) Measurement of Inductance

Test shall be performed as per IEC-60076-6.

d) Lightning Impulse Voltage Test (Wet)

The following impulses with crest value as determined in accordance with Section 4 shall be applied to one terminal with the other terminal grounded;

- Reduced wave
- 5 full waves

Both positive and negative polarity shall be applied.

The wave form shall be as close as possible to standard 1.2/50 μ s impulse.

6.6.4.2.2 Routine Tests

a) Measurement of dc Resistance

The dc resistance shall be measured corrected to 50 deg Celsius.

b) Measurement of Inductance

The inductance shall be measured at all taps at both 50 Hz and rated harmonic frequency at any convenient ambient temperature. The inductance at rated harmonic frequency shall be corrected to the value at 33^oC ambient with the reactor operating at rated current as defined in Clause 6.6.4.2 c) above and this shall be designated as rated inductance of the reactor at each tap.

c) Measurement of Resistance

The 50 Hz and rated harmonic frequency resistance shall be measured at all taps and at any convenient ambient temperature on every reactor. The resistance at rated harmonic frequency shall be corrected to the value at 33^oC ambient with the reactor operating at rated current as defined in Clause 6.6.4.2 c) above and this shall be designated as rated resistance of the reactor at each tap.

d) Lightning Impulse Voltage Test, Dry

The following impulses with crest value as determined in accordance with section 4 shall be applied to one terminal with the other terminal grounded;

- reduced wave
- 5 full waves

Both positive and negative polarity shall be applied.

The wave form shall be as close as possible to standard 1.2/50 μ s impulse.

6.9 HVDC INSULATORS, BUSHINGS, BUSES AND HARDWARE

6.9.1 GENERAL

The Contractor shall furnish all bus work necessary to meet the operational & performance requirement of this Specification.

All HVDC insulators, bushings, buses, conductors, connectors and hardware etc. As per present scope shall be in accordance with the relevant standards and other relevant publications and as modified herein. All bushings inside valve halls including wall bushings shall be porcelain/silicone rubber housing.

They shall also conform to the requirements of the Clause 6.15 regarding HVAC equipment. In case of conflict between the Clauses 6.15 & 6.9, the latter shall prevail.

Corona shields shall be provided as required.

6.9.2 BUSHINGS, SUPPORT INSULATORS, STRING INSULATORS & HARDWARE

The support insulators and bushings shall be in accordance with

Clauses

6.15.2 & 6.15.3 of this Specification.

The insulation levels shall be determined by the Contractor in accordance with Section 4 of this Specification.

All bushings shall be one piece only and no joints in insulator, tube or conductor shall be accepted. When wall bushings are used, the Contractor shall provide necessary measures to avoid uneven wetting of the same.

For HVDC Bus post Insulators (Both HV and LV side) and HVDC equipment (Both HV and LV side) support insulator shall be of silicon rubber.

6.9.3 TUBULAR BUS CONDUCTORS, FLEXIBLE BUS-BARS, EARTHWIRE, CLAMPS, CONNECTORS, SPACERS ETC.

These shall be in accordance with the relevant clauses of section 6.15 of this specification. The size of the tubular bus-conductors, number of conductors per pole along with their configuration etc. shall be determined by the contractor.

6.9.4 TYPE TESTS

The type tests for HVDC insulators, bushings, busses, conductors etc. shall be in accordance with the applicable IEC Standards. A unit of each type & rating shall be type tested. In addition, the following special type tests shall also be carried out on a unit of each type and rating :

6.9.4.1 Lightning Impulse Test

Standard lightning impulse tests shall be carried out in accordance with the relevant IEC standards at the voltage levels corresponding to the equipment LIWL to ground.

The lightning impulse waves shall be negative polarity for bushings and positive polarity for insulators.

6.9.4.2 Switching Surge Test

- a) *For self-restoring insulation*, one insulator stack of each type shall be selected at random. Both positive and negative switching surge tests shall be carried out under wet conditions. The subject of these tests is to prove that the insulation has a no more than 2.3% probability of flashover (2 standard deviations below critical flashover) in accordance with IEC publication. The test would be deemed to have been proved if there are no flashovers during the first fifteen applications of voltage. If only one flashover occurs during the application of these 15 shots, the test sequence shall be repeated and, provided no further flashover occurs, only then the object of the test shall be deemed to have been proved. Indoor insulators may be tested dry.

The switching surge voltage wave form shall be such that the

time to crest shall be between 100 and 300 microseconds, and the time to decay to half of crest value between 3000 and 5000 microseconds. Waveform as per IEC is also acceptable with no negative tolerance.

- b) *For non-self restoring insulation*, the switching surge tests shall generally be in accordance with the relevant IEC standard, and shall comprise the application of one reduced and two full voltage levels.

6.9.4.3 DC Withstand Test

An outdoor bushing or insulator of each type shall be subjected to a wet withstand test as per Clause 10.2 of IEC **65700-19-03** with water applied according to the requirements of IEC 60060-1.

The bushing shall be considered to have passed the test if no flashover or puncture occurs. If there is a puncture, the bushing shall be considered to have failed the test. If a flashover occurs, the test shall be repeated once only. If during the repetition, flashover or puncture occurs, bushing shall be considered to have failed the test.

For bushings and insulators which are exclusively used indoor, the above test shall be performed dry.

6.9.4.4 Radio Influence Voltage

Radio influence voltage shall not exceed values specified at TS Clause 4.11.13.

6.9.4.5 Temperature Rise Test

Temperature rise test shall be conducted as per IEC-60137 corresponding to the overload current level.

6.9.5 ROUTINE TESTS

The routine tests shall be performed as called for in the applicable standards.

6.10 DC MEASURING DEVICES

6.10.1 GENERAL

The Contractor shall supply all HVDC measuring devices that are necessary for control, protection, interlocking, and measurement to ensure safe and reliable operation of the HVDC system and the associated HVAC equipment in accordance with the requirements of the Specification as per present scope. Included with the supply of measuring devices shall be all necessary indoor cubicles and outdoor cabinets for mounting the associated equipment and for housing the secondary cable terminations & other necessary ancillaries.

Notwithstanding the accuracy limitations stated below, the Contractor shall ensure that the accuracy of all measuring equipment is adequate for its specific purpose.

The Contractor shall provide transient response characteristics and frequency response (at least up to and including 1500 Hz)

characteristics of all measuring devices based on factory tests.

Secondary terminals shall be provided and mounted in the base housing. The base housing shall be of metal and shall be firmly attached to the base. These terminals shall be made accessible for future testing or for use with instrumentation. The secondary circuit shall be adequately protected, without the use of fuses, to be able to be shorted for one minute without damage to the unit.

Each separately mounted measuring device shall be provided with a clamp type grounding terminal suitable for 35 mm² to 120 mm² copper wire.

Insulation requirements shall be determined by the Contractor in accordance with Section 4.

DC measuring devices shall conform to the requirements of section 6.11 for AC instrument transformers, to the extent applicable.

6.10.2 DC VOLTAGE MEASURING DEVICES

6.10.2.1 General Requirements

A proven type of voltage divider shall be provided for dc voltage measurement. The accuracy of the device shall not vary more than 0.5% with an ambient temperature change of 55°C or the change in valve hall temperature for the supplied equipments, whichever is higher.

The overall voltage measuring system shall have an accuracy of at least 1.0% of full scale. The response time shall not be longer than 150 μs, accepting an overshoot of up to 20% at that rise time. The measuring system shall achieve proper operation of the control and protection system to which it is connected. The measurement over-range shall be sufficient to measure voltages up to 1.5 p.u.

Preference shall be given to devices which provide isolation between the HV primary connection and the output signal. If the output signal is not completely isolated from the HV connection, protection shall be provided to limit the possible output signal voltages to less than 2 kV in the event of a fault on the device.

All low level signals shall be cabled separately from high level signals.

The divider shall be so arranged that no leakage current on the surface of the insulator can pass to the measuring circuit. The insulator shall for this reason be continuous without any metallic intermediate flanges.

Furthermore, the interior of the divider shall be so arranged that interior leakage currents do not influence the measurement.

For DC voltage measuring equipment to be erected in the Valve Hall, the Contractor shall ensure that discharge activity on the composite/porcelain housing shall not cause interference with the output signal.

For each voltage measuring device furnished, the Contractor shall

provide all necessary auxiliary power plus any equipment necessary for the transformation of the auxiliary power to an acceptable form. Such transformation equipment shall be mounted in the auxiliary control cubicles.

6.10.2.2 Testing

The tests for the HVDC voltage measuring devices shall demonstrate the performance of the overall dc measurement system, and not only the voltage divider device, and shall include, but not necessarily be limited to, the following tests. The type tests shall be performed on one unit of each type and rating. For performing factory tests on complete measuring system, the connecting cable to be used on site shall be simulated suitably.

.1 Type Tests

- a) Resistance linearity from 0.1 to 1.5 p.u. voltage. The test shall be carried out with at least 7 voltage levels at approximately equal steps, with both polarities.
- b) Transient response test demonstrating the dc voltage measuring system response to a step voltage input.
- c) Dielectric tests on complete divider unit as per mentioned below.
T.S. clause 6.9 & 6.11

Frequency response test demonstrating the dc measuring system's ac measurement ratio i.e. Magnitude and phase shift, up to at least 1500 Hz. (If done individually for divider unit & isolation amplifier, the total magnitude error shall be found by the arithmetic sum of the individual magnitude errors and the total phase angle error shall be the rms sum of the two measured phase shifts.)

In addition to the tests mentioned above, all type tests as mentioned in IEC 61869-15 shall also be performed.

.2 Routine Tests

- a) Determination of resistance during manufacture (measure with both polarities, calculate mean, repeat after high voltage test, variation should not exceed 0.25%).
- b) Insulation test of the low voltage circuit at 2 kV for 1 minute.
- c) Calibration test demonstrating the dc measurement ratio, and the ac measurement ratio at 50 Hz and 600 Hz.
- d) Check of spark gaps and voltage limiting devices.
- e) Radio interference and partial discharge test.
- f) Oil leakage test (if applicable). Oil filled equipment shall be subjected to an internal over pressure of 37.47 kPa for a period of 18 hours. The unit must be oil tight during 18 hour period.
- g) Dry DC withstand test with voltage level and time as per

T.S. clause 6.9

In addition to the tests mentioned above, all routine tests as mentioned in IEC 61869-15 shall also be performed.

6.10.3 DIRECT CURRENT MEASURING EQUIPMENT

6.10.3.1 General Requirements

Direct Current Transducers supplied shall be mounted in bushings, if available. In locations where bushings are not available, free standing transducers shall be provided.

For each transducer furnished, the Contractor shall provide all necessary auxiliary power plus any equipment necessary for the transformation of the auxiliary power to an acceptable form.

The design of the measuring system shall be based on maximum interchange ability where any electronic module shall be compatible with any of the core & coil assemblies.

The transducer output signal shall be of sufficient magnitude to ensure that the content of the signal is usable at all levels of primary current from 1% to 300% of the rated current, with a measurement output possible up to 600% before saturation of the output signal occurs.

In the event of high current (up to 0.2s short circuit current), the DCCT shall remain unsaturated for 20 ms or longer. This time shall be measured from the instant the current attains 10 p.u. The DCCT shall be provided with interlock circuits that indicate saturation of the DCCT, as well as DCCT faults.

The Contractor shall ensure that any low level signals generated are kept shielded from interference due to other higher voltage circuits. The low level signals shall be cabled separately from high level signals.

The Contractor shall ensure in the factory that all dc current measurement outputs are accurately calibrated with all the respective loads connected. If required, on-site adjustments to output calibration shall be possible. The sensitivity of the devices supplied for such calibration shall be appropriate for setting the required accuracy.

The electronic module shall be provided with interlock circuits to indicate that the measuring system is fully operable.

For free standing transducers, the core & coil assembly shall be housed in an oil filled porcelain or dry silicone rubber insulator enclosure. Oil filled equipment is not allowed in valve hall. The core & coil assembly for bushing mounted transducers shall be mounted around the bushing in air. Each transducer shall be provided with a capacitive tap.

Where Optical DC measuring systems are provided, utmost care shall be taken in the design of the transducers so that these operate with very high reliability in the environmental conditions as defined in chapter 2. It is to be noted that the DC measuring systems installed in outdoor environment at the site shall be subjected to extremely high humidity conditions and temperature variations during the day and over the seasons. The housings of the DC measuring systems and

associated electronics shall be suitably designed to perform reliably under harsh environmental conditions. The materials used in Optical DC measuring systems shall be non-corrosive in nature.

6.10.3.1.1 STATIONARY ACCURACY

The composite accuracy of all dc current measurement systems used for protective purposes shall be equal to or better than $\pm 2\%$ of rated dc current up to 120% of the maximum rated current and $\pm 10\%$ of rated dc current up to 1.2 times peak calculated fault dc current.

All dc current measuring system used for control purposes shall have a composite accuracy of $\pm 0.75\%$ of rated dc current from minimum rated current to 120% of the maximum rated current and $\pm 10\%$ of rated dc current from 120% up to 300% of the rated current.

All transducers used for corresponding functions, e.g. pole differential protection etc., shall have matching accuracies equal to or better than $\pm 2\%$ of rated current upto 300% of the rated current.

The Contractor shall specify (& test accordingly) the matching accuracy requirement of the measuring systems.

6.10.3.1.2 DYNAMIC ACCURACY

The response of the measuring systems shall be such that a linear current change within 150% of maximum rated current and with a rise time of

45 ms, is tracked by the transducer output with an error which does not exceed +0%,-2% of rated current on any point of the curve. The rise time is defined as the time required for the current to change from 10 to 90% of the full current change. The frequency response shall be within +3% at 1500 Hz.

6.10.3.1.3 STEP RESPONSE

The step response of the transducers shall be such that the output signal rise time for an infinitely steep input current step is less than 0.4 ms.

It is recognized that an infinitely steep current step is impossible to realize. The measuring system's rise time shall therefore be evaluated from the relation:

$t(\text{total}) = [t(\text{output})^2 - t(\text{input})^2]$ where ,

$t(\text{input})$ = rise time of the applied current step,

$t(\text{output})$ = observed rise time on the output of the transducer

and $t(\text{total})$ = calculated transducer rise time for an infinitely steep current step.

6.10.3.2 Testing

Different units of the electronic module shall be used during testing of

core & coil assembly of various types and rating.

For the tests, a connection cable of a type identical to, or with data inferior to the one used at site shall be used to connect the electronic module to the core and coil assembly.

The length of the connection cable shall be equal to or longer than the longest one to be used at site.

The supply voltage shall be minimum for all tests except the temperature rise tests where the maximum supply voltage shall be used.

Multiple loops for the primary current may be used to obtain the required number of ampere-turns for the tests.

The programme of tests for the dc current measuring system shall include, but not necessarily be limited to, the following:

.1 TYPE TESTS

The type tests shall be conducted on one unit of each type & rating.

a) All types of transducers:

- 1) DC current measurement system accuracy test up to 300% of the rated current at rated design burden.
- 2) Step response test of dc current measuring system
 - 0 p.u – 1 p.u.,
 - 1 p.u. – 0 p.u.,
 - 0.5 p.u. – 0.25 p.u., and
 - 0.5 p.u. – 0.75 p.u.

(The acceptable levels of overshoot & settling time to 1.5% of current shall be specified by the Contractor while writing the detailed Equipment Specification).

3) The measuring system behaviour at high current shall be tested with a step current. The front of the wave shall be an approximately linear ramp.

Primary step current = short circuit current

0.2 Step duration = min 20 ms

Step rise time = 4 ms

The following accuracy requirements shall be met during the step: For primary currents of 0-5 p.u., the accuracy shall be within 10% of rated current.

For currents in excess of 5 p.u., the DCCT output voltage shall be in excess of 10 V for at least 20 ms after the current attained 10 p.u. At this test, the saturation detection shall be checked. A relay contact shall be given not sooner than 15 ms nor later than 20 ms

after the current attained 10 p.u.

4) Frequency response test for frequencies up to 1500 Hz.

5) Temperature range test

The output voltage shall be recorded as a function of the temperature at rated current over the full temperature range as specified. A functional performance test at elevated ambient temperature shall also be performed for the measuring systems in accordance with IEC 68.2.2.

6) Transient Immunity Test

7) Surge withstand capability test in both longitudinal & transverse modes.

b) Free standing transducers:

1) Dielectric tests in accordance with Clauses 6.9 and 6.11.

2) Temperature rise test.

In addition to the tests mentioned above, all type tests as mentioned in IEC 61869-14 shall also be performed for all type of transducers.

.2 ROUTINE TESTS

a) All types of transducers:

1) DC current measurement accuracy test up to 100% maximum rated current. Also check matching accuracy.

2) Dynamic accuracy test with 0.5-0.25 p.u., 0.5-0.75 p.u. steps.

3) Insulation test of output windings at 2 kV, 1 minute.

4) Ratio Test.

5) Induced voltage test for core & coil verification.

6) Output amplifier limit test.

b) Free standing transducers:

1) DC dry withstands test and internal partial discharge test with voltage level and time as per T.S. clause 6.9

2) Power factor test.

3) Oil leakage test (if applicable).

4) Oil filled equipment shall be subjected to an internal oil over pressure of 34.47 kPa for a period of 18 hours. The unit shall be oil tight during an 18 hour period.

5) Demonstration of the dc current transformers, measuring system accuracy over the operating range, and for step input current of 0.5 p.u. - 0.25 p.u., and 0.5 p.u. - 0.75 p.u.

In addition to the tests mentioned above, all routine tests as mentioned in IEC 61869-14 shall also be performed for all type of transducers.

6.10.3.3 Testing of transducers based on shunt technology

.1 Type Tests

The programme of type tests shall include, but not necessarily be limited to the following:

1) Short time current tests

Short-time current test as specified in IEC 60044-1 shall be performed or verified by calculations in accordance with the provisions of IEC 60044-1.

2) Accuracy test

Determination of errors is according to IEC 60044-1, clause 12.4 and 12.5.

The test according to IEC 60044-1, clause 12.4, shall be accomplished at the ambient temperatures: -40 °C, +20 °C and +85 °C.

The accuracy test shall be done upto maximum overload current on the complete DCCT including shunt. Beyond this value and upto 600% of I_N , the contractor shall suggest a suitable method for verifying the accuracy. The accuracy (in percent of I_N) within the specified ambient temperature range of the current transducer shall be minimum for the following ranges of I_N

| | |
|----------|------|
| 0- 120% | 0.5% |
| 120-300% | 1.5% |
| 300-600% | 10% |

3) Temperature rise test

The temperature rise-test shall be carried out in accordance with IEC 60044-1, clause 7.2. The test current shall be d.c. or a.c. 50 Hz. The test shall be performed at the maximum continuous d.c. current or at an r.m.s. current equal to the maximum continuous d.c. current.

4) Step response

Transient response test on the current transducer shall be performed on the electronic part of the OCT for the following steps:

- a) 0.1 p.u. to 1 p.u.
- b) 1 p.u. to 0 p.u.
- c) 0.5 p.u. to 0.25 p.u.
- d) 0.5 p.u. to 0.75 p.u.

where 1 p.u. is a voltage corresponding to the nominal direct current, I_N .

Transient response test shall be performed for the following current steps:

a) 0 pu to 0.1 pu.

b) 0.1pu to 0 pu.

where 1 p.u. is equal to the nominal direct current,

I_N . The acceptance criteria shall be:

Maximum overshoot is 20% of step.

Maximum rise time to 90% of step is 400

μ s. Maximum settling time to 1.5% of I_N

is 5 ms.

5) Frequency response

Frequency Response Test demonstrating the a.c. measurement ratio (magnitude) and phase for sinusoidal inputs for frequencies up to 1500 Hz.

Passing criteria:

Maximum allowed amplitude error is 0.5% of I_N at 300 Arms for frequencies up to 300 Hz and 100 Arms for frequencies above 300 Hz and up to 1200 Hz.

Maximum allowed phase displacement is 500 μ s at 300 Arms for frequencies up to 300 Hz and 100 Arms for frequencies above 300 Hz and up to 1200 Hz.

6) EMC requirements

7) Dielectric tests

.2 Routine Tests

Routine test shall be performed on each unit.

The accuracy test shall be performed after the other routine tests.

The programme of routine tests for the dc current measuring system shall include, but not necessarily be limited to the following:

1) Optical check of the fibres and their terminations

2) Step response

The transient response test shall be performed on the electronic part of the OCT for the following steps:

a) 0 p.u. to 1 p.u.

b) 1 p.u. to 0 p.u.

where 1 p.u. is a voltage corresponding to the nominal direct current, I_N . The acceptance criteria shall be:

Maximum overshoot is 20% of step.

Maximum rise time to 90% of step is 100micro sec

3) Accuracy test

Determination of errors shall be performed on the electronic part of the OCT in accordance with applicable parts of IEC 60044-1, clause 12.4.

The measuring points, to be tested by voltage, shall be at least: 0, 1,1.2, 2, 3, 6 p.u. of the voltage which corresponds to the nominal primary current.

Determination of errors shall also be performed with primary current of 1p.u. The test current shall be the nominal direct current or an a.c. current with the r.m.s. value equal to the nominal direct current.

The accuracy test shall be done upto maximum overload current on the complete DCCT including shunt. Beyond this value and upto 600% of I_N , the contractor shall suggest a suitable method for verifying the accuracy.

Passing criteria:

The accuracy (in percent of I_N) shall be minimum for the following ranges of I_N

| | |
|------------|------|
| 0- 120% | 0.5% |
| 120 – 130% | 1.5% |
| 300 – 600% | 10% |

6.11 AC INSTRUMENT TRANSFORMERS

6.11.1 GENERAL

The AC Instrument Transformers and accessories shall conform to the latest version of IEC 61869 for current transformers (CT) and 60358 for voltage transformers (CVT). The instrument transformers provided for control, metering and protective relaying functions shall have accuracy ratings and burden capabilities adequate to provide their designated functions within the overall accuracy requirements of the systems.

The specification given below mainly relates to oil filled instrument transformers. If the bidder intends to offer instrument transformers other than oil filled (such as SF6, cast resin, optical, etc.), the details of the same shall be submitted with the bid.

6.11.2 TECHNICAL AND CONSTRUCTIONAL REQUIREMENTS

The following requirements shall apply:

6.11.2.1 Common for all Instrument Transformers

.1 BUSHING/INSULATORS

- a) The instrument transformers shall be oil filled or SF6 insulated with porcelain/bushings suitable for outdoor service and upright mounting on steel structures.
- b) Bushing/Insulators shall conform to requirements of Clause 6.15.

- c) Bushings shall be provided with oil filling and drain plugs, oil sight glass for CT and for electromagnetic unit of CVT etc. — SF6 filled equipment with monitoring of gas leakage alarm and trip shall also acceptable
- d) Instrument transformers shall be hermetically sealed units. The Bidder/Contractor shall furnish details of the arrangements made for the sealing of instrument transformers.
- e) Polarity shall be marked on each instrument transformer and at the lead terminals at the associated terminal block.

.2 BOX

Each single phase instrument transformers shall be complete with its terminal box. The terminal box shall meet the requirements of IP 55 as per IS-13947 Part 1 or equivalent relevant IEC/Standard. A marshalling box for a set of 3 instrument transformers shall be provided, wherever required.

.3 TANK

The Instrument transformer tank alongwith top metalics shall be cast Aluminium/ hot dip galvanised or painted.

.4 Lifting Arrangements

Instrument transformer shall be provided with suitable lifting arrangement, to lift the entire unit. The lifting arrangement shall be clearly shown in the general arrangement drawing.

6.11.2.2 Current Transformers (CT)

- .1 Current transformers shall have single primary either ring type, or bar type (live tank) , or hair pin type (dead tank) and suitably designed for bringing out the secondary terminals in a weather proof terminal box at the bottom. These secondary terminals shall be terminated to stud type non disconnecting terminal blocks inside the terminal box.
- .2 Different ratios, as specified/required shall be achieved by secondary taps only and primary reconnection shall not be acceptable.
- .3 Core lamination shall be of cold rolled grain oriented silicon steel or other equivalent alloys.
- .4 The expansion chamber at the top of the insulators shall be suitable for expansion of oil.
- .5 Facilities shall be provided at terminal blocks for star/delta formation, short circuiting and grounding of CT secondary terminals.
- .6 The guaranteed burdens and accuracy class are to be simultaneous for all cores. The accuracy class for measuring cores shall be met upto the rated extended primary current.
- .7 For 420 kV class CT's the rated extended primary current of the CT's shall be 200% of rated primary on all except (one) highest tap ratio. On the highest tap ratio, the rated

- extended primary current shall be 120% for line bays.
- .8 The current transformer shall be suitable for horizontal transportation. Live Tank Design CTs may be transported with vertical arrangement.
 - .9 The instrument security factor of metering core at all ratios shall be less than 5. If any auxiliary CTs/reactor are used in the current transformers than all parameters specified/required shall have to be met treating auxiliary CTs as an integral part of the current transformer. The auxiliary CTs/reactor shall preferably be inbuilt construction of the CT. In case these are to be mounted separately these shall be mounted in the central marshalling box suitably wired up to the terminal blocks.
 - .10 The current transformers shall be suitable for high speed auto- re-closing, if required.
 - .11 Special Technical Requirements
 - a) Through Fault Capability

The current transformers shall be capable of withstanding with the secondary short circuited, a fully offset primary current having an ac (i.e. symmetrical) component with an rms value equal to the specified short-circuit capacity of the system. The CT's shall withstand the discharges of filter banks after ground fault.
 - b) Transient Performance (If applicable)

The current transformers shall meet the requirements for transient performance and tests shall be conducted accordingly.
 - .12 The Employer shall also accept optical CT's as described and tested in accordance with IEC60044 for current transformers.

6.11.2.3 Voltage Transformers

- .1 Voltage transformers shall be capacitor voltage divider type with electromagnetic units and shall be suitable for carrier coupling. For valve timing measurement, inductive type voltage transformers are acceptable.
- .2 The electromagnetic unit consisting of compensating reactor, intermediate transformer, protective and damping devices etc. shall also be mounted in a hermetically sealed metal enclosure, which shall also be used as a mechanical support for the capacitor voltage divider. The terminals of the secondary windings of the electromagnetic units shall be brought out in a separate, weather proof terminal box, which shall be properly mounted on the wall of the metal enclosure of the electromagnetic unit. Suitable quantity of silica gel shall also be provided in a suitable porous container.
- .3 The capacitor voltage divider shall be capable of being used over a wide carrier frequency band-width. The value of

capacitance shall be suitably chosen for reliable wide band carrier coupling and shall not be less than 4400 pico farads. The reactance of the teed branch of the CVT shall be adjusted to minimize carrier loss. With carrier frequency coupling device connected to the earth lead of the intermediate coupling capacitor, the accuracy of the electromagnetic voltage transformer unit shall remain within the specified limits.

- .4 Each core of secondary winding to be used for protection purpose shall be protected by MCB's of suitable rating. NO and NC contacts shall be provided on the MCB for monitoring purposes. The secondary terminals of the CVT's shall be terminated to the stud type non-disconnecting terminal blocks in the individual phase secondary boxes via the MCB's.
- .5 The accuracy of metering winding shall be maintained through out the entire burden range upto total burden simultaneously on all the three windings without any adjustments during operation.
- .6 It shall be ensured that access to secondary terminals is without any danger of access to high voltage circuit.
- .7 A protective surge arrester shall be provided to prevent breakdown of insulation by incoming surges and to limit abnormal rise of terminal voltage of shunt capacitor, tuning reactor/RF choke etc. due to short circuit in transformer secondaries.
- .8 Special Technical Requirements

a) Transient Response

The transient response (at rated frequency and beyond) shall be such that , after sudden removal of the primary voltage, the transient secondary voltage in the capacitor voltage transformer shall not exceed 10 (Ten) percent of the peak value of the secondary voltage existing before the collapse of the primary voltage to zero nor it shall exceed value required to meet the performance. This value shall be measured

(oscillograms) following the primary short circuit when the capacitor voltage transformer is loaded with 25% and 100% of rated burden at 0.8 power factor lagging.

b) Ferro-resonance

The Ferro-resonance requirement shall be met as per the relevant standards. i

c) Protective Device

A protective device shall be incorporated in the capacitor voltage transformer for the purpose of limiting over voltages which may appear across one or more of its components. The device shall include a heavy duty class spark gap with adjustable setting and drain coil. The setting of the protective device shall be determined by

the Contractor, however, it shall be adjustable and shall not introduce distortion in the secondary voltage wave shape at rated frequency and at an applied voltage up to 1.2 per unit of nominal voltage.

Should the protective device operate on switch surge or atmospheric over voltages, the secondary voltage shall recover to its correct wave shape within 4 ms when the applied voltage is 1.2 per unit of nominal voltage.

d) Power Line Carrier Coupling Application

If required, the capacitor voltage transformers shall be equipped with power line carrier coupling components, and the capacitance value shall be that required for PLCC coupling purposes.

e) Reproduction of Harmonics

Harmonics with frequency 100 Hz to 650 Hz superimposed on the fundamental frequency shall be reproduced within an accuracy of amplitude error of 10% & phase angle error (for each separate harmonic) of 10 degree elect.

f) Reproduction of Transients

A step of 10% of rated voltage (rms) superimposed on the primary voltage shall be reproduced at maximum burden with a delay (time constant) of less than 100 microsecond and within $\pm 10\%$ of correct value within 400 microsecond.

6.11.3 TYPE TESTS

The current transformers shall be type tested as per the requirements of IEC: 61869-1, the capacitive voltage transformers shall be type tested as per IEC-61869-5, the voltage dividers shall be type tested as per IEC-61869-11. Additional type tests as specified below shall also be conducted on one unit of each type, rating and class:

6.11.3.1 Current Transformers

- a) External radio interference measurement on 400 kV CTs only.
- b) Seismic withstand verification by calculation
- c) Thermal stability test i.e. application of rated voltage and rated current simultaneously by synthetic test circuit.
- d) Thermal co-efficient test i.e. measurement of tan-delta as a function of temperature (at ambient and between 80 oC & 90 oC) and voltage (at 0.3, 0.7, 1.0 and $1.1 U_m/\sqrt{3}$). This test shall be performed for oil filled CTs ≥ 72.5 KV class
- e) Fast transient test as per IEC 60044-1.

6.11.3.2 Voltage Transformers

- a) External radio interference measurement.
- b) Seismic withstand verification.
- c) Stray capacitance and stray conductance measurement of the low voltage terminal as per of IEC-60358.
- d) Determination of temperature coefficients as per IEC-60358.
- e) Capacitive potential transformers shall also be submitted to the following type tests :
- f) Transient response test
- g) Ferro-resonance test
- h) High frequency capacitance and equivalent series resistance.

6.11.4 ROUTINE TESTS

The current transformers shall be subject to routine tests as per IEC: 61869-1 and the voltage transformers shall be routine tested as per IEC-61869-5, the voltage dividers shall be routine tested as per IEC-61869-11. Additional routine tests as specified below shall also be conducted on each unit:

6.11.4.1 Current Transformers

- a) Measurement of capacitance
- b) Measurement of tan delta at 0.3, 0.7, 1.0 and 1.1 $U_m/\sqrt{3}$
- c) Oil leakage test

6.11.4.2 VOLTAGE Transformers

- a) Capacitance and loss angle measurement before and after dielectric tests as per IEC-60358
- b) Sealing test as per IEC-60358

6.12 Not Applicable

6.13 Not Applicable

6.14 Not Applicable

6.15 HVAC INSULATORS, BUSHINGS, BUSES AND HARDWARE

6.15.1 GENERAL

The insulators, bushings, buses and hardware used in the HVAC switchyards shall be in accordance with the relevant Standards.

6.15.2 BUSHINGS AND SUPPORT INSULATORS

6.15.2.1 GENERAL

Bushings shall be manufactured and tested in accordance with IEC-60137 and IS-2099&IS-3347 while hollow column insulators shall be manufactured and tested in accordance with IEC-233 and IS-5284. The support insulators shall be manufactured and tested as per IEC-60168, IEC-60273 and IS-2544. The insulators shall also conform to IEC-60815 as applicable.

The AC Bus post Insulator may be Polymer Insulator.

The insulation levels shall be determined by the Contractor in accordance with Section 4 of this Specification, but the minimum performance characteristics for the 400 kV ac shall be as specified in Clause 6.15.2.3.

The creepage distances for the porcelain and silicon rubber insulators shall be as per Section 4 of TS.

All bushings shall be one piece only and no joints shall be accepted. If joints are unavoidable on a bushing, the Contractor shall seek Employer's approval on a case to case basis. For all bushings, all required necessary material to fix it to the wall shall be supplied along with the bushing.

All AC Bushings upto 400 KV level shall be RIP Bushings

6.15.2.2 CONSTRUCTIONAL FEATURES

- a) Porcelain used shall be homogeneous and free from imperfections that might affect the mechanical or dielectric quality.
- b) Glazing of the porcelain shall be of uniform brown color, free from blisters, burns and other similar defects. The ground surface shall not be glazed.
- c) Condenser type bushing shall be provided with :
 - i) Oil level gauge.
 - ii) Oil filling plug and drain valve if not hermetically sealed.
 - iii) Tap for capacitance and tan delta test.
- d) When bushings have an under-oil end of re-entrant form, the pull through lead shall be fitted with a gas bubble deflector.
- e) Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.
- f) Bushings of identical rating shall be interchangeable.
- g) No arching horns shall be provided on the bushings.
- h) All ferrous parts shall be hot dip galvanized or zinc plated and passivated. All joints shall be airtight. Insulator/bushing design shall be such as to ensure uniform compressive pressure on the joints.
- i) Support insulators/bushings/hollow column insulators shall be designed to have ample insulation, mechanical strength and rigidity for the conditions under which they shall be used.
- j) When operating at rated voltage there shall be no electric discharge between conductor and insulators which would cause damage to conductors or insulators by the formation of substances produced by chemical action. No radio interference shall be caused when operating at rated voltage.
- k) The design of the insulator shall be such that stresses due to

expansion and contraction in any part of the insulator shall not lead to deterioration.

- l) The Bidder/Contractor shall define the type of insulator (type A or B) as per IEC-60168.
- m) Bushing porcelain shall be robust and capable of withstanding the internal pressures likely to occur in service. The design and location of clamps and the shape and the strength of the porcelain flange securing the bushing to the tank shall be such that there is no risk of fracture. All portions of the assembled porcelain enclosures and support so there than gaskets ,which may in any way be exposed to the atmosphere shall be composed of completely nonhygroscopic material such as metal or glazed porcelain.
- n) Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection. The surface of all paper insulation shall be finished with non-hygroscopic varnish which can not be damaged easily.

6.15.2.3 PARAMETERS

The parameters shall be determined by the Contractor, however the minimum performance parameters for the 400kV class post insulator shall be as follows:

| | | |
|----|---|------|
| a) | Lightning impulse withstand positive and negative (kVp) (Dry and wet) | 1425 |
| b) | Switching impulse withstand voltage (kVp) | 1050 |

| | | |
|----|--|-------|
| c) | One min. power freq. withstand voltage (kV _{rms})(Wet and Dry) | 630 |
| d) | Total creepage distance (mm) | 10500 |
| e) | Total min. cantilever strength (kg) | 800 |
| f) | Corona extinction voltage (kV _{rms}) | 320 |
| g) | Total min. height of insulator (mm) | 3500 |

6.15.2.4 TESTS

Each type of bushing and insulator shall be subjected to type and routine tests in accordance with applicable standards and acceptance test shall include one-minute dry power frequency withstand test and ultrasonic test(except for hollow insulator).The ultra sonic test shall be done on the porcelain before assembly. All sample tests and special tests shall also be conducted.

Additional type tests to be carried out if joint is provided in bushing as follows:

1. Mechanical Bonding test at Jointed Section
2. Tracking and Erosion Test(IEC-60587)
3. Water diffusion Test(Samples to be taken from jointed area)
4. Gas leakage test followed by Mechanical tests at the Joint area

6.15.3 Not used

6.15.4 TUBULAR BUS CONDUCTORS

6.15.4.1 GENERAL

Aluminum used shall be of grade 63401WP conforming to IS-5082.

6.15.4.2 CONSTRUCTIONAL FEATURES

- a) For outside diameter (OD) & thickness of the tube there shall be no minus tolerance. The other requirements shall be as per IS-2678 and IS-2673 and IEC 114.
- b) Corona bells shall be provided wherever the bus extends beyond the clamps Andon free ends for sealing
The ends of the tubular conductor again strain and moisture and to reduce the electrostatic discharge loss at the end points.
There shall be small drain hole at the end of each corona bell.
- c) The welds in the aluminium tubes shall be kept to the minimum and there shall not be more than one welder span.
The procedure and details of welding shall be furnished for approval of the Employer. Material for welding sleeve shall be same as the Aluminium tube.

6.15.4.3 PARAMETERS

The size and other parameters of tubular bus conductors shall be determined by the Contractor.

6.15.4.4 TESTS

The tests shall be conducted on tubular bus conductors as per IS-5082/relevant IEC Standards. Also, the wall thickness by ultrasonic method and ovality of the tube by Vernier calipers shall be measured. In addition to the above tests, 0.2% proof test on both parent metal and aluminum to be after welding shall be conducted.

6.15.5 FLEXIBLE BUS-BARS AND EARTHWIRE

6.15.5.1 GENERAL

The conductors shall conform to IS-398/relevant IEC Standards.

6.15.5.2 CONSTRUCTIONAL FEATURES

a) Workmanship

All the aluminium strands shall be smooth, uniform and free from all imperfections, such as spills and splits, diemarks, scratches, abrasions and kinks after drawing and also after stranding.

The finished conductor shall have a smooth surface without any surface cuts, abrasions, scuffmarks and shall be free from dirt, grit etc.

b) Joints in Wires

No joints shall be permitted in the individual wires in the outer most layer of the finished conductor. However, joints in the inner layers the conductor shall be allowed but these joints shall be made by cold pressure butt-welding and shall be such that no two such joints are within 15metres of each other in the complete stranded conductor.

No Joints shall be permitted in the conductor spans in the AC and DC switchyard.

c) Materials

The aluminium strands shall be hard drawn from electrolytic aluminium rods having purity not less than 99.5% and a copper content not exceeds 0.04%.

6.15.5.3 PARAMETERS

The size, rating, number of conductors per phase and the configuration, etc. shall be determined by the Contractor.

6.15.5.4 TESTS

The following type, acceptance and routine tests and tests during manufacture shall be carried out on the conductor in addition to the tests specified in relevant applicable standards.

6.15.5.4.1 Type Tests

DC Resistance Test on Stranded conductor

On a conductor sample of minimum 5m length two contact clamps shall be fixed with a predetermined bolt torque. The resistance shall be measured by Kelvin double bridge by placing the clamps initially zero meter and subsequently one meter apart. The test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20°C as per IS-398 (Part-V) 1982.

6.15.5.4.2 Acceptance Tests

- a) Visual and Dimensions check on Drums b) Visual Check for Joints, Scratches etc.
- c) Dimensional check on Aluminium Strands
- d) Check for lay-ratios of various Layers

The following tests shall be conducted once on sample/samples of conductor.

- i) Breaking load test on aluminium strands
- ii) Wrap load test on aluminium strands
- iii) DC resistance tests on aluminum strands

All the above tests shall be carried out on aluminium strands after stranding only.

6.15.5.4.3 Routine Tests

- a) Check to ensure that the joints are as per specification.
- b) Check that there are no cuts, fins, etc. on the strands.
- c) Check that drums are as per specification.

All acceptance tests as mentioned above are to be carried out on each coil

6.15.5.4.4 Tests During Manufacture

- a) Chemical Analysis of Aluminium used for making aluminium strands Samples taken from the aluminium ingots/coils/strands shall be chemically/spectrographically analyzed. The same shall be in conformity to the specified requirements.

6.15.5.5 PACKING

The conductor shall be supplied in strong wooden drums constructed to protect the conductor against all damage and displacement during transit, storage and subsequent handling And stringing operations in the field. The drums shall generally conform to IS-1778. Only one length of conductor shall be wound on each drum.

6.15.6 CLAMPS & CONNECTORS

6.15.6.1 GENERAL

The clamps and connectors shall be in accordance with the requirements given in section 3.

6.15.6.2 CONSTRUCTIONAL FEATURE

All casting shall be free from blow holes, surface blisters, cracks and cavities. All sharp edges and corners shall be blurred and rounded off.

Size of the terminal/connector for which the clamp/connector is suitable shall be embossed/punched (i.e. indelibly marked) on each component of the clamp/connector, except on the hardware.

The clamp shall be designed to carry the same current as the conductor and the temperature rise shall be equal or less than that of the conductor at the specified ambient temperature. The rated current for which the clamp/connector is designed with respect to the specified reference ambient temperature, shall also be indelibly marked on each component of the clamp/connector, except on the hardware.

All current carrying parts shall be designed and manufactured to have minimum contact resistance.

The Corona extinction voltage for 400kV class clamps shall not be less than 320 kV.

6.15.6.3 TESTS

The clamps and connectors shall be subject to type and routine tests as per IS-5561/relevant IEC Standards/**relevant NEMA Standards**. Type tests as per IS-5561/relevant IEC Standards/ **relevant NEMA Standards** shall be carried out on one sample of each type and design.

One sample of each type and design shall also be type tested for:

- i) Temperature rise test
- ii) Short time current
- iii) Dry corona and RIV
- iv) Resistance test and tensile test

6.15.7 **SPACERS**

6.15.7.1 GENERAL

The spacers shall conform to IS- 10162.

6.15.7.2 CONSTRUCTIONAL FEATURES

No magnetic material should be used in the fabrication of the spacers except for the GI bolts and nuts.

Spacer design shall be made to take care of fixing and removing during installation and maintenance.

The design of spacer shall be such that the conductor does not come in contact with any sharp edge.

6.15.7.3 TESTS

The spacers shall be subjected to the type tests, acceptance tests and routine tests in accordance with IS 10162.

6.16 **CABLING SYSTEMS**

6.16.1 **GENERAL**

All cabling systems, as per present scope including cables, cable trays & trenches, wiring, terminations etc., shall be in accordance with the applicable Standards and with the additional requirements listed below and elsewhere in this Specification. Cable sealing &

termination for cable end to be terminated at Employer's side shall be included in the Contractor's scope.

The Bidder/Contractor shall estimate the total requirement of various types and sizes of cables required for the Works. The Contractor shall submit, for the Employer's approval, the individual cable data sheets for all applications justifying type & size selected considering continuous current rating, voltage drop, ambient temperature and factors due to spacing, depth of laying etc.

Also refer Annexure-Power and Control Cable Scope for more clarity.

6.16.2 CABLES

6.16.2.1 Cable Type

- a) The High Voltage (6.6 kV to 33 kV) power cables shall be XLPE insulated conforming to IS-7098 (II) or relevant IEC standards.(HT cable is not a part of present scope)
- b) The Low Voltage power cables shall be 1.1 kV XLPE insulated conforming to IS-7098 (I) or relevant IEC standards and/or PVC insulated conforming to IS-1554 (I) or relevant IEC standard.
- c) The control cables shall be 1.1 kV PVC insulated conforming to IS- 1554 (I) or relevant IEC standard.
- d) Any other special purpose cable, specified elsewhere like HF cable etc.

6.16.2.2 General Technical Requirements

- a) Replacement of existing control and power cables shall be of same or greater size and same type. Contractor shall provide suitable technical justification for selection of cables.
- b) The cables shall be suitable for laying in racks/trays, ducts, trenches, conduits and underground buried installation with uncontrolled backfill and with chances of flooding by water.
- c) They shall be designed to withstand all mechanical, electrical and thermal stresses under steady state and transient operating conditions.
- d) The HV (6.6 kV to 33 kV) power cables shall withstand without damage a 3-phase fault current of 40 kA (rms) for at least 0.12 second, with an initial peak of 110 kA in one of the phases, when the insulation screens are insulated at one end. The XLPE/FRPVC insulated LV power cables shall be suitable for withstanding short circuit currents on the basis of area of cross section of cable as per manufacturer's standard ratings. The area of cross-section of cable shall be decided on the basis of connected load.
- e) The armour for XLPE insulated power cables shall be capable of carrying 45 kA for at least 0.12 seconds without exceeding the maximum allowable temperature of PVC outer sheath.
- f) Cable construction shall include sufficient electric magnetic shielding and adequate grounding, to ensure that any interference picked up by the signal pairs is sufficiently

attenuated to prevent mal-operation, damage or danger to any equipment and personnel under all operating conditions, including the effects of switching, faults, converter operation and the environment.

- g) The copper wires used for manufacturing of the cables shall be true circular in shape before stranding and shall be of uniform good quality, free from defects. All aluminium used in the cables shall be of H2 grade.
- h) The fillers and inner sheath shall be of non-hygroscopic, fire retardant material, softer than insulation & outer sheath and suitable for the operating temperature of the cable.
- i) Strip wire armouring following method (a) mentioned in the relevant IS or equivalent relevant IEC/Standard shall not be accepted for any of the cables. For armoured control cables only round wire armouring shall be used.
- j) Progressive sequential marking of the length in metres at every one metre shall be provided on the outer sheath of all cables.
- k) Suitable chemicals shall be added to the outer sheaths of all cables to protect them from rodent and termite attack.

The measured value of temperature index shall be 21 at a temperature of 250 degree Celsius, in line with IS 1554 (Part 1).

- l) The cables shall have outer sheath of a material with an oxygen index of not less than 29 and a temperature index of not less than 250°C.
- m) The normal current rating of all PVC insulated cables shall be as per IS-3961 or equivalent relevant IEC/Standard.
- n) During a short circuit as specified in (b) above the FRPVC and PVC insulated cables shall be capable of withstanding a conductor temperature of at least 160°C. However, the XLPE insulated cables shall be capable of withstanding a conductor temperature of at least 250°C.
- o) Repaired cables shall not be accepted.
- p) Allowable tolerance on the overall diameter of the cables shall be as per the relevant IS/IEC standard.
- q) Maximum acid gas generation of weight as per IEC-60754(I) shall not be more than 20% of the outer sheath material. The cables shall meet the requirements of light transmission of 40 %(min) and shall be tested as per ASTM-D-2843.
- r) All cables shall be armoured and of fire retarded low smoke type. However, cables where mechanically protected may be unarmoured.

6.16.2.3 High Voltage (6.6kV to 33kV) Power Cables

The HV cables shall conform to IS-7098 (Part II) or relevant IEC and this Specification. The conductor shall be stranded copper, circular and compacted.

The conductor screen and insulation screen shall both be of extruded semi-conducting compound and shall be applied along with the XPLE

insulation in a single operation by triple extrusion process so as to obtain continuously smooth interfaces. The metallic part of insulation screen of each core shall consist of copper tape, which shall be capable of carrying an earth fault current of 300 amperes for at least two (2) seconds. In multicore cables, the cores shall be identified by red, yellow and blue coloured strips and a distinct inner sheath shall be provided even if the cable is unarmoured. The outer sheath shall be black in colour.

6.16.2.4 Low Voltage (415 V) Power Cables (Armoured)

- a) The XLPE insulated cables shall conform to IS-7098 (Part I) or relevant IEC read along with this Specification. The conductor shall be stranded copper circular/sector shaped and compacted. In multicore cables, the core shall be identified by red, yellow, blue and black coloured strips or colouring of insulation. A distinct inner sheath shall be provided in all multicore cables even if they are unarmoured. For armoured/unarmoured cables, the inner /outer sheath shall be extruded PVC to type ST2 of IS-5831 or equivalent relevant IEC/Standard. Armouring shall consist of aluminium wires/strip.
- b) The FR-PVC (85°C) insulated cables shall conform to IS-1554 (Part I) or equivalent relevant IEC/Standard read along with all its amendments and this Specification. These shall be suitable for a steady conductor temperature of 85°C. The conductor shall be stranded copper, sector shaped and compacted. The insulation shall be extruded PVC to type C of IS-5831 or equivalent relevant IEC/Standard. A distinct inner sheath shall be provided in all multicore cables even if they are unarmoured. For multicore armoured cables, the inner sheath shall be of extruded PVC to type ST-2 of IS-5831 or equivalent relevant IEC/Standard. When armouring is specified for single core cables, the same shall consist of aluminium wires/strips. The outer sheath shall be extruded PVC to type ST-2 of IS-5831 or equivalent relevant IEC/Standard for all cables.
- c) The PVC (70°C) insulated cables shall conform to IS- 1554 (Part I) or equivalent relevant IEC/Standard read along with all its amendments and this Specification. These shall be suitable for a steady conductor temperature of 70°C. The conductor shall be stranded Copper. The insulation shall be extruded PVC to type A of IS-5831 or equivalent relevant IEC/Standard. A distinct inner sheath shall be provided in all multicore cables even if they are not armoured. For multicore armoured cables, the inner sheath shall be of extruded PVC. The outer sheath shall be extruded PVC to type ST-1 of IS-5831 or equivalent relevant IEC/Standard for all cables.

6.16.2.5 Control Cables (Armoured)

The control cables shall conform to IS-1554 (Part I) or equivalent relevant IEC/Standard and this Specification. The conductor shall be stranded copper. The insulation shall be extruded PVC to type A of IS-5831 or equivalent relevant IEC/Standard. A distinct inner sheath shall be provided in all cables whether armoured or not. The inner sheath shall be extruded PVC in all armoured cables. The outer sheath shall be of extruded PVC to type ST-1 of IS-5831 or equivalent relevant IEC/Standard, and shall be preferably gray in colour except where specifically advised by the Employer to be black.

While cores shall be generally identified as per IS-1554 (Part I) or equivalent relevant IEC/Standard, for the cables with more than five (5) cores, the identification of cores shall additionally be done by printing legible characters on all cores. The characters shall be white, and shall be printed at about 100 mm intervals all along the cable length.

6.16.2.6 Tests

Cables of each type and size shall be subject to all type tests, Routine and Acceptance tests listed in the relevant standards.

6.16.3 CABLING REQUIREMENTS

- a)** Cable construction shall include sufficient electric and magnetic shielding, adequately grounded, to ensure that any interference picked up by the signal pairs is sufficiently attenuated to prevent maloperation, damage or danger to any equipment and personnel under all operating conditions, including the effects of switching, faults, converter operation and the environment;
- b)** Cable shields and spare pairs shall be adequately grounded to avoid insulation puncture due to potential rises;
- c)** Cables shall be segregated on a pole basis.
- d)** Separate cables shall be assigned to the following functions:
 - AC power distribution.
 - DC power distribution.
 - Current transformer circuits.
 - Voltage transformer circuits.
 - DC voltage measuring circuits.
 - DC current measuring circuits.
 - AC control circuits.
 - Control circuits with low level (weak) signals.

Separate cables shall be assigned for the following functions except where a significant increase in the number of cables shall result:

- Control circuits.
- Protection circuits.
- Alarm circuits.

- e) Appropriate de-rating factors shall be applied to power cables when used in raceways according to the Standards;
- f) The cable raceways (trenches, trays and conduits) loading shall conform with the ANSI CI Standard (National Electrical Code). The minimum distance between power and control cables shall be 300 mm.
- g) High voltage cables, compressed-air piping, water piping, low voltage power cables, fibre optic (approach) cables, and control cables shall be placed each in different raceways;
- h) Cable termination and marshalling shall be arranged such that cabling extensions for later stages of the Work, if any, shall be accomplished with minimum interruption of operating equipment;
- i) The use of trunk control cables is permissible as long the overall reliability of the station is not reduced and provided that the radial control circuit concept is maintained;
- j) All cabling to be used in the Works shall be terminated at the equipment and/or panel terminal blocks;
- k) A minimum of 10 percent spare cores shall be allowed in each control cable for possible future use by Employer.
- l) Control cable pairs, smaller than size 2.5 mm^2 shall be twisted to minimize magnetic interference. Minimum pitch of twist shall be 10 cm;
- m) All control cables shall be copper; unarmoured but screened. Where adequate mechanical protection is not provided, the cables shall be armoured.
- n) AC & DC circuits shall not be run in same cable. The battery connections shall be made by single core cables.
- o) Pre-terminated control cables shall terminate in a suitable plug or multi-pin connector. The plug or multi-pin connector shall have a means of positive anchoring such as captive screws or other effective device. The plug or multi-pin connector shall be securely clamped to the cable sheath.
- p) The requirement for fibre optic cable standard shall be as per IEC – 60793-1, 2, 3.

Fibre optic cables shall be used to transmit the signals to and from various equipments and panels located at in the AC/DC switchyards, Valve Halls, control rooms, control and monitoring of thyristor valve firing, valve cooling rooms, etc.

Fibre optic cables of standard cable jacket sizes with identification and distance markings shall be used. The Contractor shall furnish an instrument for determining high loss signal attenuation of fibre optic cables. For all fibre optic cables including connectors, budget loss calculations applicable over the life of the equipment shall be submitted.

All pre-terminated cables and connectors shall be factory tested for continuity and insulation according to relevant IEC

standards. Fibre optic cables shall be suitable for the intended application and shall have high immunity to HV electrical and electromagnetic environment. The material used in the manufacturing of the optical fibre cables and splicing/maintenance shall be self-extinguishing, non-toxic, halogen free and impervious to water penetration and dermatological safe in its life time and shall not pose any health hazards.

All cables and associated connector shall be suitable for continuous operation at ambient temperature specified in Technical specification. The optical fibre cable should be protected against corrosion. Life of cable shall be at least to meet the requirement of plant life as mentioned in section 1 of TS.

Armoured Fiber optic cables used between Control room and Switchyard Bay Controllers shall be either duplicated or have ring bus configuration to ensure high availability of the system. All unarmoured fibre optic cable shall run in GI conduit. For other places suitable mechanical protection shall be provided.

6.16.4 CABLE TRAYS

All cables shall be laid in cable trays & trenches. No part shall remain hanging for more than 750 mm. The trays shall be made of slotted steel/aluminium & may be without covers. The power & control cables shall be laid in different tiers. In a trench, the power cables shall be laid in the upper racks. The cable between trench & equipment shall run in hard conduits. If PVC conduits are used, they shall be at least of Class II as per IS-4985 or equivalent relevant IEC/Standard. In cable trenches, the Contractor may use steel brackets on which cables may be laid directly. The spacing between brackets shall not exceed 750mm. However all cables inside buildings shall be laid in trays. Cables in false flooring areas may be directly laid on the concrete slab except fibre optic cables which shall run in dedicated cable trays.

All steel cable trays and accessories including coupler plates and hardware shall be hot dip galvanized after fabrication.

The cable trays shall be made up of minimum 2 mm thick GI material and shall be supported at span of maximum 1.5 M such that the maximum deflection at mid span shall not exceed 7 mm.

6.16.5 CABLE GLANDS

Double/Single compression type tinned/nickel plated (coating thickness not less than 20 microns in case of Tin and not less than 15 microns in case of nickel) brass cable glands shall be provided by the Contractor for all power and control cables. They shall comprise of heavy duty brass casting, machine finished and tinned to avoid corrosion and oxidation. Rubber components used in cable glands shall be neoprene and of tested quality.

6.16.6 CABLE LUGS

Cable lugs shall be tinned copper solder less crimping type conforming to IS-8309 or equivalent relevant IEC/Standard and IS-

8394 or equivalent relevant IEC/Standard suitable for aluminium or copper conductor (as applicable). The cable lugs shall suit the type of terminals provided. The cable lugs shall be of Dowell make or equivalent.

6.16.7 SITE REQUIREMENTS REGARDING CABLING

a) Single core cables in trefoil formation shall be laid with a distance of three times the diameter of cable between trefoil centre lines. All power cables shall be laid with a minimum centre to centre distance equal to twice the diameter of the cable.

b) Power and control cables shall be securely fixed to the supports/trays with self locking type nylon cable ties with de-interlocking facility at every 1.5 metre interval for horizontal run and every 0.5 metre interval for vertical run. These shall be supplied in different colours so that each cable/bunch of cables is tied separately are colour codified throughout its length. Wherever, with specific approval of Employer, bare cables run over walls or structures, suitable holding clamps shall be provided at 500 mm interval.

For single core power cables, trefoil clamps shall be provided. These trefoil clamps shall be of pressure die-cast Aluminium (LM-6) or Nylon-6 or fibre glass and shall include necessary fixing GI bolts, nuts, washers etc. These are required at every 2 metre cable runs.

c) Cables shall not be bent below the minimum permissible limit. The permissible limits are as follows:

| Type of cable | Minimum bending radius |
|---------------|------------------------|
| Power cable | 12 D |
| Control cable | 10 D |

Where D is overall diameter of cable.

d) Where cables cross roads, drains and rail tracks, the cables shall be laid in reinforced spun concrete or steel pipes, buried at not less than one metre depth.

e) In each cable run some extra length shall be kept at a suitable point to enable one (for LT cables) or two (for H.T. cables) straight through joints to be made, should the cable develop fault at a later date.

f) Selection of cable drums for each run shall be so planned as to avoid using straight through joints. Cable splices shall not be permitted except where called for by the drawings, unavoidable and where permitted by the Employer.

g) Control cable terminations inside equipment enclosures shall have sufficient lengths so that switching of termination in terminal blocks can be done without requiring any splicing.

h) Metal screen and armour of the cable shall be bonded to the earthing system of the station.

- i) Rollers shall be used at intervals of about 2.0 metres, while pulling cables.
- j) All due care shall be taken during unreeling, laying and termination of cable to avoid damage due to twist, kink, sharp bends etc.
- k) Cable ends shall be kept sealed to prevent damage.
- l) Inspection on receipt, unloading and handling of cables shall generally be in accordance with IS-1255 or equivalent relevant IEC/Standard and other Indian Standard Codes of Practices.
- m) Modular Multi-diameter Cable sealing system consisting of frames, blocks and accessories to be installed wherever the electrical / instrumentation / communication cables underground and over- ground enter or leave bay kiosks / control rooms / substations. Cable sealing to be with Multi-diameter type peelable/tearable EPDM polymer (halogen free) blocks(as per present scope wherever feasible) of different sizes to cover the cable diameter sizes upto 99mm to be provided for simple, easy and quick to assemble & re- assemble. 30% spare block on the frame to be provided with usable Multi-diameter blocks with center plug, so that these spare blocks can be used for expansion in future for wide range of cables, solid blocks should not be used on frame. Cable sealing system should have been type tested for fire / water / smoke tightness and supplier shall have local presence by way of full infrastructure having service support, training support and stocks support and also have necessary sales support for any change / extension in future. Frames & stay-plate material should be galvanized steel and for compression single piece wedge with galvanized steel bolts should be used. barrier material for sealing of cable entry points into the building shall fulfill a fire resistance integrity performance with a duration of minimum 3 hours.
- n) Not used.
- o) Contractor shall paint the tray identification number on each run of trays at an interval of 10 m.
- p) In case the outer sheath of a cable is damaged during handling/installation, the Contractor shall repair it and to the satisfaction of the Employer at his own cost. In case any other part of a cable is damaged, the same shall be replaced by a healthy cable, at no extra cost to the Employer.
- q) All cable terminations shall be appropriately tightened to ensure secure and reliable connections. The Contractor shall cover the exposed part of all cable lugs with insulating tape, sleeve or paint.
- r) Cable termination work shall include drilling of gland plates, fixing of glands and lugs, taping, ferruling etc.

- s) Wherever specifically required (for equipment or cable testing), the Contractor shall disconnect all cores of a cable from the equipment terminals and reconnect subsequently, free of cost.

6.17 UNINTERRUPTED POWER SYSTEM (UPS)/ Uninterrupted Motor Drive (UMD)

The rating of the UPS/UMD shall be decided by the Contractor.

Uninterrupted Motor Drive (UMD) shall be provided for valve cooling system. In case if UMD is not feasible, a single unit of the UPS provided must be rated to support the full starting current of the main valve cooling pumps, including during pump changeover sequences. Regarding the UPS/UMD system, the bidder may offer superior system for consideration by Employer.

The UPS/UMD system shall provide continuous ac power to critical loads in the event of power failure. The critical loads shall include at least the VPS&SCADA systems, computer systems and printers in the control room.

The UPS shall consist of the following, but not limited to, main components:

- The battery charger
- Maintenance free Ni-Cd Battery
- The static inverter

The UPS system shall consist of:

- Two number UPS Systems in parallel redundant mode for supplying load.
- One set each of Maintenance free batteries for each UPS System with backup duration of 30 minutes
- UPS output AC Distribution Boards.
- Power, control and network cables
- UPS having back up time of 3 hours and connected with the station batteries shall also be acceptable. Station batteries shall be rated accordingly.

The UPS shall be designed for continuous-duty, on-line operation and shall be based on solid-state design technology to provide uninterrupted power supply for Critical loads mentioned above. The control of the UPS system shall be microprocessor based providing monitoring and control of rectifier/charger, Inverter, static switches, firing and logic control.

Each UPS system provided by the Contractor shall include all of the following sub-systems as well as any other components and support hardware necessary for complete and proper operation of the UPS:

- a) Rectifier/charger unit
- b) Inverter unit.

- c) Battery Low Voltage Disconnect device d)
Static bypass switches
- e) Manual maintenance bypass switches f)
Load transformer and filters
- g) Control panels, automatic controls and protection
- h) Hardware and software as required for parallel
operation of UPS systems
- i) All necessary cables, MCCBs/ MCBs/ switches/ fuses

In the event of a loss of AC power source, the UPS equipment shall provide uninterrupted power to the critical loads from the output of the UPS inverter subsystems through batteries.

UPS Operation

The UPS systems shall operate in parallel redundant/hot standby configuration Connected to the load.

The UPS shall primarily use the inverter subsystem to deliver AC power to the computer system loads. In case of failure of any one UPS, the other healthy UPS shall continuously supply the power to the computer system loads without any interruption. If the other healthy UPS also fails then automatically Static bypass of UPS shall start supplying the connected load through AC mains without any interruption. The Manual Maintenance Bypass shall be provided for each of the UPS separately to extend AC raw power supply to computer systems in case of complete failure or shutdown of UPS systems. The UPS system shall provide continuous ac power to critical loads in the event of power failure, e.g. converter computer control Uninterruptable motor Drive (UMD) for valve cooling shall be rated for 2 minutes. However, UPS for HMI, VPS, SCADA system, computer system & printer etc. shall be rated for 30 minutes.

6.18 BATTERY

6.18.1.1 Type

The DC batteries shall be Nickel-Cadmium type and shall be discharge type as per Annexure-Z. These shall be suitable for a long life under continuous float operations and occasional discharges. Necessary Air- conditioning/Ventilation be provided in Battery room.

The overall accuracy of controlled or measured values, relative to the specified or actual values, shall be within these tolerances as per IEC standard.:

- a) +1 % for voltage;
- b) +1 % for current;
- c) +2 °C for temperature;
- d) +0,1 % for time;
- e) 1% of capacity

Separate dedicated split Air conditioning with exhaust fans to be

provided for main station battery room.

6.18.1.2 Constructional Requirements

The design of battery shall be as per field proven practices. Partial plating of cells is not permitted. Paralleling of cells externally for Enhancement of capacity is not permitted. Protective transparent front covers with each module shall be provided to prevent accidental contact with live module/electrical connections.

6.18.1.3 Containers

The container material shall have chemical and electro- chemical compatibility and shall be acid resistant. The material shall meet all the requirements of Ni-Cd batteries and be consistent with the life of battery. The container shall be fire retardant and shall have an Oxygen Index of at least 28 %. The porosity of the container shall be such as not to allow any gases to escape except from the regulation valve. The tensile strength of the material of the container shall be such as to handle the internal cell pressure of the cells in the worst working condition. Cell shall not show any deformity or bulge on the sides under all working conditions. The container shall be capable of withstanding the rigors of transport, storage and handling. The containers shall be enclosed in a steel tray.

6.18.1.4 Cell Covers

The cell covers shall be made of suitable material compatible with the container material and permanently fixed with the container. It shall be capable to withstand internal pressure without bulging or cracking. It shall also be fire retardant. Fixing of Pressure Regulation Valve & terminal posts in the cover shall be such that the seepage of electrolyte, gas escapes and entry of electro-static spark are prevented.

6.18.1.5 Separators

The separators used in manufacturing battery cells, shall be of glass mat or synthetic material having high acid absorption capability, resistant to sulphuric acid and good insulating properties. The design of separators shall ensure that there is no misalignment during normal operation and handling.

6.18.1.6 Pressure Regulation Valve

Each cell shall be provided with a pressure regulation valve. The valve shall be self re-sealable and flame retardant. The valve unit shall be such that it cannot be opened without a proper tool. The valve shall be capable to withstand the internal cell pressure specified by the manufacturer.

6.18.1.7 Terminal posts

Both the +ve and –ve terminals of the cells shall be capable of proper termination and shall ensure its consistency with the life of the battery. The surface of the terminal post extending above the cell cover including bolt hole shall be coated with an acid resistant and corrosion retarding material. Terminal posts or any other metal part which is in contact with the electrolyte shall be made of the same alloy as that of the plates or of a proven material that does not have any harmful effect on cell performance. Both +ve and –ve posts shall be clearly and unambiguously identifiable.

6.18.1.8 Connectors, Nuts & bolts, Heat shrinkable sleeves

Where it is not possible to bolt the cell terminals directly to assemble a battery, separate non-corroding lead or copper connectors of suitable size shall be provided to enable connection of the cells. Copper connections shall be suitably lead coated to withstand corrosion due to sulphuric acid at a very high rate of charge or discharge.

Nuts and bolts for connecting the cells shall be made of copper, brass or stainless steel. Copper or brass nuts and bolts shall be effectively lead coated to prevent corrosion. Stainless steel bolts and nuts can be used without lead coating. All inter cell connectors shall be protected with heat shrinkable silicon sleeves for reducing the environmental impact including a corrosive environment.

6.18.1.9 Flame Arresters

Each cell shall be equipped with a Flame Arrestor to defuse the Hydrogen gas escaped during charge and discharge. Material of the flame arrestor shall not affect the performance of the cell.

6.18.1.10 Battery bank Stand

All batteries shall be mounted in a suitable metallic stand/frame. The frame shall be properly painted with the acid-resistant paint. The suitable insulation shall be provided between stand/frame and floor to avoid the grounding of the frame/stand.

6.18.1.11 Not Used

6.18.1.12 Expected Battery Life

The battery shall be capable of giving 1200 or more charge/discharge cycles at 80% Depth of discharge (DOD) at an average temperature of 27°Celsius. DOD (Depth of Discharge) is defined as the ratio of the quantity of electricity (in Ampere-hour) removed from a cell or battery on discharge to its rated capacity.

6.18.1.13 Routine maintenance of battery system

FOR ROUTINE MAINTENANCE OF BATTERY SYSTEM, THE

CONTRACTOR SHALL SUPPLY 1 SET OF FOLLOWING TOOLS:

- a) Torque wrench
- b) Cell test voltmeter (-3 - 0 - +3) volts

6.18.1.14 Type Test of Battery

Contractor shall submit type test reports of following tests as per IEC 60623 & IS 10918

- a) Physical examination
- b) Dimensions, mass and layout
- c) Marking
- d) Polarity and absence of short circuit
- e) Air pressure test
- f) Ampere-hour capacity
- g) Discharge performance at low temperature
- h) Life cycle test
- i) Insulation resistance
- j) Dielectric;
- k) High Temperature float charge
- l) Storage

List of Factory & Site Tests for Battery

1. Physical Verification
2. C3 Capacity test on the cell for 220V system and C5 capacity test on 48V battery system
3. 8 Hrs. Charge and 15 minutes discharge test at full rated load

6.18.1.15 Installation & Commissioning

Manufacturer of Battery shall supervise the installation and commissioning and perform commissioning tests as recommended in O&M manual / or relevant standards /OEM recommendation. Original equipment manufacturer's installation / commissioning engineer shall be present during installation / commissioning of the equipment. All necessary instruments, material, tools and tackles required for installation, testing at site and commissioning are

To be arranged by Battery manufacturer/ Contractor.

6.18.2 BATTERY CHARGER

The Battery Chargers as well as their automatic regulators shall be of static type and shall be compatible with batteries. All battery chargers shall be capable of continuous operation at the respective rated load in float charging mode, i.e. Float charging the associated Batteries while supplying the DC load.

Charger shall regulate the float/boost voltage in case of prescribed temperature rise of battery as per manufacturer's recommendation to

avoid thermal runaway. Necessary temperature sensors shall be provided in mid location of battery banks and shall be wired up to the respective charger for feedback control. The manufacturer shall demonstrate this feature during testing of each charger.

All Battery Chargers shall be provided with facility for both automatic and manual control of output voltage and current. A selector switch shall be provided for selecting the mode of output voltage/current control, whether automatic or manual. When on automatic control mode during Float charging, the Charger output voltage shall remain within +1% of the set value, for AC input voltage variation of +10%, frequency variation of +5%, a combined voltage and frequency variation of +10%, and a DC load variation from zero to full load.

All battery chargers shall have a constant voltage characteristic throughout the range (from zero to full load) at the floating value of the voltage so as to keep the battery fully charged but without harmful overcharge.

All chargers shall have load limiters having drooping characteristic, which shall cause, when the voltage control is in automatic mode, a gradual lowering of the output voltage when the DC load current exceeds the Load limiter setting of the Charger. The Load-limiter characteristics shall be such that any sustained overload or short circuit in DC System shall not damage the Charger, nor shall it cause blowing of any of the Charger fuses. The Charger shall not trip on overload or external short circuit.

Uniform and step less adjustments of voltage setting (in both manual and automatic modes) shall be provided on the front of the Charger panel covering the entire float charging output range specified. Step less adjustments of the Load-limiter setting shall also be possible from 80% to 100% of the rated output current for Charging mode.

During Boost Charging, the Battery Charger shall operate on constant current mode (when automatic regulator is in service). It shall be possible to adjust the Boost charging current continuously over a range of 50 to 100% of the rated output current for Boost charging mode.

The Charger output voltage shall automatically go on rising, when it is operating on Boost mode, as the Battery charges up. For limiting the output voltage of the Charger, a potentiometer shall be provided on the front of the panel, whereby it shall be possible to set the upper limit of this voltage anywhere in the output range specified

for Boost Charging mode.

The Charger manufacturer may offer an arrangement in which the voltage setting device for Float charging mode is also used as output voltage limit setting device for Boost charging mode and the Load-limiter of Float charging mode is used as current setting device in boost charging mode.

Suitable filter circuits shall be provided in all the chargers to limit the ripple content (Peak to Peak) in the output voltage to 1%, irrespective of the DC load level, when they are not connected to a Battery.

The chargers should have the facility for Midpoint earthing for 220V Battery system and Positive earthing for 48V Battery system. The earth fault relay should be built inside the charger.

6.18.2.1 MCCB

All Battery Chargers shall have 2 Nos. MCCBs on the input side to receive cables from two sources. Mechanical interlock should be provided such that only one shall be closed at a time. It shall be of P2 duty and suitable for continuous duty. MCCB's should have auxiliary contacts for annunciation.

6.18.2.2 Rectifier Transformer

The rectifier transformer shall be continuously rated, dry air cooled (A.N) and of class F insulation type. The rating of the rectifier transformer shall have 10% overload capacity.

6.18.2.3 Rectifier Assembly

The rectifier assembly shall be fully/half controlled bridge type and shall be designed to meet the duty as required by the respective Charger. The rectifier shall be provided with heat sink with their own heat dissipation arrangements with natural air cooling. Necessary surge protection devices and rectifier type fast acting HRC fuses shall be provided in each arm of the rectifier connections.

6.18.2.4 Instruments

One AC voltmeter and one AC ammeter along with selector switches shall be provided for all chargers. One DC voltmeter and DC ammeter (with shunt) shall be provided for all Chargers. The instruments shall be flush type, dust proof and moisture resistant.

The instruments shall have easily accessible means for zero adjustment. The instruments shall be of 1.5 accuracy classes. In addition to the above a centre zero voltmeter with selector switch shall also be provided for 220 V chargers for testing purpose.

6.18.2.5 Air Break Switches

One DC output switch shall be provided in all chargers. They shall be air break type suitable for 500 volts AC/ 250 DC. The contacts of the switches shall open and close with a snap action. The operating handle of the switch shall be fully insulated from circuit. `ON` and `OFF` position on the switch shall be clearly indicated. Rating of switches shall be suitable for their continuous load. Alternatively, MCCB's of suitable ratings shall also be acceptable in place of Air Break Switch.

6.18.2.6 Fuses

All fuses shall be HRC Link type. Fuses shall be mounted on fuse carriers which are in turn mounted on fuse bases. Wherever it is not possible to mount fuses on carriers, fuses shall be directly mounted on plug-in type base. In such case one insulated fuse pulling handle shall be supplied for each charger. Fuse rating shall be chosen by the Bidder depending on the circuit requirement. All fuses in the chargers shall be monitored. Fuse failure annunciation shall be provided on the failure of any fuse.

6.18.2.7 Blocking Diode

Blocking diode shall be provided in the positive pole of the output circuit of each charger to prevent current flow from the DC Battery into the Charger.

6.18.2.8 Annunciation System

Audio-visual indications through bright LEDs shall be provided in all Chargers for the following abnormalities:

- a) AC power failure
- b) Rectifier/chargers fuse blown
- c) Over voltage across the battery when boost charging
- d) Abnormal voltage (High/Low)
- e) Any other annunciation if required.

Potential free NO Contacts of above abnormal conditions shall also be provided for common remote indication "CHARGER TROUBLE" in Employer's Control Board. Indication for charger in float mode and boost mode through indication lamps shall be provided for chargers. A potential free contact for float/boost mode shall be provided for external interlocks.

6.18.2.9 Name Plates and Marking

The name plates shall be white with black engraved letters. On top of each Charger, on front as well as rear sides, larger and bold

name plates shall be provided to identify the Charger. Name plates with full and clear inscriptions shall also be provided on and inside of the panels for identification of the various equipment and ease of operation and maintenance.

6.18.2.10 Charger Construction

The Chargers shall be indoor, floor-mounted, self-supporting sheet metal enclosed cubicle type. The Contractor shall supply all necessary base frames, anchor bolts and hardware. The Chargers shall be fabricated from 2.0mm cold rolled sheet steel and shall have folded type of construction. Removable gland plates for all cables and lugs for power cables shall be supplied by the Contractor. The lugs for power cables shall be made of electrolytic copper with tin coat. Power cable sizes shall be advised to the Contractor at a later date for provision of suitable lugs and drilling of gland plates. The Charger shall be tropicalized and vermin proof. Ventilation louvers, if provided shall be backed with screens. All doors and covers shall be fitted with synthetic rubber gaskets. The chargers shall have hinged double leaf doors provided on front and on backside for adequate access to the Charger's internals. All the charger cubicle doors shall be properly earthed. The degree of protection of Charger enclosure shall be at least IP-42 as per IS: 13947:Part I.

All indicating instruments, control switches and indicating lamps shall be mounted on the front side of the Charger.

Each Charger shall be furnished completely wired upto power cable lugs and terminal blocks and ready For external connections. The control wiring shall be carried out with PVC insulated, 1.5sq.mm.stranded copper wires.

Control terminals shall be suitable for connecting two wires, with 2.5 sq.mm stranded copper conductors. All terminals shall be numbered for ease of connections and identification. Each wire shall bear a ferrule or tag on each end for identification. At least 20% spare terminals shall be provided for control circuits.

The insulation of all circuits, except the low voltage electronic circuits shall withstand test voltage of 2 KV AC for one minute. An air clearance of at least ten (10) mm shall be maintained throughout for such circuits, right up to the terminal lugs. Whenever this clearance is not available, the live parts shall be insulated or shrouded.

6.18.2.11 Painting

All sheet steel work shall be pre-treated, in tanks, in accordance with IS: 6005. Degreasing shall be done by alkaline cleaning. Rust and scale shall be removed by pickling acid. After pickling, the parts shall be washed in running water. Then these shall be rinsed in slightly alkaline

hot water and dried. The phosphate coating shall be 'Class-C' as specified in IS: 6005. Welding shall not be done after phosphating. The phosphating surfaces shall be rinsed and passivated prior to application of stoved lead oxide primer coating. After primer application, two coats of finishing synthetic enamel paint of RAL 7035 shall be applied, unless required otherwise by the Employer. The inside of the chargers shall be glossy white. Each coat of finishing synthetic enamel paint shall be properly staved. The paint thickness shall not be less than fifty (50) microns.

6.18.2.12 TESTS

Battery chargers shall conform to all type tests as per relevant Indian Standard. Performance test on the Chargers as per Specification shall also be carried out on each Charger as per specification. Rectifier transformer shall conform to all type tests specified in IS: 4540 and short circuit test as per IS: 2026. Following type tests shall be carried out for compliance of specification requirements:

- i) Voltage regulation test
Load limiter characteristics test Efficiency tests
- ii) High voltage tests
- iii) Temperature rise test
- iv) Short circuit test at no load and full load at rated voltage for sustained short-circuit.
- v) Degree of protection test
- vi) Measurement of ripple by oscilloscope.
- vii) Temperature Compensation Feature Demonstration
- Vii) The Contractor may be required to demonstrate to the Employer that the Chargers conform to the specification particularly regarding continuous rating, ripple free output, voltage regulation and load limiting characteristic, before dispatch as well as after installation at site. At site the following tests shall be carried out :
 - Insulation resistance test
 - Checking of proper annunciation system operation.

6.19 DIESEL GENERATOR SET

6.19.1 GENERAL

The Contractor shall supply the necessary emergency diesel generating (DG) set(s) along with their accessories for the electrical auxiliary system of converter station(s).

The exact rating of the emergency DG set(s) shall be determined by the Contractor as per the requirements of the complete auxiliary power system.

The DG set shall be designed to carry the emergency load continuously. Starting of the DG shall be automatic.

One no. generator set shall be provided for each pole per station. The DG set(s) are intended to supply power only during an emergency for essential services and may be idle for long periods except for periodic routine tests once a week. When there is a total failure of main power supply, the sets shall be required to operate continuously at full load for a period which may even exceed 24 hours.

Diesel oil storage & other installation shall meet statutory requirements and shall be approved by Controller of Explosives. This shall be the responsibility of the Contractor. The DG sets shall meet the noise level & emission parameters and other requirements in accordance with latest Notification of MOEF.

The DG sets shall be of stationary type having a net electrical out put of required capacity at specified site conditions. The DG set(s) shall be complete with all necessary component parts, accessories and appurtenances including, but not limited to, the following:

- (i) Diesel engine complete with all accessories.
- (ii) An alternator directly coupled to the engine through coupling, complete with all accessories.
- (iii) Automatic voltage regulator.
- (iv) Complete starting arrangement, including two sets of batteries & chargers.
- (v) Base frame, foundation bolts etc.
- (vi) Day tank of 990 Liter capacity.
- (vii) Diesel storage tank (one per DG set at each converter station of 12.5 kL capacity)
- (viii) Engine Cooling and lubrication system.
- (ix) Engine air filtering system.
- (x) Exhaust silencer package.
- (xi) Set of GI pipes, valves, strainers, unloading hose pipes as required for fuel transfer system from storage area to fuel tank including electrically driven fuel pump.
- (xii) All lubricants, consumable, etc. shall be provided by the Contractor till successful completion of trial operation.
- (xiii) AMF panel for control, metering and alarm.
- (xiv) Enclosure for silent type D.G. Set

6.19.2 DIESEL ENGINE

6.19.2.1 GENERAL

The diesel engine shall be of stationary type, four strokes with vertical inline of 'V' type cylinder arrangement, super charged and coolant cooled.

6.19.2.2 RATING

The engine shall be capable of driving the alternator continuously at its rated full load and rated speed without getting over loaded under the prevailing operating conditions.

It shall also be capable of satisfactory driving the alternator at 10% over load at the rated speed for one hour in any period of 12 hours of continuous running.

Continuous BHP rating of the engine shall be such that the DG set can continuously deliver the specified net electrical output, while supplying all auxiliaries connected to alternator terminals and engine shaft at the specified site conditions.

The Contractor shall furnish supporting documents/calculations to arrive at the Diesel Engine rating.

6.19.2.3 RATED SPEED

The rated speed of the engine shall not exceed 1500 RPM.

6.19.2.4 LUBRICATION

The engine shall have a closed cycle lubricating system with positive oil pressure and crank chamber for collection/storage of the lubricating oil during circulation. No moving part shall require lubrication by hand or any other external source either prior to the starting of the engine or when it is in operation.

A lubricating oil filter shall be provided for operation under normal conditions for a period of 250 hours without the necessity of its replacement or cleaning. In case lubricating oil coolers are required they shall be of the air cooled type and shall be supplied as an integral part of the DG set.

Necessary temperature and pressure gauges shall be supplied and fitted on the lubrication system. The lubricated oil recommended by the manufacturer shall conform to the requirements specified in IS-466.

6.19.2.5 FUEL SYSTEM

The engine shall be capable of running on all type of diesel fuel oil normally available in India. The fuel consumption of the engine at full, three quarters and half of its rated power output shall be indicated by the Bidder/Contractor.

A fuel day tank with sufficient capacity of 990 litres shall be provided on a suitably fabricated steel platform. The tank shall be complete with level indicator marked in litres, filling inlet with removable screen, an outlet, a drain plug, an air vent and necessary piping. The tank shall be painted with oil resistance paint and erected in accordance with Indian explosive rules.

A separate underground tank of 12.5 kL capacity for diesel storage shall be provided. The tank shall conform to the requirements of Indian Explosive act. Motor operated pump for pumping the fuel into the fuel day tank from the underground tank together with necessary pipes tubing shall be provided. The inlet to the pump may be provided with armoured hose with suitable filter.

6.19.2.6 AIR INTAKE SYSTEM

The diesel engine shall be provided with dry type air filters having low resistance to air passage, high dust retaining efficiency and provision for easy cleaning. The filters shall be suitable for achieving satisfactory engine operation and ensuring the engine life under tropical humid conditions.

6.19.2.7 COOLING

Engine shall be of radiator type. Forced coolant circulating shall be employed with the help of engine shaft driven pump.

6.19.2.8 ENGINE GOVERNOR

The governor shall be Isochronous type to maintain zero speed rate or regulation and shall preferably be of Woodward made 'AI' type in order to take care of heavy duty motor starting. It shall have necessary characteristics to maintain the speed substantially constant even with sudden variation in load. However, a tripping shall be provided if speed exceeds maximum permissible limit. The governor shall be suitable for operation without external power supply.

6.19.2.9 TURBO CHARGER

It shall be of a robust construction suitable of being driven by engine exhaust, having a common shaft for the turbine and blower. It shall draw air from air filter of adequate capacity to suit the requirements of the engine.

6.19.2.10 QUIETNESS OF OPERATION

The engine shall be designed to achieve maximum quietness of operation. Efficient Industrial silencer shall be provided for the exhaust as well as the air intake. Acoustic enclosures shall also be provided such that the noise level of acoustic enclosure DG set shall not be more than 75 dB (A) at 1 m from the enclosed surface. The diesel generator sets should also conform to Environment (Protection) Rules, 1986 (of India) as amended. The Contractor shall provide details for the enclosures along with their bid.

6.19.2.11 STARTING

The engine shall be electrical self starting type. 24 V Ni-Cd batteries of appropriate capacity with minimum life of 20 years. The battery used shall be locomotive type. The cranking device shall be designed in such a way that the engine starts automatically and reaches rated speed within the time required by the scheme of a remote starting impulse being received. The fuel oil system and the lubricating oil system shall also start operating simultaneously and automatically as soon as a starting impulse is received to obviate any change of

seizure of the piston and bearing as well as air locking in fuel supply system. The starter motor shall conform to IS-4722.

A dedicated battery charger using semi-conductor rectifier shall be provided for quick and trickle charging the battery used for DG starting. The charger shall be provided with a D.C. voltmeter, ammeter and output voltage control facility mounted on the control cubicle.

The battery for starting the engine shall be capable of performing at least six (6) normal start without recharging. In any case the continuous cranking for at least one minute shall be possible.

6.19.2.12 PIPING, VALVES AND FITTINGS

The engine shall be supplied with all piping, valves and fittings for the fuel oil, lubricating oil, engine starting air inlet and engine exhaust system, along with expansion joints, drain plugs, flanges etc.

6.19.2.13 ANCILIARY EQUIPMENT

The following equipment shall be supplied as part of or along with each engine:

- a) Flywheel
- b) Daily service fuel tank, piping and drain cock or plug.
- c) Tachometer
- d) Lubricating oil cooler (where applicable).
- e) Exhaust silencer and piping.
- f) Fuel oil filters, lubricating oil filters and air filters.
- g) Temperature gauges for coolant and lubricating oil and pressure gauge for lubricating oil.
- h) Manufacturer's standard t
- i) Instruction manuals with necessary details of equipment part list and spares.
- j) Protective equipment, preferably in the form of fuel cut-off solenoid and suitable relays to protect the engine against excessive cylinder temperature and low lubrication oil pressure.
- k) Drain taps in the cooling system and the lubricating oil system.
- l) Radiator.

6.19.3 ALTERNATOR

6.19.3.1 GENERAL

The alternator shall be of totally enclosed or screen protected and self air cooled type conforming to the requirements of IS-4722.

The continuous rating of the alternator at 50°C ambient shall at least be equal to net electrical output specified for DG set plus the power requirements of all auxiliaries connected to alternator terminal including excitation (if it is taken from alternator terminals).

The parameters for the alternator shall preferably be as given below:
i) Voltage : 415 V + 10% ii) Frequency : 50 Hz + 5% iii) Power factor : 0.8 lag
iv) Efficiency : better than 90%

All winding conductors of the alternator shall be of copper. The overall alternating winding insulation shall be epoxy thermosetting type but tinted to class 'B' operation from temperature rise consideration.

The DG sets shall be designed and rated so as to meet the load time characteristics of the essential loads of the entire

- a) station as determined by the Contractor with a 10% margin on the load.

Suitable space heaters shall be provided for alternators.

6.19.3.2 EXCITER

The alternator shall have its own excitation system. If a rotating exciter is provided for this purpose, it shall be driven by the alternator shaft. Excitation power shall be taken from alternator terminals itself if exciter is not provided. Voltage regulator shall be provided to keep the terminal voltage within $\pm 1\%$ of the set value. The setting range available on voltage regulator shall be $\pm 10\%$. The excitation system shall be complete with all necessary accessories.

6.19.3.3 NEUTRAL POINT

The winding of the alternator shall be star connected. Neutral side leads shall be brought out to a separate terminal box wherein provision of C.T. mounting shall be kept on neutral side of each phase for alternator differential protection. C.T. details as required for protection scheme shall be determined by the Contractor.

6.19.3.4 TERMINAL BOX AND CONNECTION

The alternator output terminals shall be enclosed in a terminal box mounted in an accessible position on the alternator frame. As far as possible, connections between the exciter and alternator shall be contained within the machine frame. The connections carrying ac and dc shall be segregated from each other.

6.19.4 DIESEL GENERATOR CONTROL PANEL

6.19.4.1 CONTROL OF DIESEL GENERATOR SET

A local control panel shall be provided for the DG sets.

The DG is required to start up and come into operation automatically whenever a remote starting impulse is received in the event of failure of normal supply.

Testing facility for automatic operation of DG set shall be provided on the local control panel board. DG shall be capable of being

stopped manually from remote as well as local. However, interlock shall be provided to prevent the shutting down operation as long as circuit breaker is closed.

6.19.4.2 FAILURE TO START

A three-attempt starting facility using two impulse timers and a summation timer for engine shall be provided and if voltage fails to develop within the required time from receiving the first start impulse the set shall block automatically & a visual indication and audible alarm shall be given in the station control room as well as in local control panel.

6.19.4.3 INDICATION LAMPS

a) Pilot indicating lamp shall be provided for

- Mains ON,
- Alternator ON
- Charger ON/OFF
- Digital ammeter, voltmeter, frequency meter
- Auto start/stop control
- Cycle crank & cool down timer
- Digital Dc voltmeter
- Emergency stop push button
- Engine control switch for Auto, Start/run, off/reset, stop engine speed adjust potentiometer,
- Digital oil pressure and water temperature gauges

b) Visual Annunciation shall be provided to indicate the following fault conditions.

- Set shut down due to engine overheating.
- Set shut down due to low oil pressure.
- Set failed to start.
- Set shut down due to high cooling coolant temperature.
- Low level in daily service fuel tank.
- Over speed trip.
- Alternator fault.
- Over Crank
- Low Coolant level

The control panel/board shall have the following provisions for the control of DG set. The control and protections of DG shall be numerical/PLC based.

- i) Starting and stopping of the set
- ii) Adjustment of speed and voltage including fine adjustments.
- iii) DG output voltmeter and ammeter
- iv) Frequency meter or RPM meter
- v) Local remote selector switch to facilitate remote starting and

stopping of the DG set.

vi) Not used

vii) D.C. Ammeter and D.C. voltmeter for DG field circuit.

viii) Not used

ix) Audio and visual annunciation system of DG Set fault.

x) 3 nos. single phase CTs for metering.

xi) Phase selector switch

xii) Total real power

xiii) Total reactive power

xiv) % of rated power

xv) Power factor (average)

xvi) Real power each phase

xvii) Total apparent Power

xviii) Power factor each phase

xix) Total reactive energy output

Voltage adjust potentiometer

The DG sets would normally be controlled from remote for which following provisions shall be made:

- 1) Starting and stopping of the DG set.
- 2) Indication of the DG set under operation.
- 3) Watt-hour meter, Wattmeter, Voltmeter, Ammeter meter.
- 4) Control of DG Circuit breaker.
- 5) Not used

6.19.5 TESTS

Full engine performance testing shall be carried out as per relevant standard at manufacturer's works. The alternator shall be type and routine tested as per IS-4722.

6.20 : Lighting System shall be as per Annexure-Lighting System for present scope of work (i.e. Store and Battery Room)