BHARAT HEAVY ELECTRICALS LIMITED
TRANSMISSION BUSINESS GROUP
ENGINEERING MANAGEMENT

BHEL Document No. TB-388-316-001	Rev No.		Prepared by	Checked by	Approved by
	00	Name	MS	AS/ VK	RS
Type of Document **TECHNICAL SPECIFICATION**		Sign			
Title 400kV Gas Insulated Substation (GIS)		Date	23/11/16	03/12/16	05/12/16
		Group	**TBEM**		

Customer	**BANGLADESH-INDIA FRIENDSHIP POWER COMPANY (PVT.) LIMITED (BIFPCL), BANGLADESH**
Projects	**400/230kV GIS FOR 2x660MW MAITREE SUPER THERMAL POWER PROJECT, RAMPAL, BANGLADESH**

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Note: Filled Up & Signed copy Section-4 & 6 to be furnished for Technical Evaluation.

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Distribution

SECTION – 1

1.1 SCOPE

Scope of work covers Design, Manufacture, Testing, Delivery at site, Supervision of unloading at site, storage, installation and commissioning including site testing along with necessary equipment, training of BHEL and BIFPCL personnel for 400 kV Gas Insulated Substation (GIS) as per the specification complete with all auxiliaries, accessories and spare parts.

This section covers the scope and quantities of 400 kV GIS. The Specific Technical Requirements for the above item as specified by the customer (BIFPCL) are given in Section-2. The offered equipment shall also comply with the General Technical Requirements for the project as detailed under section-3 of this specification.

In case of any discrepancies between the requirements mentioned under Section-1/Section-2 and those specified in the Section-3. The order of precedence shall be as follows:

a. Statutory Regulations
b. Section-1
c. Section – 2: BIFPCL Specification
d. Section 3
e. International standards

In case of any discrepancies between the requirements mentioned under Section-1/Section-2 and those specified in the Section-3, the specifications given under Section-1/Section-2 shall prevail and shall be treated as binding requirements.

Bidder to submit filled up **Annexure-A** attached with Section-1 confirming that there are no deviations and the offer is in full compliance with the specification.

The equipment is required for the following project:

Name of the Project	:	**400/230kV GIS FOR 2x660MW MAITREE SUPER THERMAL POWER PROJECT, RAMPAL, BANGLADESH**
Name of the Customer	:	**BANGLADESH-INDIA FRIENDSHIP POWER COMPANY (PVT.) LIMITED (BIFPCL), BANGLADESH**
Name of the Consultant	:	**M/s FICHTNER GmbH & Co KG, Stuttgart, GERMANY**
Main Contractor	:	**BHEL**

The 400kV Gas Insulated Switchgear (GIS) in One and Half Breaker configuration in separate building shall include in present four (4) diameters and provision for later extension of three (3) additional diameters as shown in single line diagram (SLD). The building will be extended later for the future diameters. Provision for extension shall ensure that all existing feeders can be kept in operation during installation and commissioning (also during high voltage test of extension on site) of the new diameters/ feeders.

- Diameter 1 for ICT & GT
- Diameter 2 for ICT & Bus Reactor
- Diameter 3 for Dhaka line including Line Reactor feeder and GT
- Diameter 4 for Dhaka line including Line Reactor feeder and Future GT
- 400kV Bus VT & LA = 2 Nos.

1.2 BILL OF QUANTITIES:

As per Annexure-1

1.3 Spare Parts:

The bidder shall include in his scope of supply the spare parts comprising as listed in BOQ as "Initial spare parts".

(a) All the spares listed in BOQ are basic minimum requirement of initial spare parts.

(b) In addition to aforesaid basic minimum requirement of initial spare parts, the bidder shall further assess requirement of additional spare parts as part of the initial spare parts which are necessary to operate, repair/ maintain the plant to achieve the guaranteed availability during the warranty period (i.e. 24 months from the PAC/ COD) and maintain the plant efficiency.

The bidder shall indicate the prices for each and every item of initial spare parts (except for items not applicable to bidder's design) in their bid. If the bidder fails to comply with the above or fails to quote the price of any spare item, the cost of such spares shall be deemed to be included in contract price. The bidder shall furnish the population of each item in the schedules. Whenever the quantity is mentioned in "sets" the bidder has to give item details and prices of each item.

The spares under initial spare parts list shall be part of Lump sum Turnkey contract price and shall be considered for Financial Evaluation.

If for any item of the enclosed Initial Spare Parts List, if Bidder in its Bid indicates as "NOT APPLICABLE", but same is found applicable subsequently during detailed design and/or at the time of commissioning of the unit/ system/ sub-system/ equipment, same shall be supplied by the Bidder without any extra cost to BHEL/BFPCL.

Whenever the quantity is indicated as percentage, it shall mean percentage of total population of that item in the project, unless specified otherwise, and the fraction will be rounded off to the next higher whole number.

The assembly/ sub-assembly which have different orientation (like left hand, right hand, top or bottom), different direction of rotation or mirror image positioning or any other regions which result in maintaining two different sets of spares to be used for subject assembly/ sub-assembly shall be considered as different type of assembly/ sub-assembly.

Wherever quantity is specified both as percentage and a value, the bidder has to supply the higher quantity until & unless specified otherwise.

1.3.1 Handling, Storage, Preservation and Handing Over

All initial spares shall be delivered at site in due time and at least two (2) months before COD/PAC of first unit. However, spares shall not be dispatched before dispatch of corresponding main equipment.

The Initial Spares shall be received at site by BHEL on behalf of Employer (BFPCL) and the same shall

be stored by the Contractor in the Store.

Each item shall be labelled in English language and be separately packed against damage and sealed to prevent deterioration from corrosion. The protection shall be sufficient for a minimum of 10 years storage in a dry weatherproof building.

After handing over, if any spare is required by bidder for use in the plant during warranty period the same may be issued to the bidder on loan basis and the same shall be replenished by bidder at their cost at the earliest. Before issuance of PAC all the Spares Parts taken by bidder shall be replenished by them at their own cost.

1.3.2 Final Spare Parts List:

The Bidder shall provide a "Final Spares Parts List" which shall comprise of all items of the Initial Spare Parts List as well as other spares required for long term routine/ planned and breakdown maintenance. Bidder shall indicate all details for each item of aforesaid Final Spare Parts List, such as vendor's/ original equipment manufacturers (OEM's) name and location , drawings, normal delivery period, quantity, life time/ service life, vendor's/ OEM's serial numbers and price labelling according to the plant numbering code etc. The format and content of the Final Spare Parts List shall be agreed in the basic/ detailed engineering phase and shall be subject to Employer's (BFPCL) approval. This Final Spare Parts List shall be submitted by the bidder to the Employer (BFPCL) for approval not later than eighteen (18) months prior to the Scheduled Commercial Operation Date (COD)/ Issuance of Provisional Acceptance Certificate (PAC) of 1st unit.

The bidder shall name OEMs/ three (3) vendors with complete address for each of the spare parts.

Spare parts remain available for order anytime during the first three (3) years commencing from COD of each unit, at the initial Unit prices as adjusted pursuant to the indexation mechanism approved by employer.

However, BHEL/BIFPCL shall have the freedom to decide at its sole discretion to purchase spare parts either from bidder (according to agreed unit price as stated above) or directly from vendors/ OEMs or from any other source.

1.3.3 Start-Up & Commissioning Spares:

Start-Up & Commissioning spares are those spares which may be required during the start-up and commissioning of the equipment/ system. All spares used till the COD/ PAC shall come under this category. The bidder shall provide for an adequate stock of such start up and commissioning spares to be brought by him to the site for the plant erection and commissioning. They must be available at site before the equipment are energized. The unused spares, if any, should be removed from there only after issue of PAC. All start up spares which remain unused at the time PAC shall remain the property of Contractor. These start-up & commissioning spare part list shall not be included in initial Spares Parts List.

1.3.4 General Requirements pertaining to the supply of spares given below:

All spares supplied under this contract shall be strictly inter-changeable with parts for which they are intended for replacements. The spares shall be treated and packed for long storage under the climatic

conditions prevailing at site e.g. small items shall be packed in sealed transparent plastic with desiccator packs as necessary.

All the spares (Initial Spares) shall be manufactured along with the main equipment components as a continuous operation as per same specification and quality plan.

The bidder will provide BHEL/ BFPCL with cross-sectional drawings, catalogues assembly drawings and other relevant documents so as to enable the BHEL/ BFPCL to identify and finalize order for recommended spares.

The bidder shall warrant that all spares supplied will be new and in accordance with the Contract Documents and will be free from defects in design, material and workmanship.

The bidder shall ensure long term availability of spares to the Employer (BFPCL) for the full life of the equipment covered under the contract. The contractor shall guarantee that before going out of production of spare parts of the equipment covered und the Contract, he shall give the Employer (BFPCL) at least 2 years advance notice so that the latter may order his bulk requirements of spares, if he so desires. The same provision shall also be applicable to Sub-vendors. Further, in case of discontinuance of manufacture of any spares by the vendor and/ or his sub-vendors, bidder will provide the Employer, two years in advance, with full manufacturing drawings, material specifications and technical information including information on alternative equivalent makes required by the Employer for the purpose of manufacture/ procurement of such items.

Bidder to submit list of tools, tackle, slings, spanners, gauges, slings and other lifting devices, drills, instruments and appliances necessary for the complete assembly and erection at site of the GIS, required for installation, gas filling, maintenance, site testing of the GIS which shall be arranged by BHEL.

1.4 SPECIFIC TECHNICAL REQUIREMENT

As per section 2,

1.5 Training:

The bidder shall provide comprehensive training for Employer's (BFPCL/BHEL's) engineering, operating & maintenance staff covering all aspects of GIS equipment, systems, operation & maintenance.

The bidder shall train, instruct and supervise the Employer's (BFPLC/ BHEL) staff to an adequate standard of knowledge and capability for good trouble shooting, repair and of the GIS equipment as well as to an adequate standard for safe and efficient commercial operation of GIS.

The training shall at least include:

- Training at manufacturer's works during the assembly of the major items.
- Classroom and hands on training.
- On the job training during erection, commissioning and reliability test run
- Simulator training

The bidder shall submit the training plan for the classroom, on the job and simulator training including schedule, place, contents of lectures etc. for the Employer's approval no less than six (6) months in advance to the cold commissioning.

Post training assessment shall be carried out and documented in case the results of the training are below the expectations, which have been agreed upon by both bidder and Employer before training, the respective training modules shall be repeated in an improved way and the related cost for the repeated training shall be borne by the Contractor.

1.6 It may be noted that:

- *For system details and transport details refer Project Information in section 3.*
- *Covered Store will be provided by BHEL for items which require indoor storage. The size of covered store shall be 10 m X 20 m. Bidder to confirm the requirement for hydra, entry area and space requirement, if required as mentioned).*
- *Manufacturer to mark Indoor storage requirement on the material to be stored in covered storage. The rest of the material shall be stored outdoor.*
- *Bidder to submit list of consumables with shelf life of fewer than two years. It shall be supplied before erection after clearance from BHEL.*
- *Supplier will submit detailed bar chart indicating all the milestones from Engineering till manufacturing/ testing, dispatch to site and commissioning.*
- *Packing of GIS shall be suitable for long term (minimum 2 years) outdoor or indoor storage of GIS in project conditions.*
- *Bidder shall offer their latest Tested compact Model to minimize the building size requirement.*
- *Bay spacing if required to be changed as per building column and beam requirement. Same shall be adjusted without any cost implicating to BHEL at contract stage.*
- *Bidder shall conduct system studies, insulation coordination for establishing Surge Arrester's rating and any other requirement for successful operation of GIS.*
- *Bidder shall check and ensure adequacy of the system protection for successful operation of GIS. After checking of system/site by bidder, GIS shall be installed and if any failure, malfunction of any part occurs after commissioning bidder shall replace the part unconditionally within a month.*
- *Successful bidder shall submit 3D OGA drawing for complete GIS and section drawing of each equipment. OGA drawings shall also be furnished in AutoCAD file format.*

1.7 Earthing of GIS

Supply of Earthing Material and Erection of all Earthing connection for GIS to GIS, GIS to Earth Mesh, GIB to structure, Bushing to structure and structure to Main Earth mate on Floor shall be in bidder's scope.

The quantity shall be estimated by the bidder, based on their design philosophy. Supply of Earthing

Material and Erection of Earth mesh on floor/ switchyard shall be done by BHEL in supervision of manufacturer as per manufacturer's design. Design philosophy shall be submitted along with the bid in line with **Clause B10.4.30** of section 2 to be followed for earthing.

Only supply of following items shall be done by BHEL:

1. Tinned Cu. conductor (240mm^2 for outdoor below ground earth mat)
2. 18mm dia Cu. Clad/ Bonded Steel rod
3. 30mmx8mm bare Cu. Flat/ bar - Busbar for indoor earthing
4. 35sqmm for Panels

Any other earthing material if required shall be in bidder's scope of supply and erection.

1.8 Extension of GIS:

a. The arrangement of gas sections and compartments shall be such as to facilitate future extension of any make without any drilling, cutting or welding on existing equipment. To add equipment, it shall not be necessary to move or dislocate the existing switchgear bays.

b. As the GIS is likely to be extended in future, the GIS supplier shall make available during detailed engineering stage, the complete design detail of interface module such as cross section, enclosure material, enclosure dimensions (inner & outer), Flange diameter (inner & outer), conductor connection arrangement, bolt spacing & dimension, rated gas pressure etc. Further GIS manufacturer supplying GIS under present scope shall furnish all the required details in addition to mentioned above necessary for design and successful implementation of an interface module during later stage while extending GIS by any other GIS manufacturer, without any help of GIS manufacturer who has supplied the GIS equipment in present scope.

c. The Interface module shall be designed to provide Isolating link with access hole on enclosure. The Isolating link shall be provided in such a way so that HV test can be performed on either side of the interface module separately, keeping other side of GIS remain isolated.

1.9 Drawings Enclosed

Sl. No.	BIFPCL/BHEL Drg. No.	Drawing Title
1.	TB-1-388-510-001	SINGLE LINE DIAGRAM OF 400/230KV GIS (230kV GIS SLD is only for reference)
2.	TB-0-388-316-001	400/230kVkV Switchyard Plan Layout

Note: Refer attached layout drawing, GIS Building Size considered is 70m x 14.5 m, consists of space on each side for maintenance on both side. GIS to be supplied should be accommodated in above area. Space for future requirement shall be indicated.

1.10 Type Testing

Type test certificates will be accepted for the equipment used in the similar applications if the proposed equipment does not deviate in the relevant technical characteristics and if the type tests are made in an internationally recognized test laboratory and if the reports are not older than 5 years as on 22.09.2015.

In case the contractor is not able to submit valid Report of Type Test(s) or in case Type tests Reports are not found to be meeting the specification requirements, or not including all specified tests, the contractor shall conduct all such tests under this contract. The costs of such test shall be deemed to be included in the price. The BIFPCL/BHEL shall have right to witness the Type Tests. Waiver of Type Tests will not be entertained in normal circumstances.

All acceptance, routine and sites tests as per the specification (Refer Section-2) and relevant standards shall be carried out. Charges for these shall be deemed to be included in the equipment price.

The bidder shall submit the following type test reports for the tests conducted on the GIS package. However any other Type test reports not mentioned but required as per relevant standards shall also be submitted.

The type tests shall be as per latest editions of IEC 62271-1, IEC 62271-203 and the report shall include following tests. :

a. Tests to verify the insulation level of the equipment and dielectric tests on auxiliary circuits.
b. Tests to prove the radio interference voltage (RIV) level (if applicable).
c. Tests to prove the temperature rise of any part of the equipment and measurement of the resistance of the main circuit.
d. Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short time withstand current.
e. Tests to verify the making and breaking capacity of the included switching devices.
f. Tests to prove the satisfactory operation of the included switching devices.
g. Tests to prove the strength of enclosures.
h. Verification of the degree of protection of the enclosure.
i. Gas tightness tests
j. Electromagnetic compatibility tests (EMC).
k. Additional tests on auxiliary and control circuits.
l. Tests on partitions.
m. Tests to prove the satisfactory operation at limit temperatures.
n. Tests to prove performance under thermal cycling and gas tightness tests on insulators.
o. Corrosion test on earthing connections (if applicable).
p. Tests to assess the effects of arcing due to an internal fault.
q. Seismic test

Tests Witness

Tests shall be performed in presence of Owner's representative if so desired by the Owner. The bidder shall give at least ten (10) days' advance notice of the date when the tests are to be carried out.

1.11 INSPECTION & TESTING

All acceptance, routine and sites tests as per the specification (Refer Section-2) and relevant standards

shall be carried out. Charges for these shall be deemed to be included in the equipment price.

Prior to dispatch, the routine & acceptance tests shall be carried out on equipment and accessories in accordance with Section-2 and applicable IEC and the material shall be offered for final inspection by BHEL and BIFPCL in accordance with quality assurance plan.

During manufacture and on completion, all equipment shall be subjected to the Routine tests as laid down in latest editions of IEC 62271-203 & IEC 62271-1. Test shall include but not limited to the following:

- Dielectric test on the main circuit.
- Tests on auxiliary and control circuits.
- Measurement of the resistance of the main circuit
- Tightness test.
- Design and visual checks.
- Pressure tests of enclosures.
- Mechanical operation tests
- Tests on auxiliary circuits, equipment and interlocks in the control mechanism.
- Pressure test on partitions.
- Short duration power frequency withstand test on the main circuits.
- Partial discharge measurement

1.12 Tests after installation on Site

Field acceptance tests after installation of the complete switchgears shall be made according to IEC 62271-203 and shall be subject to agreement between manufacturer and Employer/Employer's Representative before purchase order award. The Tenderers shall state in their offers the type of tests to be conducted on site. The dielectric tests shall comprise at least a power frequency voltage withstand test and partial discharge test according to IEC 62271-203 Procedure A for 170 kV and below and Procedure B for 220 kV and above, where partial discharge test shall include UHF or acoustic method. Voltage transformers shall also be tested, erected and assembled to GIS.

Other tests

The following checks and test measurements shall be made during erection and commissioning in accordance with agreed standards, but not limited to:

- measurement of insulation values
- verification of earthing grid neutralization conditions (e.g. step and touch voltage) in accordance with VDE 101 / IEEE80
- phase rotation
- polarity checks in the case of DC voltages
- protection circuit tests which will be not limited to CT polarity and magnetization curves
- insulation resistance tests of relays, wiring and CTs
- primary injection of all CTs to prove CT ratio and correct connection of 50, 51, 50 N, 51 N, 67, 67 N, 87 relays
- secondary injection tests for proof of timing tests on the relays and pickup/ drop off values of important auxiliary relays shall be tested

- operation of tripping elements at reduced DC voltage
- safety signs and warning signs
- setting indicators
- checks on wiring and cabling for conformity with the constructional circuit-drawings and plans
- high voltage test on cables and switchgear
- Functional test on equipment.

All defects detected as a result of routine or on site testing shall be repaired by the manufacturer and tests repeated at his own expense.
Acceptance of any equipment by Employer's representatives shall not relieve the manufacturer from any of his performance guarantees, or from any of his other obligations resulting from this Contract.

Where no tests are detailed for items of equipment, a full program of tests shall be agreed with the Employer/Employer's Representative. The Employer/Employer's Representative reserves the right to call for such extra tests as may be necessary to prove compliance with the specification.

1.13 Proven-ness Criteria:

Refer relevant clause given elsewhere.

1.14 Warranty:

Refer relevant clause given elsewhere.

1.15 Sea Worthy Packing, Packing & Shipping Instructions:

Refer Annexure-E of Section-3.

1.16 QUALITY PLAN

The contractor shall carry out the works in accordance with sound quality management principles which shall include such as controls which are necessary to ensure full compliance to all requirements of the specification & applicable international standards. These quality management requirement shall apply to all activities during design, procurement, manufacturing, inspection, testing, packaging, shipping, inland transportation, storage, site erection & commissioning. Contractor shall submit detailed Quality Plan for BHEL / customer's approval.
Attached Manufacturing Quality Assurance Plan (MQP) and Field Quality Plan formats in Section-3 shall be followed.

1.17 INFORMATION TO BE FURNISHED BY THE CONTRACTOR/ SUB CONTRACTOR

Information/ documents to be furnished at the TENDER STAGE shall be as per section 2 & 3.

1.18 DRAWINGS / DOCUMENTS

The drawings / documents submitted shall be project and product specific and shall incorporate all project details and title block and numbering scheme of the customer as detailed in Section 2 & 3.

Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity
A		**Supply Item - 400kV GIS as per enclosed SLD with One and Half Breaker scheme comprising of Items A1-A21**	The 400 KV SF6 gas insulated switch gear shall have One and Half Breaker arrangement. The SF6 gas insulated switch gear (50 HZ) shall be of the indoor metal- enclosed type, comprising of following modules:- a) Two (2) Generator Transformer bays b) One (1) Bus Reactor bay c) One (1) equipped bay for future GT d) Two (2) Line bays e) Two (2) Line Reactor bays f) Two (2) ICT bays g) Four (4) Tie Bays h) Two (2) Bus VTs i) Two (2) Bus LAs. j) Provisions for later extension of three additional diameters as shown in SLD shall ensure that all existing feeders can be kept in operation during installation and commissioning (also during high voltage tests of extension on site) of the new diameters/feeders. The Switchgear shall be complete with all necessary terminal boxes, inspection window, SF6 gas filling, interconnecting power and control wiring, grounding connections, gas monitoring equipment and piping, support structures etc. Any other item required for completion of project and not covered above - Complete List to be provided by bidder along with unit prices. The scope of supply shall also include all erection and mounting hardware and interconnecting power and control cables between GIS to LCC and between LCC to LCC including **cable tray,** glands, lugs, ferrules etc.	**lot**	**1**
	A1	BusBar Modules	One set of three single phase(isolated), 4000A, 50kA for 1 sec, SF6 gas-insulated metal enclosed bus bars, each comprising of : a) Three individual 4000A bus bars enclosures running across the length of the switchgear to inter connect each of the circuit breaker bay modules in one and half breaker bus system. b) Gas monitoring systems, pressure switches, telescopic enclosure etc. as required. c) Barriers (communicating , non-communicating types) Length of bus bar to be indicated by bidder.	Set	2
	A2	Bus VT & LA Modules for Main Buses	400kV, **4000A, 50kA for 1 sec**, SF6 gas insulated Bus VT bay module, Disconnector module with Earth switches (Maintenance & High speed) and LA module connected to Main Bus Bars, each comprising of: a) ONE set of 3x1-phase, 4000A, 50kA group operated Disconnector switches, complete with manual and motor driven operating mechanisms. b) THREE nos. single phase Voltage transformers c) ONE set of 3x1-phase, group operated safety grounding switches, complete with manual and motor driven operating mechanisms. (Suitable for Bus Bar Earthing Duty) d) ONE set of 3x1-phase, group operated high speed earthing switches, complete with manual and motor driven operating mechanisms. e) THREE nos. single phase of lightning arresters. f) Gas monitoring devices, barriers, pressure switches, etc. as required.	Set	2
	A3	**Fully equipped 400kV, 50kA for 1 second, SF6 GIS GT bay Module (BAY NO. 403 & 409)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed GT bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, SF6 insulated circuit breaker, complete with operating mechanism (suitable for 1&3 phase auto reclose) b) ONE set of 3x1-phase, 4-core, multi ratio, current transformers (CT No. VI) as per single line diagram. (Core details shall be finalised at detail engg. stage) c) ONE set of 3x1-phase, 3-core, multi ratio, current transformers (CT No. V) as per single line diagram. (Core details shall be finalised at detail engg. stage) d) ONE set of 3x1-phase, 2-core, multi ratio, current transformers (CT No. XIV) as per single line diagram. (Core details shall be finalised at detail engg. stage) e) THREE sets of 3x1-phase, group operated Disconnector switches, complete with manual and motor driven operating mechanisms. f) TWO sets of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) g) ONE set of 3x1-phase, group operated high speed earthing switches, complete with manual and motor driven operating mechanisms. h) Gas monitoring System, pressure switches etc as required. i) Barriers and other items as required.	Set	2
	A4	**Fully equipped 400kV, 50kA for 1 second, SF6 GIS BUS REACTOR bay Module (BAY NO. 406)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed BUS REACTOR bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, SF6 insulated circuit breaker, complete with operating mechanism (suitable for 1&3 phase auto reclose) b) ONE set of 3x1-phase, 4-core, multi ratio, current transformers (CT No. VI) as per single line diagram. (Core details shall be finalised at detail engg. stage) c) ONE set of 3x1-phase, 3-core, multi ratio, current transformers (CT No. V) as per single line diagram. (Core details shall be finalised at detail engg. stage) d) THREE sets of 3x1-phase group operated Disconnector switches, complete with manual and motor driven operating mechanisms. e) TWO sets of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) f) ONE set of 3x1-phase, group operated high speed earthing switches, complete with manual and motor driven operating mechanisms. g) Gas monitoring System, pressure switches etc as required. h) Barriers and other items as required.	Set	1
	A5	**Equipped 400kV, 50kA for 1 second, SF6 GIS FUTURE GT bay Module (BAY NO. 412)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed GT bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, group operated Disconnector switches, complete with manual and motor driven operating mechanisms. b) ONE set of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) c) Gas monitoring System, pressure switches etc as required. d) Barriers and other items as required.	Set	1

Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity
	A6	**Fully equipped 400kV, 50kA for 1 second, SF6 GIS LINE bay Module (BAY NO. 407 & 410)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed LINE bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, SF6 insulated circuit breaker, complete with operating mechanism (suitable for 1&3 phase auto reclose) b) ONE set of 3x1-phase, 4-core, multi ratio, current transformers (CT No. I) as per single line diagram. (Core details shall be finalised at detail engg. stage) c) ONE set of 3x1-phase, 3-core, multi ratio, current transformers (CT No. II) as per single line diagram. (Core details shall be finalised at detail engg. stage) d) THREE sets of 3x1-phase group operated Disconnector switches, complete with manual and motor driven operating mechanisms. e) TWO sets of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) f) ONE set of 3x1-phase, group operated high speed earthing switches, complete with manual and motor driven operating mechanisms. g) Gas monitoring System, pressure switches etc as required. h) Barriers and other items as required.	Set	2
	A7	**Fully equipped 400kV, 50kA for 1 second, SF6 GIS LINE REACTOR bay Module (BAY NO. 407R & 410R)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed LINE REACTOR bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, SF6 insulated circuit breaker with **PIR**, complete with operating mechanism (suitable for 1&3 phase auto reclose) b) ONE set of 3x1-phase, 3-core, multi ratio, current transformers (CT No. VIII) as per single line diagram. (Core details shall be finalised at detail engg. stage) c) TWO sets of 3x1-phase, group operated Disconnector switches, complete with manual and motor driven operating mechanisms. d) TWO sets of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) e) ONE set of 3x1-phase, group operated high speed earthing switches, complete with manual and motor driven operating mechanisms. f) Gas monitoring System, pressure switches etc as required. g) Barriers and other items as required.	Set	2
	A8	**Fully equipped 400kV, 50kA for 1 second, SF6 GIS ICT bay Module (BAY NO. 401 & 404)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed ICT bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, SF6 insulated circuit breaker, complete with operating mechanism (suitable for 1&3 phase auto reclose) b) ONE set of 3x1-phase, 4-core, multi ratio, current transformers (CT No. I) as per single line diagram. (Core details shall be finalised at detail engg. stage) c) ONE set of 3x1-phase, 3-core, multi ratio, current transformers (CT No. II) as per single line diagram. (Core details shall be finalised at detail engg. stage) d) THREE sets of 3x1-phase group operated Disconnector switches, complete with manual and motor driven operating mechanisms. e) TWO sets of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) f) ONE set of 3x1-phase, group operated high speed earthing switches, complete with manual and motor driven operating mechanisms. g) Gas monitoring System, pressure switches etc as required. h) Barriers and other items as required.	Set	2
	A9	**Fully equipped 400kV, 50kA for 1 second, SF6 GIS TIE bay Module (BAY NO. 402, 405, 408 & 411)**	400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed TIE bay module. Each set shall be complete & shall comprising of a) ONE set of 3x1-phase, SF6 insulated circuit breaker, complete with operating mechanism (suitable for 1&3 phase auto reclose) b) TWO set of 3x1-phase, 4-core, multi ratio, current transformers (CT No. III & IV) as per single line diagram. (Core details shall be finalised at detail engg. stage) d) TWO sets of 3x1-phase, group operated Disconnector switches, complete with manual and motor driven operating mechanisms. e) FOUR sets of 3x1-phase, group operated maintenance earthing switches, complete with manual and motor driven operating mechanisms. (If required, high speed fault make grounding switch to be provided) f) Gas monitoring System, pressure switches etc as required. g) Barriers and other items as required.	Set	4
	A10	Single Phase isolated, 400kV, 50kA for 1 second, SF6 gas-insulated metal enclosed bus bars for Tie Bay interconnection	Isolated phase, 400kV, **4000A, 50kA for 1 second**, SF6 gas-insulated metal enclosed bus bars, each set comprising of : (a) Three Nos. single phase(isolated) bus bars to inter connect the Tie Bay circuit breaker bay modules with Circuit breaker bay Modules of Line/Line Reactor/GT/ICT/Bus Reactor Bays in one and half breaker bus system. (b) Gas monitoring System, barriers, pressure switches, etc. as required. Length to be indicated by bidder.	Set	9
	A11	400kV, 3150 GIS duct from GIS GT/Outgoing Lines to SF6 to Air bushing	400kV, **3150A 50kA for 1 sec**, SF6 gas insulated GIS duct shall be complete & comprising of:- a) Three Nos. single phase (isolated) SF6 ducts along with all accessories to connect 400kV GIS with 400kV side GT/Outgoing Lines. b) Gas monitoring devices, barriers, pressure switches, etc. as required. Total length is equal to sum of single phase lengths of all GIS ducts and is to be calculated rating wise by the bidder as per the layout drg. enclsoed. Estimated length to be indicated by the bidder alongwith layout drg & calculation sheet in the offer. Extra claim to be entertained only if there is change in layout drg. & for variation arising out of it is in excess of 120% of the length in submitted calculation.	lot	1
	A12	400kV, 2500A GIS duct from GIS Bus Reactor/ Line Reactors/ICT to SF6 to Air bushing	400kV, **2500A 50kA for 1 sec**, SF6 gas insulated GIS duct shall be complete & comprising of:- a) Three Nos. single phase (isolated) SF6 ducts along with all accessories to connect 400kV GIS with 400kV side ICT/ BUS REACTORS/ LINE REACTORS to SF6 to Air Bushing. b) Gas monitoring devices, barriers, pressure switches, etc. as required. Total length is equal to sum of single phase lengths of all GIS ducts and is to be calculated rating wise by the bidder as per the layout drg. enclsoed. Estimated length to be indicated by the bidder alongwith layout drg & calculation sheet in the offer. Extra claim to be entertained only if there is change in layout drg. & for variation arising out of it is in excess of 120% of the length in submitted calculation.	lot	1
	A13	400kV,3150A SF6 to Air Bushing	400kV, **3150A, 50 kA for 1 sec**, 31mm/kV creepage, SF6 gas insulated, SF6 to Air Bushing for Over head connection of Line/GT with GIS.	Nos.	12

Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity
	A14	400kV, 2500A SF6 to Air Bushing	400kV, **2500A, 50 kA for 1 sec**, 31mm/kV creepage, SF6 gas insulated, SF6 to Air Bushing for Over head connection of ICT/BUS REACTOR/ LINE REACTOR with GIS.	Nos.	15
	A15	Local Control Cubicles	Bay Control Cabinet for GT/BUS REACTOR/ FUTURE GT BAY/LINES/ LINE REACTORS/ ICT/ TIE BAYS/ VT.	Nos.	15
	A16	First filling of SF6 gas plus extra for compensating losses for 10 % of total gas (Bidder to indicate quantity).	First filling of SF6 gas, and hydraulic fluid, if required for the equipment supplied plus an additional quantity sufficient for conducting all tests on equipment at site before placing it into successful operation plus expected gas loss during **20 years of operation**. Additionally, 10 % of total quantity of SF6 gas shall also be supplied in non returnable cylinders.	Lot	1
	A17	Supply of structure work for Installation of GIS including support structure for GIS ducts, SF6 to air bushings, supports, platforms, ladders, foundation bolts, embedded parts in floors etc., which are required for installation of GIS as per the specification. (The civil works will be done based on supplier design & drawings).	Bidder to indicate estimated weight in the bid (in MT) alongwith support documents & unit prices per MT in their offer. Bidder to quote in units as MT. Addition/deletion shall be on unit rate basis but only if there is any change in input.	Lot	1
	A18	Supply of Earthing material for GIS including High frequency earthing material. The quantity shall be estimated provided by bidder for above floor earthing connection.	Supply of Earthing Material and Supervision of Erection of all Earthing connection for GIS to GIS and GIS to Earth Mesh on Floor shall be in bidder's scope. The quantity shall be estimated by the bidder, based on their design philosophy. Design philosophy shall be submitted alongwith the bid in line with section 2. Supply of Earthing Material and Erection of Earth mesh on floor shall be done by BHEL in supervision of manufacturer as per manufacturer's design. Only supply of 1. Tinned Cu. conductor (240mm2 for outdoor below ground earth mat) 2. 18mm dia Cu. Clad/ Bonded Steel rod 3. 30mmx8mm bare Cu. Flat/ bar - Busbar for inddor earthing as recommended by bidder 4. 35sqmm for Panels shall be in BHEL's scope. Any other earthing material if required shall be in bidder's scope of supply and erection.	Lot	1
	A19	Consumables (with limited shelf life) required for GIS (Bidder to quote item wise with detailed BOQ for these consumables)	Consumables inluding grouting material having limited shelf life required during erection, testing and commissioning. It shall be supplied just before erection after confirmation from BHEL.(1 lot is for complete package).	Lot	1
	A20	Consumables required for GIS (with unlimited shelf life) (Bidder to quote item wise with detailed BOQ for these consumables)		Lot	1
	A21	Controlled Switching Device for ONE set of 4000A, 3x1-phase, SF6 insulated circuit breaker without PIR, complete with operating mechanism (suitable for 1&3 phase auto reclose)	**Optional Item.**	Nos	1
B		**Supply Item - Mandatory Maintenance equipment (B1 to B7)**	Mandatory Maintenance equipment shall be as per Clause no. 10.4.5.10 & 10.4.5.11	**lot**	**1**
	B1	SF6 gas filling and evacuating plant (portable)		Nos	1
	B2	SF6 gas Recycling & Purifying Plan (300 ltrs)		Nos	1
	B3	SF6 gas leak detector		Nos	1
	B4	Operating analyzer with DCRM kit		Nos	1
	B5	Dew Point Meter		Nos	1
	B6	Portable PD Monitoring equipment for GIS		Nos	1
	B7	Air Content Measurement		Nos	1
C		**Supply Items - Mandatory spares (C1 to C14)**	These prices will also be used for addition/deletion/replacement (shall be considered as initial spares)	Lot	1
		400kV GAS INSULATED SWITCHGEAR			
	C1	SF6 gas pressure Relief Devices, 3 Nos. of each type		Sets	2
	C2	SF6 Pressure gauge with coupling device cum switch or density monitors and pressure gauge, as applicable (1 no. of each type)		Set	1
	C3	Rubber gaskets, "O" Rings and seals for SF6 gas, including Circuit Breaker, Disconnector and other GIS equipments (6 no. of each type)		Set	1
	C4	Molecular filter for SF6 gas with filter bags		%	20 % of total supply
	C5	SF6 gas		%	20 % of total gas
	C6	Covers with all accessories necessary to close a compartment in case of dismantling of any part of the Enclosure to ensure the sealing of the compartment			
	C6.1	For 1 phase enclosure (3 Nos. of each type)		Set	1
	C6.2	Locking device to keep the Dis-connectors and Earthing switches in close or open position in case of removal of the driving mechanism (If applicable)		No.	3

Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity
	C6.3	Bus support insulator of each type for single phase enclosure (6 Nos. of each type)		Set	1
	C6.4.1	SF6 to air bushing for 1 phase enclosure (2500A)		Nos.	1
	C6.4..2	SF6 to air bushing for 1 phase enclosure (3150A)		Nos.	1
	C6.5	Spares for Local control cabinet including MCB, fuses, timers, Aux Relay of each type & rating, terminals of each type (Set)		No.	1
	C6.6	All types of Corona shield (3 Nos. of each type)		Set	1
	C6.7	Windowscope/ Observing window, 3 Nos. of each type (if applicable)		Set	1
	C7	**Circuit Breaker**			
	C7.1	Complete Circuit Breaker 1 phase pole of each type & rating complete with interrupter, main circuit and enclosure with operating mechanism		Sets	3
	C7.2	Fixed, moving and arcing contacts (3 nos. of each type)		Set	1
	C7.3	Trip Coil assembly with resistor as applicable, 3 Nos. of each type		Sets	2
	C7.4	Closing Coil assembly with resistor as applicable, 3 Nos. of each type		Sets	2
	C7.5	Relays, Power contactors, push buttons, timers & MCBs etc of each type & rating		Set	1
	C7.6	Closing assembly/ valve, 3 nos. of each type (If applicable)		Sets	2
	C7.7	Trip assembly/ valve, 3 nos. of each type (If applicable)		Sets	2
	C7.8	Aux. switch assembly, 3 Nos. of each type		Set	1
	C7.9	Operation counter, 3 nos. of each type		Set	1
	C7.10	Rupture disc, 3 Nos. of each type (if applicable)		Set	1
	C7.11	Set of spares for pneumatic/spring/hydraulic operated mechanism Spare for pneumatic operated mechanism a. Motor for compressor – one no. b. Pressure switch and valve – one no. of each type Spare for spring operated mechanism a . Motor – one no. b. Limit switch – one no. of each type Spare for hydraulic operated mechanism a. Motor – one no. b. Limit switch – one no. of each type	(1 Set for each type of Circuit Breaker)	Set	1
	C7.12	Insulating nozzle (6 nos. each) (1 Set for each type of Circuit Breaker)		Set	1
	C8	**Disconnector**			
	C8.1	Complete set of 3 nos. of single phase disconnector including main circuit, enclosure and driving mechanism		Set	1
	C8.2	High speed/ fast acting fault making grounding switch, 3 nos. of single phase of each rating, including main circuit, enclosure and driving mechanism		Set	1
	C8.3	3 nos. of single phase Earthing switch including main circuit, and driving mechanism		Set	1
	C8.4	Copper contact fingers for disconnector male & female contact – for one complete (3phase) disconnector of each type & rating		Set	1
	C8.5	Copper contact fingers for earthing switch male & female contact – for one complete (3phase) earthing switch of each type & rating		Set	1
	C8.6	Open/ close contactor assembly, timers, key interlock for one complete (3phase) disconnector and earthing switch of each type & rating		Set	1
	C8.7	Push button switch – each type		set	1
	C8.8	Limit switches and Aux. switches for complete 3-phase equipment			
	C8.8.1	For Disconnector		Sets	3
	C8.8.2	For earth switch		Set	1
	C8.8.3	For High speed earth switch		Set	1
	C8.9	Rotor housing bearing assembly for complete 3-phase equipment			
	C8.9.1	For Disconnector		Sets	2
	C8.9.2	For earth switch		Set	1
	C8.9.3	For high speed earth switch		Set	1
	C8.10	Motor with gear assembly for complete 3-phase equipment			
	C8.10.1	For Disconnector		Sets	3
	C8.10.2	For earth switch		Set	1
	C8.10.3	For high speed earth switch		Set	1
	C8.11	Bearings for complete 3-phase equipment			
	C8.11.1	For Disconnector		Sets	5

Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity
	C8.11.2	For earth switch		Set	1
	C8.11.3	For high speed earth switch		Set	1
	C8.12	Interlocking coil with resistors, timers, key interlock for complete 3 phase equipment, as applicable (each type & rating)		Set	1
	C8.13	Relays. Power contactors, resistors, fuses, push buttons, timers & MCBs (Complete for one 3 phase equipment)			
	C8.13.1	For Disconnector		Sets	3
	C8.13.2	For earth switch		Set	1
	C8.13.3	For high speed earth switch		Set	1
	C9	**Current Transformer**			
	C9.1	Complete CT, as applicable, with enclosure, as applicable, 1 no. of each type & rating		Set	1
	C10	**Voltage Transfomer**			
	C10.1	Gas Insulated complete VT with enclosure		No.	1
D	D.1	**Supply Item - Final Spares required for long term routine/ planned and breakdown maintenance (Optional)**	Bidder to quote detailed BOQ alongwith unit price. The Bidder shall provide a "Final Spares Parts List" which shall comprise of all items of the Initial Spare Parts List as well as other spares required for long term routine/ planned and breakdown maintenance ***Optional Item (Refer clause No. 1.3.2)*** .	lot	1
	D.2	**Supply Item - Commissioning spares for testing & commissioning of GIS till handing over**	Bidder to quote detailed BOQ alongwith unit price. Start-Up & Commissioning spares are those spares which may be required during the start-up and commissioning of the equipment/ system. All spares used till the COD/ PAC shall come under this category. The bidder shall provide for an adequate stock of such start up and commissioning spares to be brought by him to the site for the plant erection and commissioning. They must be available at site before the equipment are energized. The unused spares, if any, should be removed from there only after issue of PAC. All start up spares which remain unused at the time PAC shall remain the property of Contractor. These start-up & commissioning spare part list shall not be included in initial Spares Parts List.	lot	1
E		**Supply Item - Tools & tackle & Testing Equipment (E1 to E10)**	Only special tools shall be in bidder's scope. The following list (E1 to E10) is minimum to be supplied. Any special tools required is deemed to be included in scope. Bidder to submit list of tools, tackle, slings, spanners, gauges, slings and other lifting devices, drills, instruments and appliances necessary for the complete assembly and erection at site of the GIS, required for installation, gas filling, maintenance, site testing of the GIS which shall be arranged by BHEL. EOT cranes shall be provided by BHEL, capacity of EOT crane to be recommended by bidder. Bidder to furnish detailed BOQ for non-returnable Tools and Tackles along with unit prices to be handed over to ultimate customer. Bidder to arrange returnable tools and shall submit list of such tools.	Lot	1
	E1	Hygrometer		Nos.	1
	E2	Portable dust counter		Nos.	1
	E3	Special gas mask for GIS maintenance		Nos.	5
	E4	Vacuum meter		Nos.	1
	E5	Digital contact resistance meter		Nos.	1
	E6	Mobile platform		Nos.	1
	E7	Power operated insulation tester		Nos.	1
	E8	Tong testers of suitable ranges		Nos.	1
	E9	Contact resistance measuring set for micro ohms	same as E6	Nos.	1
	E10	Non -returnable tools & tackles	Bidder to submit detailed breakup	lot	1
F		**Services: Supervision of Erection, commissioning & site testing including earthing (F1 to F7)**	**GT bAYS, BUS REACTOR bay, FUTURE GT BAY, LINE BAYS, LINE REACTOR BAYS, ICT BAYS, Tie Line Bays, BUS PT BAY etc. will be commissioned seperately at diffferent stages.**	Lot	1
	F1	Insulation co-ordination studies		Lot	1
	F2	Site visit for supervision of unloading, storage & verification of material at store	Store shall be provided by BHEL	Lot	1
	F3	Supervision of Erection of GIS	Complete GIS including busbar, GT bAYS, BUS REACTOR bay, FUTURE GT BAY, LINE BAYS, LINE REACTOR BAYS, ICT BAYS, Tie Line Bays, BUS VT BAY etc.	Set	1
	F4	Supervision of Erection of GIS Duct (2500/3150/4000A) - GIS to SF6 to Air Bushings	Complete GIS ducts of all rating	Lot	1
	F5	Supervision of Erection of complete SF6 to Air Bushing (2500A/3150A)		Set	27
	F6	Testing & Commissioning of GIS	Complete GIS including busbar, GT bAYS, BUS REACTOR bay, FUTURE GT BAY, LINE BAYS, LINE REACTOR BAYS, ICT BAYS, Tie Line Bays, BUS PT BAY etc.	Set	1
	F7	Final successful Testing of GIS including HV test kit	HV Test kit shall be arranged by the bidder on returnable basis. (GT bAYS, BUS REACTOR bay, FUTURE GT BAY, LINE BAYS, LINE REACTOR BAYS, ICT BAYS, Tie Line Bays, BUS PT BAY etc. may be commissioned seperately.) Final testing as per IEC for complete GIS including busbar, GT bAYS, BUS REACTOR bay, FUTURE GT BAY, LINE BAYS, LINE REACTOR BAYS, ICT BAYS, Tie Line Bays, BUS PT BAY & LAs bays, Ducts, SF6 to Air Bushing etc.	Lot	1

Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity
G		**Services: Training (G1 to G2)**			
	G1	Training for GIS to BIFPCL/BHEL engineers -Visit to manufacturer's works = 30 mandays	Lodging and boarding of Training participants shall be in bidder's scope.	Lot	1
	G2	Training for GIS to BIFPCL/BHEL engineers - ETC, Operation and maintenance of Plant (GIS) at site = 30 mandays		Lot	1
H		**Any other item required for completion of project (H1 to H2)**			
	H1	Supply - Any other item required for completion of project and not covered in A to G- Complete List to be provided by bidder along with unit prices.		Lot	1
	H2	Services - Any other item required for completion of project and not covered in F&G - Complete List to be provided by bidder along with unit prices.		Lot	1
I		**Supply - Unit Prices of Individual Item/Equipment (I1 to I26)**	Unit Prices of Individual Equipment included here or in manadatory spares are required for any Addition/Deletion of Equipment and replacement of damaged items. Vendor to ensure that the unit prices have a logical relationship with prices of assemblies in main items (Bay, Busbar etc). Quoting for unit prices is mandatory and shall be considered for evaluation.		
	I1	400kV, 4000A Circuit breaker (1 pole complete without enclosure without operating mechanism)		No	1
	I2	400kV, 4000A Circuit breaker with PIR (1 pole complete without enclosure without operating mechanism)		No	1
	I3	400kV, 4000A Isolator (1 pole) without operating mechanism		No	1
	I4	400 kV Maintenance Earhing switch without operating mechanism		No	1
	I5	400kV High speed earth switch without operating mechanism		No	1
	I6	400kV Current transformer (1 of each type) (Individual prices to be furnished).		No	1
	I7	Operating Mechanism box for 400kV, 4000 A Circuit Breaker		No	1
	I8	Operating Mechanism box for 400kV, 4000 A Isolator		No	1
	I9	Operating mechanism for 400kV, Maintenance Earthing Switch		No	1
	I10	Operating Mechanism for 400kV, High Speed Earthing Switch		No	1
	I11	Single Phase Bus bar (Any type)	Complete single phase 400kV,4000A, 50 kA for 1s bus bar including Gas monitoring systems, barriers, pressure switches	m	1
	I12	Conductor for Single phase Bus bar/ bus duct (any type)	Conductor for bus bar, bus duct, GIB, Interconnecting conductors of any type with interconnecting parts as required.	kg	10
	I13	GIS metallic enclosure (any type)	Enclosure for bus bar, bus duct, GIB, straight cast enclosure etc with fixing hardware as required.	m	1
	I14	Epoxy resin insulators for bus suppoert with holes for gas flow (of each type and rating)	Bidder to inform details at tender stage	set	1
	I15	Gas barrier insulators (of each type and rating)	Bidder to inform details at tender stage	set	1
	I16	Density switch		no.	1
	I17	Gas monitoring system devices	1 set =1 no of each type	lot	1
	I18	PD sensor		No.	1
	I19	Optical indicator for CB, Isolator		No.	1
	I20	Elbow /Angle / T-bends		No.	1
	I21	Telescopic enclosure		No.	1
	I22	Sleeve enclsoure		No.	1
	I23	Expansion joints for bellows		m	1
	I24	cross tank		No.	1
	I25	Services of manpower for erection per day (excl. travel time)		days	1
	I26	Services of manpower for Testing & commissioning per day (excl. travel time)		days	1
	I27	Hiring charges of HV test kit	Additional HV test kit charges including charges of manpower, HV test kit, accessories & tools required for completion of HV test (Dielectric Test after installation of GIS). HV test kit charges include one or more bay at site.	lot	1

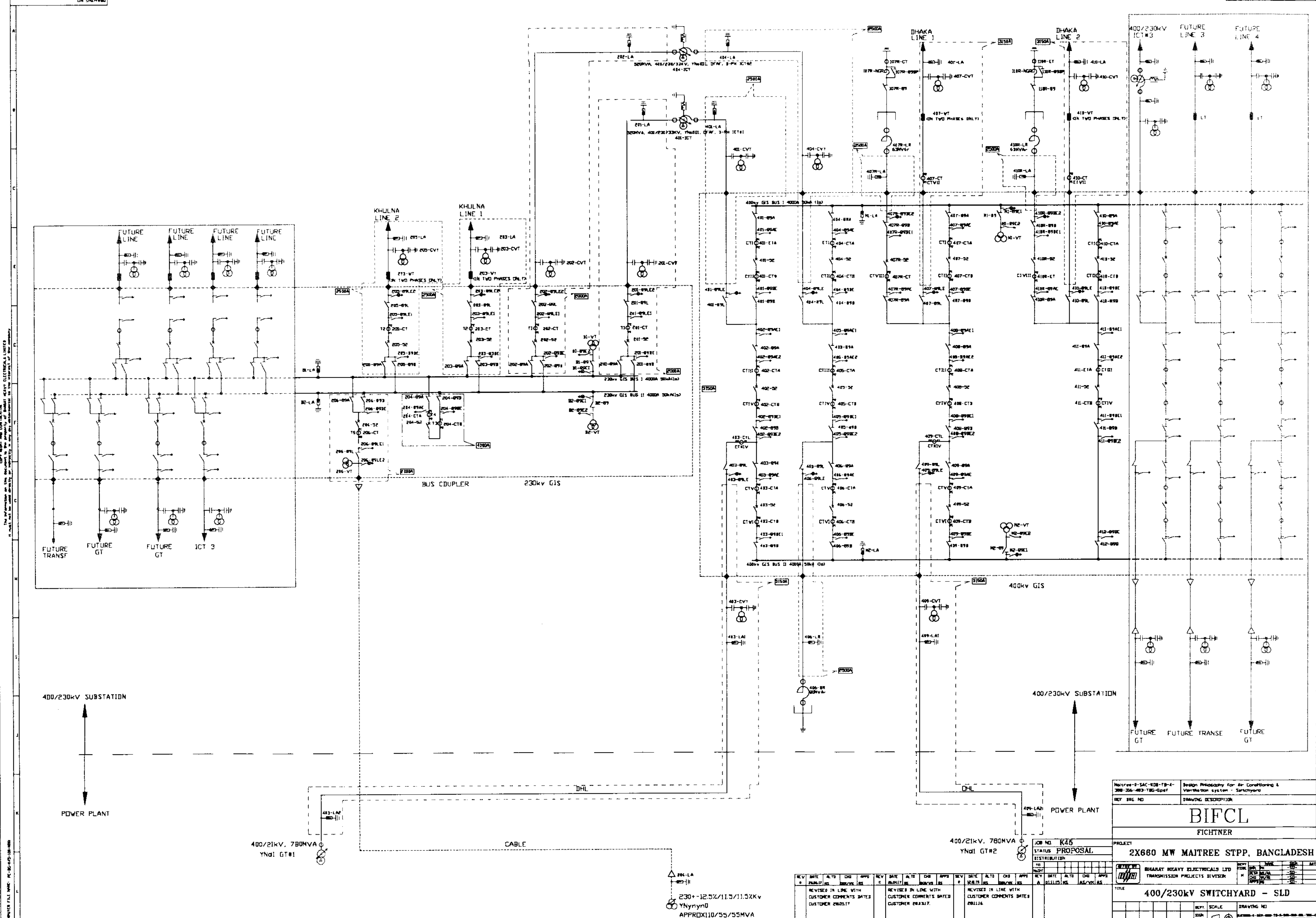
Sl.No.	SL	Description	Remarks_Long_Description	Unit	Quantity

Note :

1 **CT & VT details given in single line diagram are tentative and may change at contract stage. Changes to be incorporated by bidder without any cost and delivery implication.**

2 **Item no. A21 & D.1 are optional items and BHEL reserves right at its sole discretion to order these items or not.**

3 **BHEL reserves the right for quantity variation due to any reason upto ±30% of total value at same unit rate and terms during execution of contract. The quantity of individual items may however vary upto any extent.**



BIFCL

FICHTNER

JOB NO K45

STATUS PROPOSAL

PROJECT 2X660 MW MAITREE STPP, BANGLADESH

BHARAT HEAVY ELECTRICALS LTD
TRANSMISSION PROJECTS DIVISION

TITLE 400/230kV SWITCHYARD - SLD

FIRST ANGLE PROJECTION

ALL DIMENSIONS ARE IN MM

A. 400 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOLS	LEGEND	BAY NO/LOCATION	UNIT	QTY
1.	520MVA, 400/230/33KV, YNa0D1, OFAF, 3-PH ICT		ICT	401, 404.	NOS	02
2.	80MVAr, YN0, ONAN, 3-PH BUS REACTOR (BR)		BR	406.	NOS	01
3.	63MVAr, YN0, ONAN, 3-PH LINE REACTOR (LR)		LR	407R, 410R.	NOS	02
4.	400kv, 3150A, 1-PH, 6-CORE CURRENT-TRANSFORMER (CTVII)		CT	407, 410.	NOS	06
5.	400kV, 1-PH, CAPACITIVE VOLTAGE TRANFORMER (CVT)		CVT	401, 403, 404, 407, 409, 410.	NOS	18
6.	390kV, 20kA, CLASS-IV, 1-PH, LIGHTING ARRESTER (LA)		LA	401, 403X2, 404, 406, 407, 407R, 409X2, 410, 410R.	NOS	33
7.	400kV, 3150A, 1.0mH, 1-PH, PEDESTAL TYPE WAVE TRAP (WT)		WT	407, 410.	NOS	04

B. 230 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOL	LEGEND	BAY NO/LOCATION	UNIT	QTY
1.	210kV, 20kA, CLASS-IV, 1-PH LIGHTING ARRESTER (LA)		LA	201, 202, 203, 205, 206.	NOS	15
2.	230kV, 2500A, 1.0mH, 1-PH, PEDESTAL TYPE WAVE TRAP (WT)		WT	203, 205.	NOS	04
3.	230kV, 1-PH, CAPACITOR VOLTAGE TRANSFORMER (CVT)		CVT	201, 202, 203, 205.	NOS	12

C. 120 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOL	LEGEND	BAY NO/LOCATION	UNIT	QTY
1.	NEUTRAL GROUNDING REACTOR (NGR)		NGR	107R, 110R	NOS	02
2.	ISOLATOR 1-PH		89 89BP	107R, 110R 107R, 110R	NOS	04
3.	CURRENT-TRANSFORMER (CT), 1-PH		CT	107R, 110R	NOS	02

NOTES: RATING OF NGR & ASSOCIATED ISOLATOR & CT IS TO BE FURNISHED BY CUSTOMER BASED ON RESULT OF NETWORK STUDIES AS PER CLAUSE NO. B10.4.18 OF TECHNICAL SPECIFICATION.

BIFCL

FICHTNER

PROJECT: 2X660 MW MAITREE STPP, BANGLADESH

BHARAT HEAVY ELECTRICALS LTD TRANSMISSION PROJECTS DIVISION

TITLE: 400/230kV SWITCHYARD - SLD

JOB NO. K45

STATUS PROPOSAL

DRAWING NO.

SHEET 3 OF 4 REV 3-A

D. 400 kV INDOOR GIS

S.N.	DESCRIPTION	SYMBOLS	LEGEND	BAY NO/LOCATION	UTIT	QTY
1A.	CIRCUIT BREAKER (CB), 3X1-PH		52	401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411.	SETS	11
1B.	CIRCUIT BREAKER (LB), 3X1-PH WITH PIR		52	407R, 410R	SETS	02
2.	DISCONNECTING SWITCH, 3X1-PH		89 89A 89B 89L	M1, M2. 401, 402, 403, 404, 405, 406, 407, 407R, 408, 409, 410, 410R, 411 401, 402, 403, 404, 405, 406, 407, 407R, 408, 409, 410, 410R, 411, 412. 401, 403, 404, 406, 407, 409, 410.	SETS	36
3.	EARTH SWITCH, 3X1-PH		89E1/E2 89AE/AE1/AE2 89BE/BE1/BE2	M1, M2. 401, 402X2, 403, 404, 405X2, 406, 407, 407R, 408X2, 409, 410, 410R, 411X2. 401, 402X2, 403, 404, 405X2, 406, 407, 407R, 408X2, 409, 410, 410R, 411X2, 412.	SETS	37
4.	HIGH SPEED EARTHING SWITCH, 3X1-PH		89E1/E2 89LE 89BE2	M1, M2. 401, 403, 404, 406, 407, 409, 410. 407R, 410R.	SETS	11
5.	CURRENT TRANSFORMER, 1-PH		CTI CTII CTIII CTIV CTV CTVI CTVIII CTXIV	89CTA-401, 404, 407, 410 - 12 NOS. 89CTB-401, 404, 407, 410 - 12 NOS. 89CTA-402, 405, 408, 411 - 12 NOS. 89CTB-402, 405, 408, 411 - 12 NOS. 89CTA-403, 406, 409 - 09 NOS. 89CTB-403, 406, 409 - 09 NOS. CT-407R, 410R - 06 NOS. CTL-403, 409 - 06 NOS.	NOS.	78
6.	VOLTAGE TRANSFORMER (VT) 1-PH.		VT	M1, M2.	NOS.	06
7.	SF6 TO AIR BUSHING, 1-PH				NOS.	27
8.	LIGHTING ARRESTER (LA), 1-PH		LA	M1, M2.	NOS.	06

E. 230 kV INDOOR GIS

S.N.	DESCRIPTION	SYMBOL	LEGEND	BAY NO/LOCATION	UNIT	QTY
1.	CIRCUIT BREAKER, 3X1-PH		52	201, 202, 203, 204, 205, 206.	SETS	06
2.	DISCONNECTING SWITCH, 3X1-PH		89 89A 89B 89L	B1, B2. 201, 202, 203, 204, 205, 206. 201, 202, 203, 204, 205, 206. 201, 202, 203, 205, 206.	SETS	19
3.	EARTH SWITCH, 3X1-PH		89E1/E2 89AE 89BE 89LE1	B1, B2. 204. 201, 202, 203, 204, 205, 206. 201, 202, 203, 205, 206.	SETS	14
4.	HIGH SPEED EARTHING SWITCH, 3X1-PH		89LE2/89E	B1, B2, 201, 202, 203, 205, 206.	SETS	07
5.	CURRENT TRANSFORMER (CT), 1-PH		T1 T2 T3 T4 T5	201, 202 - 06 NOS. 203, 205 - 06 NOS. 204 - 03 NOS. 204 - 03 NOS. 206 - 03 NOS.	NOS.	21
6.	VOLTAGE TRANSFORMER (VT), 1-PH		VT	B1, B2, 206.	NOS.	09
7.	SF6/AIR BUSHING, 1-PH				NOS.	15
8.	LIGHTING ARRESTER (LA), 1-PH		LA	B1, B2.	NOS.	06

NOTE : ⚠

Following provisions shall be made for extension of GIS in future so that all existing feeders can be kept in operation during installation and commissioning (also during high voltage tests of extension on site) of new diameters/ feeders.

a) The arrangement of gas sections and compartments shall be such as to facilitate future extension of any make without any drilling, cutting or welding on existing equipment. To add equipment, it shall not be necessary to move or dislocate the existing switchgear bays.

b) As the GIS is likely to be extended in future, the GIS supplier shall make available during detailed engineering stage, the complete design detail of interface module such as cross section, enclosure material, enclosure dimensions (inner & outer), Flange diameter (inner & outer), conductor connection arrangement, bolt spacing & dimension, rated gas pressure etc. Further GIS manufacturer supplying GIS under present scope shall furnish all the required details in addition to mentioned above necessary for design and successful implementation of an interface module during later stage while extending GIS by any other GIS manufacturer, without any help of GIS manufacturer who has supplied the GIS equipment in present scope.

c) The Interface module shall be designed to provide Isolating link with access hole on enclosure. The Isolating link shall be provided in such a way so that HV test can be performed on either side of the interface module separately, keeping other side of GIS remain isolated.

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JOB NO. K45

STATUS PROPOSAL

PROJECT 2X660 MW MAITREE STPP, BANGLADESH

BHARAT HEAVY ELECTRICALS LTD TRANSMISSION PROJECTS DIVISION

TITLE 400/230kV SWITCHYARD – SLD

F. BASIC DESIGN DATA FOR SUB-STATION

DATA	400 kv GIS	230 kv GIS
NOMINAL VOLTAGE (kV)	400	230
HIGHEST SYSTEM VOLTAGE	420	245
RATED FREQUENCY (Hz)	50	50
RATED BUS BAR AND DIAMETER CURRENT (A)	4000	
RATED BUS BAR AND BUS COUPLER CURRENT (A)		4000
RATED FEEDER CURRENT (GT AND OR OHL)	3150	2500
RATED FEEDER CURRENT (OTHERS)	2500	2000
RATED POWER FREQUENCY WITHSTAND VOLTAGE (kV)	650	460
LIGHTNING IMPULSE WITHSTAND VOLTAGE (kV)	1425	1050
RATED SHORT CIRCUIT CURRENT (1 SEC)	50	50
RATED PEAK WITHSTAND CURRENT	125	125
CREEPAGE DISTANCE (mm/Phase Voltage in kV)	53.7	
CREEPAGE DISTANCE (mm/Line Voltage in kV)	31	
AMBIENT TEMPERATURE RANG(°C INDOORS)	45° C AS PER BO (GENERAL SPECIFICATION)	
AUXILIARY SUPPLY VOLTAGE (V AC)	230/415	
CONTROL VOLTAGE (V DC)	220	
TELECOM. AUX. VOLTAGE (V DC)	48	
SEISMIC CONDITIONS (GROUND ACCELERATION)	0.12g	

LIGENDS :

- 230kV CABLE
- PRESENT SCOPE
- FUTURE/NOT IN BHEL SCOPE
- FUTURE

NOTE :

1. LINE REACTOR CBs WILLL BE PROVIDED WITH PIR
2. WAVE TRAPS WOULD BE IN TWO PHASES OF LINES ONLY.
3. CVT & WAVE TRAPS RATINGS OF LINES TO BE PROVIDED BY CUSTOMER.
4. RATING OF NGR & ASSOCIATED ISOLATOR & CT IS TO BE FURNISHED BY CUSTOMER BASED ON RESULT OF NETWORK STUDIES AS PER CLAUSE NO. B10.4.18 OF TECHNICAL SPECIFICATION.
5. NOMENCLATURES OF EQUIPMENT MAY CHANGE AFTER FINALIZATION OF VENDOR.
6. CT/VT PARAMETERS ARE SUBJECT TO CHANGE BASED ON GIS MANUFACTURER'S RECOMMENDATIONS
6. CT/VT PARAMETERS ARE SUBJECT TO CHANGE BASED ON GIS MANUFACTURER'S RECOMMENDATIONS
7. CURRENT RATING OF FEEDERS / DIAMETERS IS CLEARY MARKED IN SLD (SHEET-2)

400kV CT DETAILS

Diameter CT core data (CTI, CTIII, CTIV, CTVI)		
Rated primary current	A	1000-2000-4000
Rated secondary current	A	1/1/1/1
Core 1 Class and burden		5P20 30 VA
Core 2 Class and burden		5P20 30 VA
Core 3 Class and burden		5P20 30 VA
Core 4 Class and burden		0.2S FS5 30 VA
Diameter CT core data (CTII, CTV)		
Rated primary current	A	1000-2000-4000
Rated secondary currents	A	1/1/1
Core 1 Class and burden		5P20 30 VA
Core 2 Class and burden		5P20 30 VA
Core 3 Class and burden		5P20 30 VA
Line reactor CT core data (CTVIII)		
Rated primary current	A	250-500-1000
Rated secondary currents	A	1/1/1
C1 Class and burden		5P20 30 VA
C2 Class and burden		5P20 30 VA
C3 Class and burden		5P20 30 VA
GT feeder CT core data (CTXIV)		
Rated primary currents for bypass & bus coupler bay	A	1000-2000-4000
Rated secondary currents	A	1/1
Core 1 Tariff metering (Main)		0.2S FS5
Core 2 Measuring and trafiff metering (Check)		0.2S FS5
Line feeder CT core data (CTVII) - OUTDOOR		
Rated primary current	A	1000-2000-4000
Rated secondary currents	A	1/1/1/1/1/1
C1 Class and burden		5P20 60 VA
C2 Class and burden		5P20 60 VA
C3 Class and burden		5P20 60 VA
C4 Class and burden		5P20 60 VA
C5 Class and burden		0.2S FS5 30 VA
C6 Class and burden		0.2S FS5 30 VA

400kV EMVT DETAILS

Rated primary voltage	kV	420	420
Rated secondary voltages (W2 measuring/protection)	kV	0.110/√3	0.110/√3
Metering winding (W1)	kV	0.110/√3	0.110/√3
Open delta winding (WE)	kV	0.110/3	0.110/3
Rated output (W1/W2/WE)	VA	100/100/100	100/100/100
Accuracy class			
• for tariff metering	-	0.2	0.2
• for measuring and protection	-	0.5 / 3P	0.5 / 3P
• for protection	-	3P	3P

400kV CVT DETAILS

Rated secondary voltages (W2 measuring/protection)	kV	0.110/√3
Metering winding (W1)	kV	0.110/√3
Protection winding (W3)	kV	0.110/√3
Rated output (W1/W2/W3)	VA	100/100/100
Thermal capacity of the ground fault detection winding	A	25
Accuracy class for metering		0.2
Accuracy class measuring and protection		0.5 / 3P
Accuracy class protection		3P

230kV CT DETAILS

Rated primary currents for ICT and line bays (T1, T2)	A	1000-2000
Rated secondary currents	A	1/1/1/1/1/1
C1 Class and burden		5P20 30 VA
C2 Class and burden		5P20 30 VA
C3 Class and burden		0.2M5 30 VA
C4 Class and burden		0.2M5 30 VA
C5 Class and burden		5P20 30 VA
C6 Class and burden		5P20 30 VA
Rated primary currents for SUT bay (T5)	A	500-1000-2000
Rated secondary currents	A	1/1/1/1/1/1
C1 Class and burden		5P20 30 VA
C2 Class and burden		5P20 30 VA
C3 Class and burden		0.2M5 30 VA
C4 Class and burden		0.2M5 30 VA
C5 Class and burden		5P20 30 VA
C6 Class and burden		5P20 30 VA
Rated primary currents for bus coupler bay (T3)	A	1000-2000
Rated secondary currents	A	1/1
C1 Class and burden		5P20 30 VA
C2 Class and burden		0.2M5 30 VA
Rated primary currents for bus coupler bay (T4)	A	1000-2000
Rated secondary currents	A	1/1
C1 Class and burden		5P20 30 VA
C2 Class and burden		5P20 30 VA

230kV EMVT DETAILS

Rated secondary voltages (W2 measuring/protection)	kV	0.110/√3
Metering winding (W1)	kV	0.110/√3
Protection winding (W3)	kV	0.110/√3
Rated output (W1/W2/WE)	VA	100/100/100
Accuracy class		
• for tariff metering	-	0.2
• for measuring and protection	-	0.5 / 3P
• for protection	-	3P

230kV CVT DETAILS

Rated secondary voltages (W2 measuring/protection)	kV	0.110/√3
Metering winding (W1)	kV	0.110/√3
Protection winding (W3)	kV	0.110/√3
Rated output (W1/W2/W3)	VA	100/100/100
Accuracy class for metering		0.2
Accuracy class measuring and protection		0.5 / 3P
Accuracy class protection		3P

BIFCL

FICHTNER

JOB NO: K45 PROJECT: 2X660 MW MAITREE STPP, BANGLADESH

STATUS: PROPOSAL

DISTRIBUTION

BHARAT HEAVY ELECTRICALS LTD TRANSMISSION PROJECTS DIVISION

TITLE: 400/230kV SWITCHYARD – SLD

SCALE: DRAWING NO:

SHEET 4 OF 4 REV 0-B

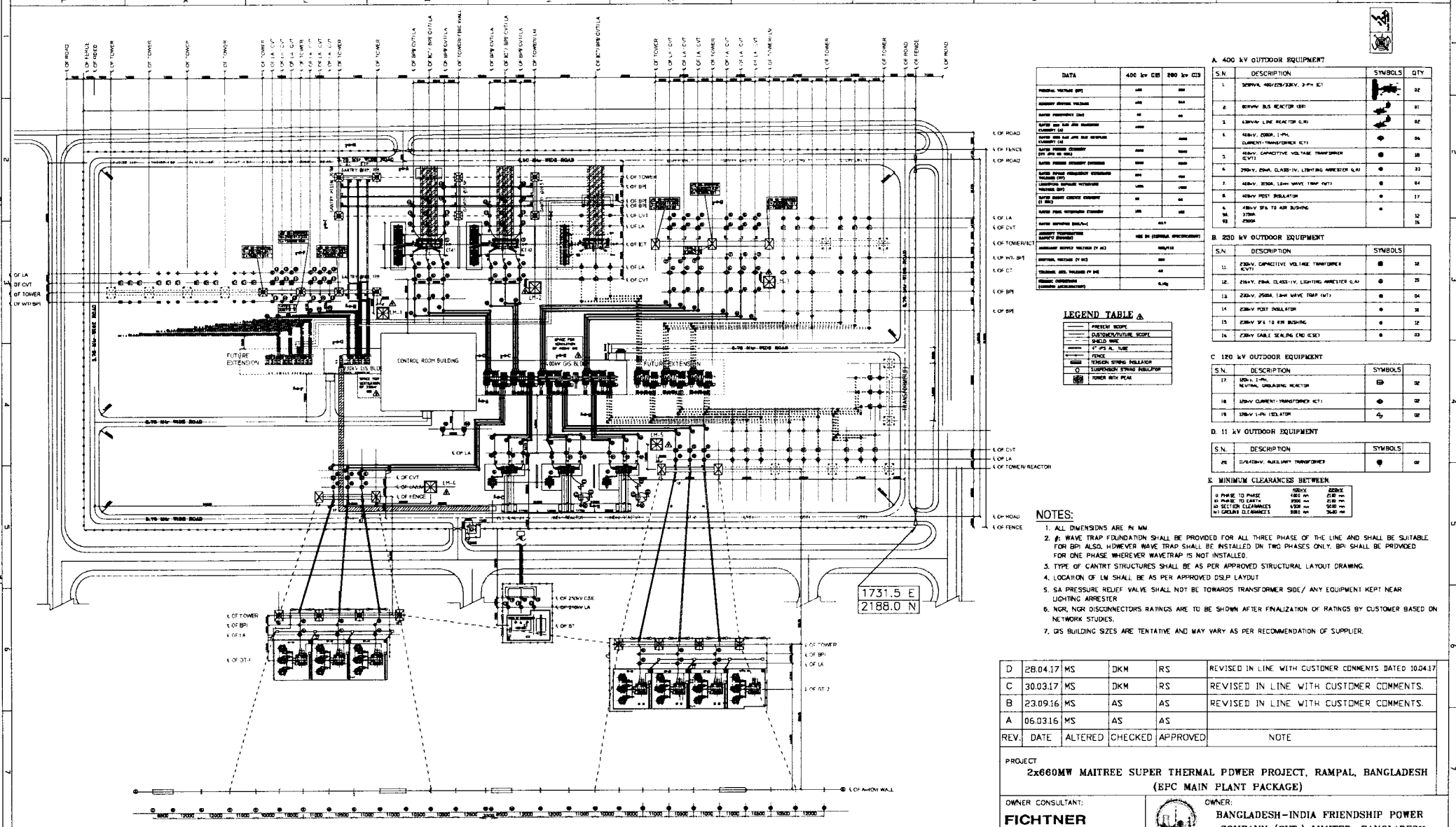
REVISED IN LINE WITH CUSTOMER COMMENTS DATED CUSTOMER PB0517

REVISED IN LINE WITH CUSTOMER COMMENTS DATED CUSTOMER 280317

REVISED IN LINE WITH CUSTOMER COMMENTS DATED /08/17

AS-BUILT/MS AS-BUILT/MS

DRAWING NO.: Maitree-0-BTW-LD-TB-0-388-316-001-TBG-D



DATA	400 kv GIS	230 kv GIS
RATED VOLTAGE (kV)	420	245
HIGHEST SYSTEM VOLTAGE	420	245
RATED FREQUENCY (Hz)	50	50
RATED BUS BAR AND BUS COUPLER CURRENT (A)	4000	
RATED BUS BAR AND BUS SECTION CURRENT (A)		4000
RATED FEEDER CURRENT (MY AND BE ONLY)	4000	1600
RATED FEEDER CURRENT (OTHERS)	1600	1600
RATED SHORT CIRCUIT CURRENT (1 SEC)	50	50
RATED PEAK WITHSTAND CURRENT	100	100
RATED DENSITY (GAS/Air)	GAS	
CAPACITY CONFIGURATION (CURRENT INTERRUPTING)		NOS IN (CONSULT SPECIFICATION)
AUXILIARY SUPPLY VOLTAGE (V AC)		110/415
CONTROL VOLTAGE (V DC)		220
CLOSING AND TRIPPING (V DC)		48
WEIGHT (APPROX) (CONSULT MANUFACTURER)		0.4Kg

LEGEND TABLE ⚠

	PRESENT SCOPE
	CUSTOMER/FUTURE SCOPE
	SHIELD WIRE
	4" IPS AL. TUBE
	FENCE
	TENSION STRING INSULATOR
	SUSPENSION STRING INSULATOR
	TOWER WITH PEAK

A. 400 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOLS	QTY
1.	3CB/PHASE, 400/√3/230/√3 kV, 3-PH BCT		02
2.	80MVAr BUS REACTOR (BR)		01
3.	63MVAr LINE REACTOR (LR)		02
4.	420kV, 2000A, 1-PH CURRENT TRANSFORMER (CT)		06
5.	420kV, CAPACITIVE VOLTAGE TRANSFORMER (CVT)		18
6.	390kV, 20kA, CLASS-IV, LIGHTING ARRESTER (LA)		33
7.	420kV, 3150A, 1.8mH WAVE TRAP (WT)		04
8.	420kV POST INSULATOR		17
9. 9A. 9B.	420kV SF6 TO AIR BUSHING 2750A 2500A		12 15

B. 230 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOLS	
11.	230kV, CAPACITIVE VOLTAGE TRANSFORMER (CVT)		12
12.	216kV, 20kA, CLASS-IV, LIGHTING ARRESTER (LA)		15
13.	230kV, 2500A, 1.8mH WAVE TRAP (WT)		04
14.	230kV POST INSULATOR		18
15.	230kV SF6 TO AIR BUSHING		12
16.	230kV CABLE SEALING END (CSE)		03

C. 120 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOLS	
17.	120kV, 1-PH, NEUTRAL GROUNDING REACTOR		02
18.	120kV CURRENT TRANSFORMER (CT)		02
19.	120kV 1-PH ISOLATOR		02

D. 11 kV OUTDOOR EQUIPMENT

S.N.	DESCRIPTION	SYMBOLS	
20.	11/0.415kV, AUXILIARY TRANSFORMER		02

E. MINIMUM CLEARANCES BETWEEN

	420kV	220kV
a) PHASE TO PHASE	4200 mm	2100 mm
b) PHASE TO EARTH	3500 mm	2100 mm
c) SECTION CLEARANCES	6300 mm	5040 mm
d) GROUND CLEARANCES	9800 mm	7640 mm

NOTES:

1. ALL DIMENSIONS ARE IN MM.
2. #: WAVE TRAP FOUNDATION SHALL BE PROVIDED FOR ALL THREE PHASE OF THE LINE AND SHALL BE SUITABLE FOR BPI ALSO, HOWEVER WAVE TRAP SHALL BE INSTALLED ON TWO PHASES ONLY. BPI SHALL BE PROVIDED FOR ONE PHASE WHEREVER WAVETRAP IS NOT INSTALLED.
3. TYPE OF CANTRT STRUCTURES SHALL BE AS PER APPROVED STRUCTURAL LAYOUT DRAWING.
4. LOCATION OF LM SHALL BE AS PER APPROVED DSLP LAYOUT
5. SA PRESSURE RELIEF VALVE SHALL NOT BE TOWARDS TRANSFORMER SIDE/ ANY EQUIPMENT KEPT NEAR LIGHTING ARRESTER
6. NGR, NGR DISCONNECTORS RATINGS ARE TO BE SHOWN AFTER FINALIZATION OF RATINGS BY CUSTOMER BASED ON NETWORK STUDIES.
7. GIS BUILDING SIZES ARE TENTATIVE AND MAY VARY AS PER RECOMMENDATION OF SUPPLIER.

REV.	DATE	ALTERED	CHECKED	APPROVED	NOTE
D	28.04.17	MS	DKM	RS	REVISED IN LINE WITH CUSTOMER COMMENTS DATED 10.04.17
C	30.03.17	MS	DKM	RS	REVISED IN LINE WITH CUSTOMER COMMENTS.
B	23.09.16	MS	AS	AS	REVISED IN LINE WITH CUSTOMER COMMENTS.
A	06.03.16	MS	AS	AS	

PROJECT
2x660MW MAITREE SUPER THERMAL POWER PROJECT, RAMPAL, BANGLADESH (EPC MAIN PLANT PACKAGE)

OWNER CONSULTANT:
FICHTNER
M/s FICHTNER GmbH & Co KG,
Stuttgart,GERMANY

OWNER:
BANGLADESH-INDIA FRIENDSHIP POWER COMPANY (PVT.) LIMITED, BANGLADESH

BHARAT HEAVY ELECTRICALS LTD
TRANSMISSION BUSINESS GROUP
NOIDA

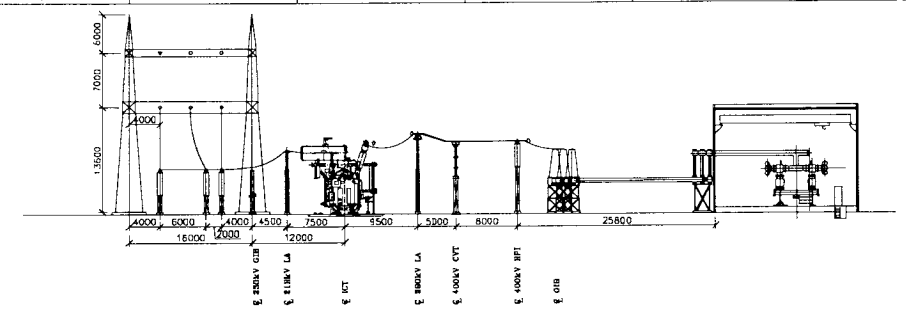
SCALE:
SHEET 01 OF 02

	DATE	NAME
DRAWN BY		
DESIGN BY		
CHECKED BY		
APPROVED BY		
SUPERSEDES:		
SUPERSEDED BY:		

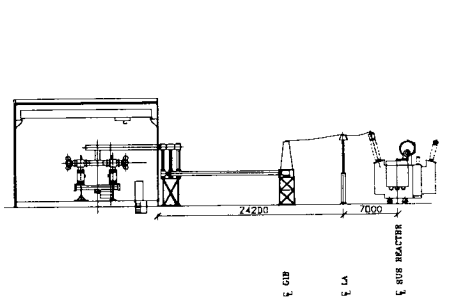
TITLE
400/230kV Switchyard Plan Layout & Sectional Elevation

SIZE: | PROJECT NO.: | FILE:
ANNEX: | DRAWING NO.: Maitree-0-BTW-LD-TB-0-388-316-001-TBG-D | REV: D

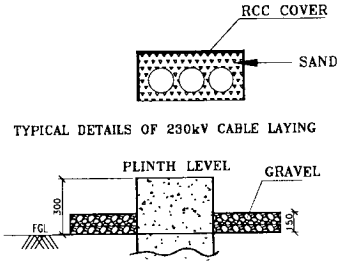
SN	DRAWING NO.	DRAWING TITLE	SYSTEM
5.	Maitree-0-BAU-ED8-TB-0-388-316-003-TBG-D	400/230kV Switchyard- DSLP Calculation & Layout	
4.	MAITREE-0-BAY-ED8-TB-3-510-316-001-TBG-C	400/230kV SWITCHYARD - SLD	
3.	MAITREE-0-MA-LD-421100M001PEN-C	PLOT PLAN	
2.	TENDER DRAWING E-06	TENTATIVE LAYOUT 400/230kV SUB STATION	
1.	TENDER DRAWING, Part-C, Annexure-XXV	KEY SLD GRID CONNECTION	



SECTION: A-A: (400/230KV ICT)

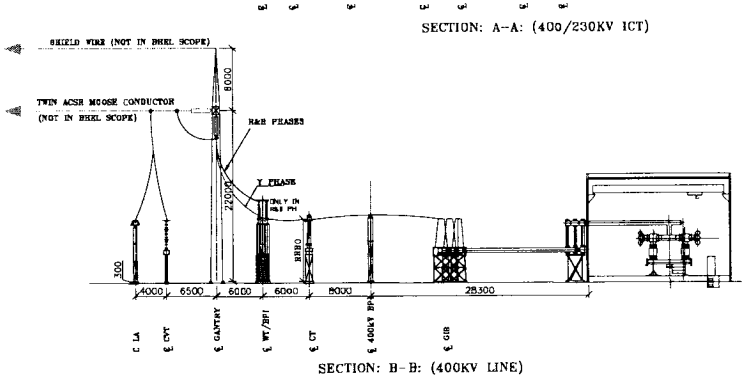


SECTION: C-C: (400KV BUS/ LINE REACTOR)

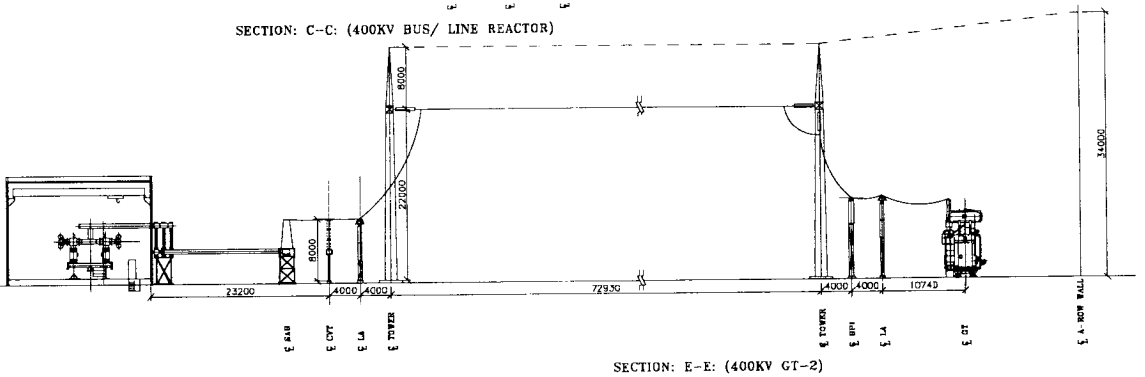


TYPICAL DETAILS OF 230kV CABLE LAYING

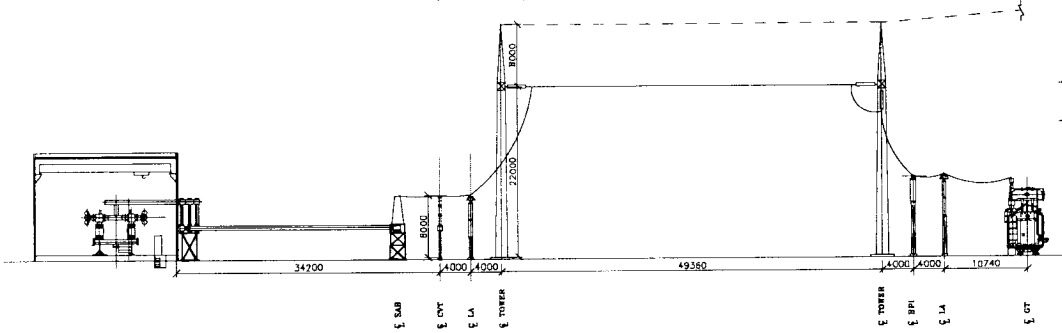
TYPICAL DETAILS OF GRAVEL LAYING



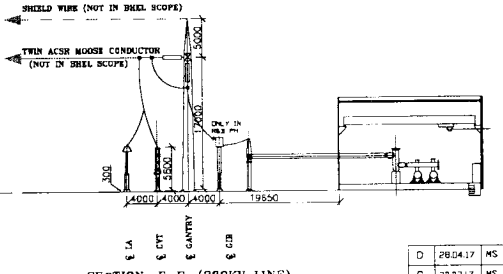
SECTION: B-B: (400KV LINE)



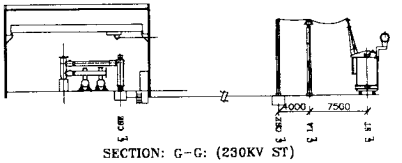
SECTION: E-E: (400KV GT-2)



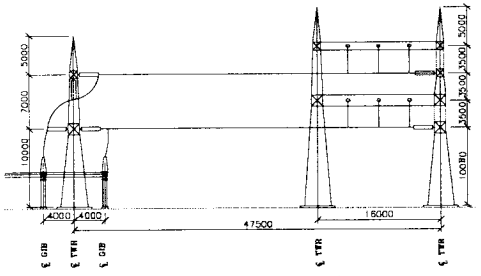
SECTION: D-D: (400KV GT-1)



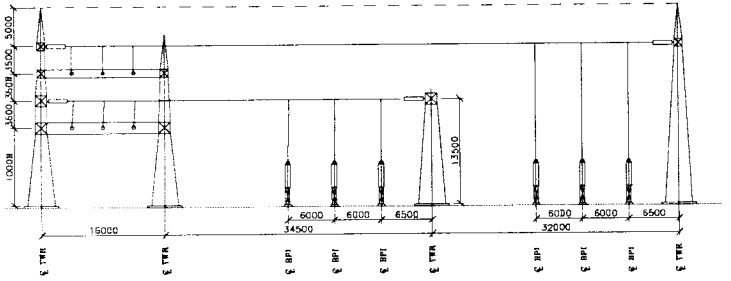
SECTION: F-F: (230KV LINE)



SECTION: G-G: (230KV ST)



SECTION: H-H: (230KV GIS-ICT)



SECTION: I-I: (230KV GIS-ICT)

REV.	DATE	ALTERED	CHECKED	APPROVED	NOTE
D	28.04.17	MS	DKM	RS	REVISED IN LINE WITH CUSTOMER COMMENTS DATED 18.04.17.
C	30.03.17	MS	DKM	RS	REVISED IN LINE WITH CUSTOMER COMMENTS.
B	23.09.16	MS	AS	AS	REVISED IN LINE WITH CUSTOMER COMMENTS.
A	06.09.16	MS	AS	AS	

PROJECT
2x660MW MAITREE SUPER THERMAL POWER PROJECT, RAMPAL, BANGLADESH
(EPC MAIN PLANT PACKAGE)

OWNER CONSULTANT:
FICHTNER
M/s FICHTNER GmbH & Co KG,
Stuttgart,GERMANY

OWNER:
BANGLADESH-INDIA FRIENDSHIP POWER COMPANY (PVT.) LIMITED, BANGLADESH

BHARAT HEAVY ELECTRICALS LTD
TRANSMISSION BUSINESS GROUP
NOIDA

SCALE
SHEET 02 OF 02

	DATE	NAME
DRAWN BY		
DESIGN BY		
CHECKED BY		
APPROVED BY		
SUPERSEDES		
SUPERSEDED BY		
SYSTEM		

TITLE
400/230kV Switchyard Plan Layout & Sectional Elevation

SIZE: A1 | PROJECT NO: | FILE
ANNEX: | DRAWING NO: Maitree-S-BTW-LD-TB-0-3X8-315-001-TBC-0 | REV: 0

B10.3.2 400 kV gas insulated switchgear

The 400 kV gas insulated switchgear in 1 ½ breaker configuration in separate building shall include in present scope four (4) diameters and provision for later extension of three (3) additional diameters as shown in single line diagram. The building will be extended later for the future diameters. Provisions for extension shall ensure that all existing feeders can be kept in operation during installation and commissioning (also during high voltage tests of extension on site) of the new diameters/feeders. Following equipments as show in the attached single line diagram **Annex E** and layout drawing **Annex E** shall be provided:

The following technical standards to be followed:The mechanical and electrical endurance as per IEC 62271-100/ -102. Circuit breaker and Disconnector class M2, Fast acting earthing switch class E1 as minimum. Maintenance earthing switch class E0. See also technical data sheets B10.

Each diameter will be arranged with, but not be limited to the following equipments (three-phase sets):

Diameter 1 (Bays 1-A, 1-B and 1-C) for Interconnection transformer and for generator transformer connection:

- Three (3) sets of circuit breakers (1- and 3-pole reclosing cycle)
- Eight (8) sets of disconnectors
- Eight (8) sets of maintenance earthing switches
- Two (2) sets of high speed earthing switches
- Seven (7) sets of current transformers
- Two (2) sets of gas insulated lines (GIL)
- Two (2) sets of SF_6 air bushings.

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Diameter 2 (Bays 2-A, 2-B and 2-C) for Interconnection transformer and for bus reactor connection:

- Three (3) sets of circuit breakers (1- and 3-pole reclosing cycle)
- Eight (8) sets of disconnectors
- Eight (8) sets of maintenance earthing switches
- Two(2) sets of high speed earthing switches
- Six (6) sets of current transformers
- Two (2) sets of gas insulated lines (GIL)
- Two (2) sets of SF_6 air bushings.

Diameter 3 (Bays 3-A, 3-B and 3-C) for OHL Dhaka including line reactor feeder and for generator transformer connection:

- Four (4) sets of circuit breakers (1- and 3-pole reclosing cycle)
- Ten (10) sets of disconnectors
- Ten (10) sets of maintenance earthing switches
- Three (3) sets of high speed earthing switches
- Eight (8) sets of current transformers
- Three (3) sets of gas insulated lines (GIL)
- Three (3) sets of SF_6 air bushings.

Diameter 4 (Bays 4-A, 4-B and 4-C) for OHL Dhaka including line reactor feeder and for generator transformer connection:

- Three (3) sets of circuit breakers (1- and 3-pole reclosing cycle)
- Eight (8) sets of disconnectors
- Nine (9) sets of maintenance earthing switches
- Two (2) sets of high speed earthing switches
- Five (5) sets of current transformers
- Two (2) sets of gas insulated lines (GIL)
- Two (2) sets of SF_6 air bushings.

Note: For the "future generator transformer feeder" only the isolators/earthing switches as indicated in the SLD shall be provided. However the extension shall be possible without disconnection of any other feeder.

Bus bar equipment:

- Two (2) sets of disconnectors
- Two (2) sets of inductive voltage transformers
- Two (2) sets of maintenance earthing switches
- Two (2) sets of high speed earthing switches
- Two (2) sets of lightning arresters.

Local control cubicles

- Local bay control cubicles shall have conventional hardwired control mimic as backup including supervision, apart from bay control units for each bay and bus bar equipments.
  GIL = Gas Insulated Line to be understood also as GIB = Gas Insulated Bus Duct.

Note: Line reactor circuit breakers have to be provided with PIR.

B10.4.5 400 kV ~~and~~ 230 kV gas insulated switchgear

B10.4.5.1 General

The design and performance of the switchgear shall comply with this Specification and the latest revision of the relevant International Electro technical Commission (IEC) Standards.

The principle single line diagrams are given in Annexes as well a layout of the switchgear units in Annexes.
Key electrical data are indicated in the Technical Data Sheets.

The design of the SF6 gas insulated metal enclosed switchgear shall comply with IEC Publications 62271-1, 62271-100, 62271-102 and 62271-203.

The switchgear shall be single-phase encapsulated and itsha l be designed in such a manner so as to avoid any effects of VFTO (very fast transient overvoltages)

The switchgears shall be supplied complete with all auxiliary equipment necessary for safe operation, routine and periodic maintenance and repairs, as well as for the storage of used SF6 gas prepared for refurbishment.

The switchgears to be supplied shall have rated impulse and power frequency withstand voltages equal to or greater than the specified levels, at the minimum operating SF6 gas density or pressure.

The actual guaranteed withstand voltages, applicable to the maximum filling pressure at 20°C minimum and nominal SF6 gas pressures, shall be given in schedules.

The minimum clearances between phases and from phase to earth at the minimum working density shall be consistent with the specified impulse withstand level. In the event of leakage from any compartment, the equipment shall withstand rated voltage with SF6 at atmospheric pressure.

For performance assessment, the continuous power frequency withstand voltage with the SF6 gas at atmospheric pressure shall be stated in the schedules.

The insulation levels shall be able to withstand basic test voltages in accordance with the relevant standards for synchronizing operation for breakers.

Dielectric strength curves of GIS shall be submitted (insulation level in relation to gas pressure)

The switchgear shall operate satisfactorily and safely under all normal and fault conditions. Arc faults shall be positively confined to the originating

compartment and shall not spread to other parts of the switchgear. Routine replenishment of insulating gas shall not be required in intervals of less than ten (10) years.

The thermal rating of all current carrying parts shall be of 50 kA for 400 kV GIS and 50 kA for 230 kV GIS, for a minimum of 1 second for the rated symmetrical short-circuit current. Bracing of all mechanical components shall withstand the effects of short-circuit currents as indicated, 2.5 times the rated symmetrical short-circuit current.

Bus bar connections and enclosures shall be designed to absorb the effects of thermal expansion without application of stress to the supporting structure.

The layout and arrangement of the switchgears shall be made as shown on the drawings and shall fit in the available space. However, the layout may be adjusted as necessary to suit the manufacturer's standard design, subject to the provisions of this specification and the approval of the Employer.

Equipment foundation requirement details, complete with floor and structure fixings and consistent with the switchgear design shall be provided at an early stage in order to be incorporated into the civil works design.

The arrangement of the individual switchgear bays shall comply with the Single Line Diagrams and shall be such so as to achieve optimum space-serving, next and logical arrangement, and adequate accessibility to all external components. Optimized routing of cable ducts to 230 kV connections shall be taken into account. Space for the later extensions using cable or GIL connections shall be foreseen. The arrangement of the equipment offered must provide adequate access for operation, testing and maintenance.

For routine inspections and maintenance, all elements shall be accessible without removing support structures. The removal of individual enclosure parts, or entire breaker bays, shall be possible without affecting the adjacent compartments and bays, respectively, obtaining their continuous operation.

The design of the switchgear bays shall minimize assembly work during installation.

The manufacturer shall design an air conditioning system for the switchgear systems, if necessary, and submit calculations showing all heat losses of conductors and enclosures to prove the adequate dimensioning considering the most unfavorable operational and ambient conditions.

Control facilities shall be simple and clearly designated with the respective function and instructions on operation and maintenance shall be unambiguous.
The following provisions shall be made for control and indications:

- Local Control cubicle placed next to equipment control of circuit breakers, disconnectors and earthing switches complete with electromechanical indications. mimic diagram, gauges or density monitors and alarm annunciator
- PD sensors incorporated in the GIS enabling UHF partial discharge control during site testing, routine and maintenance testing PD sensors shall be provided of Offline measurement (not for Online measurement). Bidder/Contractor is responsible for the design af the GIS including the PD sensors.
- remote panel in the control room on the site control of circuit breakers, disconnectors and line side earthing switches with position indication in each instance
- supervisory control from the system control centre provision of control of circuit breakers, disconnector, earthing switches and high speed earthing switches
- all necessary local/remote and remote/supervisory control switches, relays, interposing relays and selector switches are to be provided as part of this Contract
- all main and operating parts of the switchgear shall be suitably labeled; this shall include but not necessarily be limited to primary switches, auxiliary switches, gauges and valves
- circuit identifying labels shall be fitted at the front and rear of each individual circuit assembly and on the local control cubicle.

Busbars

Unit (busbars) design will be single-phase enclosed design. The disconnector-earthing switch (three-positioned design) or the disconnector can be situated in the bus bar compartment, having proved ability to withstand heating due to bus bar rated current flow.

Each bay shall have at both ends the barrier spacers for disabling the internal arc propagation over the bus bar. The facilities shall be obtained to enable the evacuation and filling of the maximal bus bar zone in the frame of 8 hours.

The expansion joints will be positioned at every other bay to enable assembling and disassembling work, as well as to cover the thermal dilatation of the bus bars and prevent the stresses on the supporting structure.

End of bus bar will be equipped with barrier spacer, I element and end cover to enable the assembling of the future bay without SF6 gas evacuation under the atmospheric pressure at the neighboring gas compartment.

Bay wise gas segregation is specified so that internal arc propagation over the whole bus bar is not possible. Gas compartment drawing shall be provided with the tender.

B10.4.5.2 Safety requirements

The switchgears must offer a maximum degree of safety for the operators and bystanders under all normal operating and fault conditions.

It must be impossible to perform operations which may lead to arcing faults.

The primary design goal shall be to avoid any known reasons for internal arcing. Should it occur, nevertheless, the release of pressurized gas into the atmosphere must occur in such a controlled way that personnel standing at the operating position of the switchgear will not be hurt directly by the gas stream or any part of the release device.

Furthermore, no part of the enclosure, or any loose parts, may be blown away in such an event, and no holes may burn through the enclosure as per IEC 62271-203 paragraph 5.102.2, Table 104. The requirements considering the specified 50 kA are the following:

- 200 ms no external effects are allowed, except the activation of pressure relief device
- 500 ms without fragmentation (burn through is allowed).

The material and thickness of the enclosures shall be such as to withstand an internal flash over without burn through for a period of 300 ms till the backup relay protection clears the fault. The material shall be such that it has no effect of environment as well as from the by-products of SF6 breakdown under arcing condition. Evidence based on IEC 62271-203 Annex B and D shall be provided during basic/detail engineering

High speed earthing switches must be able to make full rated fault current minimum 2 times without exchange of contact system.
Maintenance earthing switches must be able to withstand full rated short circuit current for 3 s.

Maintenance earthing switches must be able to withstand full rated short circuit current for 1 second.

Storage springs of breakers and grounding switch actuators must be totally enclosed under normal operating conditions of the switchgear. No moving parts of the switchgear may pose any danger to the operator when standing at his normal operating position.

High speed spring operated earth switches shall be discharged in open/close position, they shall be charged when the command to open or close is given.

All interlocking devices that prevent potentially dangerous and – thus - not allowed operations must be constructed such that they cannot be defeated easily. The actual position of isolators and grounding switches must be positively displayed by mechanical indicators visible from the operating position.

In design of pressurized equipments safe working conditions shall be considered. Further extension shall be possible without interruption of existing parts in future

B10.4.5.3 Type of switchgear

The 400 kV and 230 kV switchgears shall be of the compact SF6 gas insulated metal-enclosed type suitable for accommodation indoors and gas insulated lines (GIL) shall be suitable for outdoors capable of continuous operation under the climatic conditions existing at the site integrating all necessary components for switching, isolating and monitoring as a compact unit.

The arrangement of the switchgear shall be such that particular emphasis is put on the provision of adequate clearance between chambers in order to facilitate maintenance and later extensions.

The spacing of the feeders shall be provided to allow easy installation of the conductors and convenient access to the cable terminations. Intermediate bus sections shall be installed if the standard feeder spacing does not cope with this requirement.
The Tenderers need to submit cable arrangement drawings with their Tenders.

The design shall include all facilities necessary to enable the performance of the specified site checks and tests. The Contractor shall state the test facilities provided and indicate any attachments or special equipment provided for this purpose.

Circuit breakers, isolators, earthing switches, VTs, CTs, cable termination chambers, all and any other chambers and components must be capable of withstanding a gas overpressure of 130% of normal operating pressure continuously.

The welded enclosures have to withstand routine test pressure of 1.3 x design pressure and casted enclosures have to withstand 2 x design pressure. The gas barriers shall withstand maximum possible pressure on one side and full vacuum on the other side. The gas barriers have to withstand routine testing pressure of 2 x design pressure.

B10.4.5.4 Position indicators

Position indicators shall be provided for all circuit breakers, disconnectors and earthing switches to show whether the main contacts of these switches are in the fully open or closed positions.

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Each pole of the breakers, disconnectors or earthing switches shall have a mechanical position indicator. The device shall be labeled "ON" and "OFF" and shall be clearly visible.

If a disconnector or earthing switch is not in the fully open or closed position, a "Control Circuit Faulty" alarm shall be initiated, and electrical operation shall be blocked.

Indicators shall be of a reliable mechanical design and shall be positively driven in both directions by the final drive stage of the contact operating mechanism. Reference marks shall be punched or engraved on the main frame for this purpose. Each indicator shall be clearly visible to operating staff at operating control points and access routes provided under this Contract.

B10.4.5.5 400 kV and 230 kV circuit breakers

Operating duty and performance:
The requirements of IEC62271-100 in respect of type tests, service, operation and the making and breaking of fault currents shall be applied to the specified circuit breakers.

Circuit breakers shall be capable of making and breaking short circuit terminal faults in accordance with the requirements of IEC 62271-100 for the specified fault currents.

The temperature rise of current carrying parts shall be limited to the values stipulated above under rated current and the environmental conditions.

All current carrying components shall be capable of withstanding these conditions for a period of one (1) seconds.

In case the circuit breaker is blocked due to gas pressure below minimum permissible level this shall be considered in protection scheme. Circuit breakers for switching generators shall have the capability to break all generator fault currents without any delays taking into consideration also the DC components.

The circuit breaker design/selection is in Bidder's/Contractor's scope of works. In case pre-insertion resistors are required they shall be included in the scope of supply.

The current ratings for the circuit-breakers at ambient conditions shall be as outlined in the Technical Data Sheets.

Evidence shall be provided that enclosures subject to pressures in excess of normal atmospheric pressure during service operation have withstood approved pressure tests without leakage, permanent distortion or any temporary distortion such as might cause mal operation of the circuit

breakers. Each circuit breaker shall be equipped with an operation counter to record the number of operations.

Facilities for measurement of circuit breaker contact resistance and timing tests without removal of covers or SF6 gas filling shall be provided. **All details of the testing procedures shall be submitted with the Tender.** Means shall be provided to allow access for the inspection and maintenance of fixed and moving contacts and other enclosed components.

Circuit breakers shall use the SF6 gas conforming to IEC as the insulating medium, as well as for arc quenching.

Circuit breakers shall operate on the principle of self-generating gas pressure within the interrupter for arc extinction, e.g. puffer type or auto puffer type. A lockout feature shall be incorporated to prevent operation of the circuit breaker whenever the gas pressure falls to a value below which it would be incapable of performing in accordance with its rated duty.

Gas density switches shall be provided for each phase of the CB, an alarm shall be incorporated to give indication of falling gas pressure prior to the lockout of the circuit breaker.

Suitable facilities shall be included for gas sampling and for draining and replenishing the gas volume for maintenance. Absorption of moisture and the decomposition products of arcing or discharge in the gas shall be achieved by proper equipment.

Circuit breakers shall be complete with spring or hydraulic-operated mechanisms. Where circuit breakers require other services, these shall be included in the supply and erection of the common services installation at the GIS switchgear and shall include alternative back-up facilities.

Emphasis is placed on reliability of design in order to give long continuous service with low maintenance costs.

Tender submissions shall include evidence of circuit breakers mechanism reliability on operation.

Offers of circuit breakers shall include proof (by means of reference lists and end-user certificates) that the type and rating of circuit breakers put forward, a satisfactory period of commercial operational experience of not less than two (2) years in climatic conditions similar to the ones has been obtained. Failure to provide this proof may result in rejection of the Tender

Test certificates:
Circuit breakers and all other metal-enclosed switchgear modules like bus ducts, disconnectors etc. shall be covered by test certificates and complete test reports issued by an accredited internationally recognized independent short circuit testing laboratory to certify the satisfactory operation of the circuit breakers at duties corresponding to the rated making and breaking capacities of the circuit breakers. The test duty shall not be less onerous than the requirements of IEC 62271-100 or equivalent. Test certificates shall be submitted with the Tender.

Rate of rise of restriking voltage:
Attention is drawn to the transient recovery voltage (TRV) requirements of the BS and IEC Standards. Where not specifically stated in the test certificates submitted with the Bid, the Bidder shall certify that the TRV to which the circuit breaker was subjected during the short circuit tests was the most severe condition that could be imposed by the available test plant for first pole-to-clear factor of 1.5.

Drawings and data with respect to C.B. operation shall be submitted as per requirement of IEC standards.

Interrupting duties:
Apart from the requirements for interrupting terminal faults, all circuit breakers shall be capable of coping with the interrupting duties produced by the switching of low inductive currents associated with reactors and transformer magnetizing currents, and by the switching of capacitive currents associated with overhead line, cables and capacitor banks as may be applicable according to IEC 62271-100. Circuit breakers for these duties shall be of the restrike-free type only.

All circuit breakers shall also be capable of interrupting currents associated with short-line faults and the out-of-phase switching conditions that may occur in service.

Fault clearance time:
The overall fault clearance time including relay operating time shall be in accordance with the requirements specified.

Operating mechanism:
The circuit breaker operating mechanism shall be power operated and of the type specified. Operation will normally be from a remote or supervisory position but facilities shall be provided for operation locally by electrical release and by direct manual release from stored energy devices when the circuit breaker is isolated for maintenance. It shall be possible to padlock each local control function in the open position. Operation counters shall be fitted to all circuit breaker mechanisms.

Operating mechanisms to be provided shall be for single- and three-phase operation.

The circuit breakers shall be provided with the facility for mechanical and electrical timing of the contacts. Pole discrepancies shall be less than 5 ms on closing.

The ability of circuit breakers to perform a rapid open-close-open cycle should be demonstrated. **For this purpose, Tenderer should provide along with the submission of Tender documents, test records with oscillograms for opening (tripping) and closing characteristics.**

Anti-pumping relays shall be provided to prevent reclosing if the closing coil remains energized and the circuit breaker fails to latch in the closed position or is tripped during closing.

CB fail protection (CB FP) shall be included in the CB control system with function of CB closing inhibit.

Power closing mechanisms shall be recharged automatically for further operations as soon as the circuit breaker has completed the closing operation and the design of the closing mechanisms shall be such that the circuit breaker cannot be operated inadvertently due to external shock forces resulting from short circuits, circuit breaker operation, or any other cause. Operating mechanisms shall be capable of storing energy for at least one opening and one close-opening operation (O-CO), local to the equipment and without recharging.

Means shall be provided for the local manual "non-electrical" tripping of the circuit breaker, preferably by a shrouded push button and facilities shall be provided for locking off these means of tripping. It shall not be possible to lock mechanically the trip mechanism so as to render the electrical tripping inoperative.

Facilities shall be provided to permit manual slow closing and slow opening of the circuit breaker for maintenance purposes. It shall not be possible to "slow down" or "slow open" a circuit breaker when connected in the normal service condition.

Circuit breakers fitted with DC motor for charging spring-operated closing mechanism shall also meet the following requirements.

When fully charged, the spring mechanism shall have sufficient stored energy to permit the operating sequence O-C-O to be performed following the loss of supply to the charging motor.

The mechanism shall be charged automatically, for further operations, as soon as the circuit breaker has completed a closing operation. The time required to charge the spring shall not exceed 20 s.

The spring shall be fully charged before it can be released to close the circuit breaker. It shall not be possible for the breaker to close whilst the spring is being charged.

Spring closing mechanisms shall be designed in a way that it shall not possible for a fully charged spring to be released inadvertently due to external shock or vibration caused by the breaker opening under short circuit conditions or any other cause.

The mechanisms shall be provided with means for manually charging the spring. This operation may be carried out with the doors of the cubicle opened. During this process no electrical or mechanical operation of the mechanism shall endanger the operator or damage the equipment.

A mechanical indicating device shall be provided to indicate the state of the spring. The indication shall be visible with the doors of the mechanism cabinet closed. An auxiliary switch shall give the remote indication of "spring discharged".

An indicating device shall be provided at the local control panel and the main control room and also over the supervisory system to indicate a spring failing to be charged by a preset time after circuit breaker closing.
Means shall be provided for discharging the spring when the circuit breaker is in the open position without the circuit breaker attempting to close.

B10.4.5.6 400 kV and 230 kV circuit disconnectors and earthing switches

Disconnectors and Earthing Switches shall be of the metal enclosed design and shall generally comply with the requirements of IEC 62217-102 and 62271-203.

Isolating and earthing switches shall be arranged to permit safe maintenance of any section of the equipment when the remainder is alive. Disconnectors shall be arranged for operation while the equipment is alive, but will not be required to break current other than the charging currents of an open circuit breaker line.

Disconnectors shall be housed in compartments partitioned from the circuit breakers.

It shall be possible with such partitioning and with the disconnector compartments maintained at full gas pressure, to carry out high voltage insulation withstand tests on outgoing circuits, without taking adjacent equipment out of service.

Disconnector and earthing switch operating mechanisms shall comply with IEC 62217-102 and shall be of robust construction, carefully fitted to ensure free action and shall be unaffected by the climatic conditions at site. Mechanisms shall be as simple as possible and comprise a minimum of bearing and wearing parts.

They shall be so designed that the disconnector/ earthing switches cannot be opened by forces due to currents passing through them and shall be self-locking in both, the "open" and "closed" positions. The mechanism shall open and close all three phases simultaneously.

Power operated drives shall be provided suitable for local, remote and supervisory control (supervisory control of earthing switches is not required) and shall be fitted with a removable, manual emergency switch. The mechanisms shall be capable of being locked and secured by padlock in the open or closed position with the motor automatically disengaged.

For supervision purposes the local control panel shall be equipped with position indicators. Nevertheless, local mechanical position indicators shall be provided for all disconnectors and earthing switches and shall be visible from ground level.

The mechanisms shall be electrically operated with provision for local manual operation, if possible. The contacts of these earthing switches shall have twice the same fault making capability as that of the circuit breaker. After two (2) times closing on fault the contacts have to be replaced. The operating mechanism of disconnector and the maintenance earthing switches shall be motor driven.

Slow speed maintenance earthing switches shall be operated from the local position only.

Critical gas pressure drop in the disconnector/earthing switch compartment should block the closing and opening functions.

In the event of driving motor failure, means for hand operation shall be provided which are operable from ground level or walkways provided.

In case, power supply fails in the middle of operation, the driven motor shall not restart upon resumption of power and the disconnector/earthing switch shall be operated, manually only.

All earthing switches shall be assembled so that they may be used to facilitate such tests as CT primary injection, contact timing and voltage drop measurement without the necessity to open gas filled compartments and with a minimum use of tools and special fittings. Detailed means of performing these tests shall be provided.

The earthing cable of these earthing switches shall be fed through a bushing insulated to at least 2 kV DC and connected to earth through a removable earth strap.

Each disconnector/earthing switch shall have its own separate power and control supply.

Disconnectors:

The nominal current ratings of disconnectors shall be correlated to the adjacent circuit breaker ratings (please refer to the Technical Data Sheets).

The disconnectors shall have a short-time withstand current as specified in the Technical Data Sheets). Disconnectors shall be arranged to permit safe maintenance of any section of the equipment when the remainder is live. Disconnectors shall be provided with motor driven mechanisms, operated from a low voltage DC supply and shall open and close all three phases simultaneously. It shall not be possible for the disconnectors to open or close inadvertently due to forces which may occur under operational or under short-circuit conditions.

All disconnectors shall be fully interlocked with associated circuit breakers, to ensure safe operation of the equipment under all service conditions. For maintenance purposes, the earthing switches shall be closed and remain locked in this position until the maintenance will be finished. Mechanical and electrical interlocking is required for maintenance and operation.

The insulation level for the isolating distance between disconnector contacts shall be higher than that for the remainder of the equipment as per IEC 62271-203. Disconnectors shall be capable of switching bus charging currents when shunted by a parallel path and capacitance charging currents associated with open bus bar, bushings and capacitor voltage transformers as per IEC 62271-102.

The Contractor shall submit the type test certificate and report to confirm that the disconnectors are able to carry out a load transfer at full load from one bus bar to the other without any reduction or interruption of load.

If the disconnectors are expected to generate fast rising transients during interruption of capacitive currents, adequate protection shall be provided for transient voltage control.

Maintenance earthing switches:
Earthing switches integrally mounted with disconnectors or separately mounted shall be provided for earthing in order to enable safe maintenance. Motor operated mechanisms shall be provided and operated by low voltage DC but it shall be possible to operate the switch manually in emergency conditions.

The earthing switch shall have a short-time withstand current, as specified in the Technical Data Sheets. No burning or welding of contacts shall occur.

Provisions for testing purposes shall be incorporated in the design of the earthing switch to facilitate primary current injection tests and other low voltage checks. Fully insulated designs of earthing shall incorporate removable earth links, suitable for the short-time current rating specified. It shall be possible to apply maintenance earths on either side of the test zone for safety reasons.

All earthing switchgear shall be interlocked with associated circuit breakers and disconnectors so that it shall not be possible to close an earthing switch onto a live circuit or to make the circuit alive when the earthing switch is closed.

Facilities for padlocking earthing switches in the open and closed positions shall be provided together with means for isolating the motor drives.

High speed earthing switches:
High speed earthing switches shall comply with the requirements of IEC 62271-104 and IEC 62271-203.

These earthing switches shall be capable of making short circuit current and suitable for high speed power operation. It shall be impossible to slow-close these earthing switches.

High speed earthing switches shall be fully type tested and shall be capable of withstanding the rated peak withstand current and sustaining the rated short-circuit current of the switchgear. They shall be located at all line feeder terminal points and bus bars or other location where there is no certainty that the point to be earthed is not energized. Power mechanisms operated by LV DC shall be self locking in both open and closed positions. High speed earthing switches shall be capable of making and breaking small induced inductive and capacitive currents, as may be necessary to operate the earthing switches for earthing of one out of two or more long parallel lines.

Facilities integral with the earthing switch for primary current injection or low voltage checks shall be insulated from earth and incorporate a disconnectable earth strap.

These earthing switches shall otherwise be in accordance with the requirements for maintenance of earthing switches.

B10.4.5.7 400 kV and 230 kV current transformers

The current transformers to be supplied suitable for the duty specified and comply with the requirements of IEC 61869 and IEC 61869-2 as appropriate.

Current transformers shall be of the toroidal core type, compatible with the switchgear.

Current transformers shall comply with the requirements of the common sections of this Specification. Where separate terminal boxes are used for current transformer's secondary wiring, the identifying labels shall be fitted to the terminal boxes in a conspicuous position but not on removable covers.

Current transformers including primary conductors shall have a short time current rating and duration not less than that of the associated switchgear. All current transformers shall have sufficient overload capacity to permit continuous operation with currents up to 150% of the rated current of the associated equipment.
Secondary windings of each current transformer shall be earthed through a disconnectable link at one point only, in the relay panel for protection circuits and in the control panel for instrumentation.

Current transformers for tariff metering shall not be used for any other purpose. Current transformers for statistical metering may also be used for other instruments except for protection.

Where double ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformer, indicating clearly the connection required for either ratio. These connections and the ratio in use shall be shown on the appropriate schematic and connection diagrams.

CT design calculations shall be submitted to the Employer/Employer's Representative for approval.

Where multi-ratio current transformers are specified and current transformers with multiple windings are bided, it shall be possible to select either ratio for each winding without alteration to the number of primary turns. All connections from secondary windings shall be led out and taken by means of separate insulated leads to a terminal board mounted in the local control cubicle.

The characteristics of current transformers used for protection circuits shall be fully compatible with the protection relays and shall include the following requirements:

- For overcurrent protection, they shall not saturate, change ratio or produce harmonic voltages in the secondary winding, which will affect the accuracy of the relay with primary currents up to 20 times rate full load current or maximum through fault current, whichever is higher.
- For earth fault protection and balanced forms of protection, when connected as in service, they shall not produce spill currents in excess of half the minimum operating current of the relay but provide stable equipment with primary currents up to 20 times rated full load or maximum through fault current whichever is higher.
- Provision shall be made to carry primary injection test of bushing CTs for 100% rating. The partial discharge level permissible shall be less than 10 pC at measuring voltage of 1.2 Um/√3.

The terminal board for CT connection shall have shorting, testing and disconnecting facilities which shall allow tests to be conducted with the circuit on load and which may be operated without disturbing the wiring.

It shall be possible to carry out primary injection testing of CT's with 100% rating when the switchgear is fully assembled or re-testing of the CTs during the service life of the switchgear without interruption of supply to adjacent circuits or any part of bus bar. The access for primary injection facilities for site testing shall be clearly stated by the Bidder/Contractor. Unless otherwise approved, current transformers shall be accommodated separately from to the circuit breaker. Where it is required to accommodate free issue current transformers, the Contractor shall advise the limitations as to types and sizes of current transformers which can be accommodated and material limitations for the transformer to be compatible for use in SF6 gas.

The secondary windings of each set of current transformers shall be capable of being open circuited as per IEC standards with maximum voltage of 4.5 kV peak. The secondary wiring of all CTs shall be brought up to a common terminal block located within the local control cubicle.

The magnetization characteristic of all current transformers shall be checked up to 100% current rating to identify the current transformers with reference to the manufacturer's design curve. Special measures may have to be taken to ensure that the core is fully demagnetized before commencing the test.

CTs for protection shall not be used for metering. CTs for protection and metering shall be physically separate.

The rated short time thermal current on all taps shall not be less than the through fault capacity of the associated circuit breakers.

The characteristics of current transformers shall be submitted to the Employer/Employer's Representative for approval, together with details of the protection, instrumentation or measuring equipment with which each current transformer is to be used. Each current transformer shall be capable of providing the necessary output to operate the related devices satisfactorily at the burdens involved.

All technical parameters are specified in the Technical Data Sheets.

However Bidder/Contractor is free to decide any parameter (which is not in data sheet) to be decided according to prescribed standard.

Current transformers having accuracy classes between 0.1 and 2 may be provided with extended current rating in accordance with IEC 61869-2, up to an equivalent primary current rating not exceeding that of the associated switchgear circuit current rating.

The magnetic characteristics of the CTs of the circuit of each group shall be appropriate for the optimum operation of the protection system.

The polarity of the primary and secondary windings of each transformer shall be clearly indicated at the respective terminals and in addition, labels

shall be fitted in a readily accessible position to indicate the ratio, class and duty of each transformer winding.

Current transformers shall be located as shown in the Single Line Diagrams.

B10.4.5.8 400 kV and 230 kV GIS voltage transformers

Primary connections shall have the same short time current rating as the associated switchgear.

Each secondary winding of the voltage transformers shall be protected by suitable approved fuses and links Voltage transformers shall be of dry type, compatible with the switchgear and shall not contain any hygroscopic insulating material which could affect the SF6 gas in either the voltage transformer or in the associated switchgear chamber.

Voltage transformers shall comply with the common sections of this Specification, with the requirements of IEC 61869, IEC 61869-3 for inductive VTs and IEC 61869-5 for capacitive VTs and shall be provided with three (3) secondary windings, as specified in the Technical Data Sheets.

- The rated secondary voltage per phase shall be $110/\sqrt{3}$ volts in the case of star connected windings and 110/3 in the case of delta connected windings, and the rated voltage factor shall be 1.2 continuously and 1.5 for 30 seconds and 8 hrs. for ungrounded DELTA connection 1.9

The ratio and phase angle error of the voltage transformers shall not exceed the permissible values specified in IEC standard.

VTs shall be rated for the highest equipment voltage per General Design Criteria.

Voltage transformers shall preferably be integrated with the compact switchgear system and they shall be compatible with the switchgears. Facilities for isolating the primary connections without having to lift the VT from the switchgear are required. Alternatively, performance VT withstanding high-voltage tests can be supplied.

It shall not be possible for voltage transformer's secondary windings to be connected directly in parallel, except through interposing voltage transformers associated with a synchronizing scheme. To prevent any possibility of back energizing a VT secondary winding via synchronizing circuits, circuit-breaker auxiliary contacts which are of the late make-early break type shall be employed.

Voltage transformers shall be capable of carrying continuously, without thermal damage, 150% of their rated output.

Voltage transformers shall be included in the protected zone afforded by the feeder protection or miniature circuit breakers which shall be located as close as possible to the voltage transformer, preferably within the terminal box. All secondary winding, connections, including both ends of the secondary winding shall be led out to the fuses and links. The fuses and links shall be connected to approved terminal blocks for termination of multi-core cables. A metallic label shall be provided and fixed at the voltage transformer clearly indicating the connections required for each winding. A minimum of 2 main secondary fuses per phase shall be provided to allow the implementation of fuse failure supervision with pre-closing alarm when specified in the scope of work. Protection, synchronizing and instrumentation circuits etc. shall be distributed between the two main secondary circuits and then sub-fused at the local control panel in accordance with the appropriate circuit schematic diagram.

Separate sets of fuse and links or MCBs shall be provided at the VT for:

- each protection scheme
- instruments, disturbance recorder, fault locator etc.
- synchronizing.

VT supply supervision circuit shall be provided.

The circuits for each main protection scheme shall be segregated in separate multi-core cables from the VT to the protection panels. An alarm (VT failure) shall be provided for each set of fuses and MCBs.

The neutral point of each voltage transformer's secondary circuit shall be earthed at one point only at the local control panel via a separate removable link of approved design. The earth link shall be situated in an accessible position and shall be suitably labeled.

A magnetization and no-load losses curve shall be provided for each voltage transformer up to 110% of rated voltage level for approval by the Employer/Employer's Representative.

The location of the voltage transformers to be installed on the primary switchgear shall be approved by the Employer/Employer's Representative.

Mechanical shock recorders shall be fitted to VTs prior to dispatch from the factory, to indicate how the VT was handled during transit and to determine if detailed inspection is required at site.

Electromagnetic voltage transformers shall be capable of discharging the capacitance of line, cables and switchgears, which may remain connected to them during switching operations. The Bidder shall declare any limitations of the equipment for this duty.

The Contractor shall ensure that no disruptive overvoltages will be generated due to ferro-resonance phenomena and if necessary, by suitably

connecting resistors across the secondary's of VT after approval of the Employer/Employer's Representative.

B10.4.5.9 SF_6 Lightning arresters

For the 400 kV and 230 kV GIS bus bars, SF_6 lightning arresters are foreseen for tendering purposes. Based on insulation coordination study which belongs to the scope of works, the lightning arresters needed in the bus bars shall be indicated and they will be accordingly selected and designed so as to protect the associated equipment. For required Technical Data please refer to the Technical Data Sheets.

The design data shall be proven by calculations and shall be subject to the Employer's approval.

Lightning arresters shall be of the metal-oxide type without gaps and shall be designed to fulfill requirements of IEC 60099.

A lightning arrester arrangement shall be proposed to suitably protect the switchgear.

The lightning arresters shall be designed as non-linear metal-oxide resistor type without spark gaps.
Each (single-phase) lightning arrester shall be equipped with a suitable lightning counter and an indicator for monitoring of the leakage current.

Lightning connectors shall be designed for continuous operation and shall be capable of passing repeatedly, without distress the maximum discharge current of the arrester. The lightning connector shall be connected to the main earth lead from the arresters. Bolted links shall be provided so that the lightning connector may be short circuited and removed without taking the arrester out of service.

Contractor shall give evidence about the suitability of the type and location of the employed arresters.

Beside the type tests documented by appropriate certificates attached to the Bid, routine tests shall be performed according to IEC 60099-4 and documented.

The following tests shall be performed as witness tests according to IEC 60099-4 under supervision of the Employer and / or his representative:

- Power Frequency Voltage Test on complete arrester
- Lightning Impulse Residual Voltage Test on complete arrester
- Internal Partial Discharge Test
- Thermal Stability Test.

B10.4.5.10 SF6-Equipment and handling

Gas compartments:
The switchgear units and bus bar systems shall be divided into several gas-filled compartments, sealed from each other by gas-tight partitions so that any leakage may be quickly localized. The various gas zones shall be further subdivided where necessary to restrict any internal arcing damage, particularly within sections of bus bars and to enable gas handling procedures to be completed with the minimum of delay. The partitions should confine any internal faults to a respective section of the switchgear. Enclosures shall be designed to minimize burn through in the event of internal arcing.

The number of gas compartments shall be such so as to limit the amount of switchgear which has to be isolated and taken out of service as a result of gas leakages, planned maintenance or internal faults.

Gas section volumes shall be as large as required to minimize the effects of any internal overpressure. They shall be consistent with the need to allow changes in the switching arrangements for maintenance, repair or extension whilst ensuring the remaining parts can remain energized.

The compact GIS bay shall at least consist of the following arc and gas-tight high-voltage compartments:

- busbar per each bay
- disconnector and earthing switch
- circuit breaker compartment
- feeder compartment
- potential transformer
- lightning arrester
- GIL at least each 30 meters.

Gas compartment drawings will be subjected to BIFPCL approval during basic/detail engineering.

Each gas compartment shall be provided with facilities for routine checking of moisture content and impurity level in the gas. Gas compartments shall be fitted with permanent connection points for filling, evacuating and gas treatment equipment without moving the switchgear.

Bus bar enclosures shall be segregated into gas-tight compartments of such volumes so as to ensure the minimum necessary time for the SF6 gas evacuation and its subsequent vacuum treatment and refilling

Total time for gas evacuation and filling of the largest chamber shall not exceed 8 hours.

The equipment and connections within each compartment shall be so arranged as to allow easy removal and replacement of any section with minimum isolation and disturbance of adjacent pressurized sections.

This feature should also permit the erection and testing of extension units alongside equipment already in service with the minimum of outage time being required for final connections. Outage time requirements shall be clearly indicated in the Tender.

All external gas pipe work shall be connected via vacuum couplings of proven design which will enable joints to be broken and remade without loss of gas.

Suitable arrangements shall be provided for the thermal expansion and contraction of the bus bars and bus bar chambers without detriment to the current carrying capacity or gas volume. Where special tools are involved in the setting up of these arrangements on site, the special tools and full instructions shall be delivered to the Employer by the Contractor.

Special attention shall be paid to the sealing of housing joints so that leakage of SF6 gas is kept less than 0.5% per annum in any single gas compartment.

All metal parts other than those forming part of any electrical circuit shall be connected to the earthing system to create one path for the short circuit current. Any necessary terminals on part of the equipment required for this purpose shall be provided by the Contractor.
The design of the GIS components shall be suitable to avoid the effect of trapped charges generated on the GIS equipment.

To prevent ingress of moisture or leakage of gas during the service life of the equipment, the sealing materials used at all joints and interfaces shall satisfy the following requirements:

- not affected by SF6 gas
- non-hygroscopic, containing no silicon
- non-aging and non-shrinking
- retain resilience for long periods under stress
- stable under all temperature conditions.

Seals including those at compartment partitions shall continue to function correctly throughout the temperature and pressure ranges in service and the pressure differentials, including vacuum and test pressures, during erection, maintenance and subsequent extensions. All gas barrier spacers shall be clearly indicated by color banding at each seal.

Expansion bellows, diaphragms and pressure relief devices shall be designed to be free of leakage under the same conditions as stated for seals.

Where the use of cast aluminum is envisaged, the manufacturer shall submit to the Employer/Employer's Representative evidence of tests carried out for porosity and extended pressure testing to show the quality of the castings used.
The guaranteed leakage rate of SF6 gas shall be less than 0.5% per annum for each compartment of the switchgear. Initial filling of the equipment must guarantee gas service periods of not less than 10 years. Suitable sensitive leakage tests shall be performed on each shipping unit prior to dispatch from the factory and on all junction points of components assembled at site prior to commissioning.

Pressure relief devices shall be provided for each section of switchgear as appropriate to allow excessive pressure relief. All pressure relief devices shall be located in such a way operation of the devices shall not endanger personnel working on the equipment or in the vicinity of the equipment. Where necessary, the devices shall be fitted with cowls to deflect any gases or fragmented parts away from locations where personnel may be expected to be present. Internal relief devices into adjacent compartments are not acceptable.

Each separate compartment or gas zone must be provided with its own device for monitoring continuously the gas density. This means all phases in case of single-phase design shall have their own gas supervision (no gas piping between the phases. These devices shall be arranged to give individual compartment indication in the local control units and initiation of remote alarms. Means shall also be provided to facilitate the regular maintenance checking of moisture content. Each gas filled chamber shall be fitted with static filters to absorb any moisture which may be present.
In addition, filters for removal of SF6 decomposition products shall be provided in those compartments in which arcing or corona discharge can take place.

The moisture content of the breaker compartment during service shall thereby be kept to a minimum so as to ensure satisfactory operation.

Each gas compartment must have its own independent gas supervision and alarm systems with contact density gauges for alarm and indication. Alarms shall be wired to and indicated in the local control cubicles.
Each compartment must provide the following functions by means of suitable fittings and valves:

- indication of the actual gas pressure by means of temperature-compensated indicators
- monitoring of pressure and alarming of pressure losses in two adjustable stages
- access for evacuating and filling via gas service cart

Especially for the circuit-breaker compartments, the following shall be foreseen:

- Indication and monitoring of pressure and alarming of pressure losses in two adjustable stages and additionally two contacts for blocking of the circuit breaker.

Gas barrier and supporting insulators:
All internal support insulators and gas barriers shall be of a high quality material design to minimize internal and surface electrical stresses. The materials shall be free of voids and partial discharges at the maximum working voltages.

The manufacturer shall submit the proof that all insulators have sufficient margin between Martens point of the insulating material and maximal operating temperature.

Gas barriers shall be gas-tight and of sufficient strength and factor of safety to withstand short circuit forces and the maximum pressure differential that can occur under internal fault conditions.

Gas seals:
All static and moving gas seals shall be designed to prevent gas leakages and moisture ingress under all normal conditions of service. The materials used for gas seals shall withstand exposure to SF6 gas and its decomposition products without deterioration for the service life of the equipment.

Measures shall be incorporated to eliminate any deterioration of gas sealing surface, finishes and fixings due to the influence of climatic conditions. Seals between different insulating media, sliding or rotating surfaces and those exposed to the risk of deterioration due to their use outdoors shall preferably include multiple seals or other means should be obtained, what is subject of Employer/Employer's Representative approval.

The equipment shall be designed to minimize gas leakage which shall not exceed 0.5% per annum by weight for each gas compartment.

Enclosures:
Manufacturers shall take account of the influence of climatic conditions for indoor installation.

Equipment supplied shall be capable of continuous operation at the specified ratings without exceeding the maximum temperature rises stated in the appropriate IEC recommendations. The switchgear room will be vented but not air-conditioned.

The enclosure for the SF6 gas insulated switchgear shall be of aluminum alloy and shall be designed to minimize losses and heating due to circulating currents.

Dimensioning of enclosure shall be such as to safely withstand overpressures caused by internal faults corresponding to maximum fault levels as per IEC 62271-203.

Pressure relief device shall be provided where necessary to prevent excessive pressure rise which could lead to bursting of enclosures and spacers. Circuit enclosures shall be of single phase. All connections and bus bar chambers shall be color-coded to indicate the phase color associated with the connection.

Evidence shall be provided to verify that enclosures have been designed and tested in accordance with established pressure vessel codes without encroaching on internationally agreed safety factors for this type of equipment. Each enclosure shall be tested and stamped by the inspecting authority issuing the test certificate that shall be independent from the manufacturer.

Ample provision shall be included for access to the circuit breaker, disconnector and earthing switch contacts for inspection and repair.

Voltages induced in the enclosures (touch voltage) shall not be allowed to exceed safe limits of 70 V. All enclosures containing discontinuity elements shall be earthed around the discontinuity via two (2) low inductive conductors from each side, having the capacity to withstand the same short circuit current as associated conductive parts inside the enclosures

Each enclosure shall be provided with lifting points to facilitate maintenance or repair works.

SF6 immersed insulation:
Bus bars and items of switchgears shall be supported in the enclosures by insulators of materials compatible with SF6 gas and the gas decomposition products.

Gas barrier insulators and bushings, including gas-oil and gas-air bushings (if any) shall comply with the specified conditions for sealing of enclosures. The Employer/Employer's Representative shall be advised of design pressures used and may require test evidence to substantiate performance under extremes of differential pressure and temperature.

The surfaces of insulation in contact with SF6 shall not be glazed or otherwise treated with silica compounds or other materials which may deteriorate in the presence of gas decomposition products due to arcing. Alternative glazing or surface treatment which is compatible with SF6 and its by-products may be acceptable what will be the subject to prove the durability.

The insulation shall be tested for partial discharge free operation at the maximum service voltage according to IEC 62271-203 and other relevant Standards for the equipment.

SF6 immersed insulation shall otherwise comply with the relevant clauses for insulators and bushings.

SF6 gas requirements:
All SF6 gas supplied for use in the switchgears shall comply with the detailed requirements of IEC 62271-303 which is the minimum standard acceptable.

The gas systems of the switchgears shall utilize low pressure to minimize leakages and eliminate any possibility of liquefaction at the lowest ambient temperatures.

The GIS equipment shall be designed in such a manner that no heating elements will be required for satisfactory operation within the range of ambient temperatures and pressure encountered under service conditions.

The minimum dew point temperature in unheated SF6 gas filled equipment shall not exceed -20°C at the working pressure.

Gas monitors:
Temperature compensated, digital type, gas density monitors shall be provided for each gas section and gas compartment. Facilities shall be provided to test these monitors without having to reduce the gas pressure.

The gas monitors shall be fitted with density monitors and / or manometers to indicate the gas density / pressure and electrical contacts which shall initiate an alarm to warn that the gas pressure/density is falling to a critical level. In the manometers necessary damping arrangement shall be provided. Manometer and contacts shall be in the same density monitor unit.

For circuit breaker compartments, a lockout feature shall be provided to prevent operation whenever SF6 gas pressure is less than that permitted by the design for satisfactory operation. Contacts shall be included to initiate alarms to warn of this condition.

Two sets of voltage-free electrical changeover contacts shall be provided for every alarm for remote SCADA and repeat alarm facilities in addition to alarm facias, incorporated in the local control panel/marshalling kiosk associated with each primary circuit.

SF6 gas handling:
SF6 is the gas with the highest molecular weight. It is an inert gas, colorless, tasteless and non poisonous. It is heavier than normal air so it will gather at the lowest point, will displace air and oxygen and can cause death by asphyxia. Once inhaled, it can be exhaled only by making a headstand. Locations in which SF6-handling takes place are strongly recommended to have facilities for efficient ventilation to prevent from accidents.

SF6 can absorb a high amount of energy and thus is the ideal insulating and arc quenching gas available. However, SF6 is not a natural gas but man-made. Once released to the atmosphere it takes 3,200 years for neutralization by means of high energy ultra-violet radiation. The impact to

the atmosphere caused by 1 kg of SF6 is as high as that of 22.8 tons of CO2 and thus it is a very efficacious greenhouse gas. Therefore, provisions have to be taken to minimize the release of SF6 to the atmosphere.

SF6 Pollution:
During switching operations, SF6 will be subject to decomposition due to the switching arc. It has to be assured by appropriate means that the gas will be held as pure as required for its employment as insulating / arc quenching medium. For this purpose, the content of decomposition products should be as low as possible during service life. Appropriate filters have to be employed where applicable or formation of these decomposition products should be reduced to a minimum. Bidder shall describe measures considered and shall give evidence of their suitability to the Employer / Employer's Representative.

SF6-Recycling:
Measures shall be taken at the GIS to facilitate complete removal of the SF6 for maintenance / repair / extension works. Respective tapping points for all gas compartments shall be easily accessible. The gas shall be stored in containers suitable to serve for the gas of the entire switchgear in its final extent plus 10% spare capacity.
Suitable filtering and handling devices shall be supplied to purge the gas from moisture, decomposition products and other impurities so that the gas can be re-used after completion of the maintenance / repair / extension works. The said equipment shall be handed over to the Employer upon completion of installation and commissioning works.

Temperature rise:
The temperature rise limits shall be in accordance with IEC 62271-203. The switchgear shall be capable of carrying the specified rated current at rated frequency continuously in accordance with normal service conditions as defined in IEC 62271-1.

Any derating to meet site ambient conditions shall be taken into account and declared in the schedules.

Every part of the switchgear shall also withstand, without mechanical or thermal damage the instantaneous peak currents and rated short-time currents pertaining to the rated breaking capacity of the circuit breaker. Rated duration of short circuit shall be taken as one (1) second.

The design of sliding type, current carrying connectors and joints shall be such that they meet the afore-mentioned conditions over the full permitted range of movement. Where such joints may be made or adjusted on site, full details of alignment procedure, together with any necessary alignment tools or gauges shall be described in the maintenance manual and included in the supply of special tools.

The maximum temperature of the external surface of enclosures accessible during normal operation shall not exceed 70°C.

Arrangement/testing facilities:
The switchgears shall be installed in buildings with cable basements suitable for accommodation of all HV and LV cables, both rooms being maintained at a slight positive pressure of filtered air such that any SF6 gas released in the building will be discharged externally via pipes from the lowest point.

The Contractor shall supply the necessary ladders and galleries for access to all levels of equipment during normal operation or maintenance.

The Contractor shall include in his supply power operated lifting appliances as appropriate to the size and weight of component parts of the switchgears which require to be lifted in the course of installation, maintenance or repair.

Testing flanges for connection of testing devices shall be provided where relevant on each circuit for HV withstand testing of switchgears. Each testing flange shall be positioned in a separate gas zone compartment which shall be independent of adjacent disconnector and earthing switch gas sections.

Suitable links shall be provided to allow disconnection of voltage transformers and cable heads without dismantling.

All test equipment and erection tools for the GIS shall be submitted before the end of the commissioning period.

Anti-condensation heaters:
Anti-condensation heaters of an approved type shall be provided inside each cubicle provided for all parts of the project. They shall be shrouded and located so as not to cause injury to personnel or damage to equipment. The heaters shall have individual thermostatic control and shall be arranged to cut off when the cubicle internal temperature exceeds between 30 to 35°C. A master heater circuit switch shall be provided on the switchboard or panel with an indicating lamp to show whether the supply is on or off. The location of the heater circuit switch and indicating lamp shall be in such a location that it does not require moving when extensions are provided. The heaters shall be operated from the specified AC supply.

Gas handling equipment:
A gas handling plant shall be provided at each installation to permit emergency topping up of gas in the switchgears in the event of leakage.

In addition, mobile gas handling units, the size of which shall allow full mobility within the switchgear rooms, shall be included for the complete sampling, testing, filtering, drying, extraction and refilling of SF6 gas.

These units shall be self-contained and comprise of a wheeled trolley housing all necessary compressors, gauges, piping and controls, etc., together with gas storage tanks with usable capacity compatible to the

design of the switchgear. The capacity of the tank shall be such that at least the content of the biggest three phase gas compartment can be stored. The storage may be gaseous or liquid. Filters shall be provided in order to clean gas taken out of the switchgear or tanks to eliminate impurities such as decomposition products or moisture. The units shall be capable of evacuating air from the switchgear compartments and replenishing them with gas at the end of a maintenance period. They shall also be capable of being used for all gas (SF6, nitrogen and air) operations necessary if replacement of a gas enclosure is undertaken. Facilities shall also allow for circulation of the gas from a compartment through filters in order to extract moisture present.

Additional mobile or static storage shall be provided for use in combination with the gas trolleys and to extend storage facilities.

All necessary pipe work, flexible hoses, couplings, valves, pressure and vacuum gauges shall be included to enable interconnection between the switchgear compartments, gas trolleys and storage tanks and the cylinders provided by major producers of SF6 gas.

An approved SF6 gas leakage detector, oxygen analyzer and moisture meter shall be provided.

To enable safe maintenance to be carried out on any portion of the switchgears when all electrical supplies to the local control units are switched off, a portable gas alarm unit shall be provided. The alarm unit shall be self-contained and capable of giving clear audible warning should the gas pressure in any adjoining gas-filled chamber become unsafe

Compact GIS manufacturer shall recommend adequate and user friendly recycling equipment for SF6 reuse, provide instruction and technical support.

SF6 gas that cannot be reused on site shall be transported to a specialized Company in appropriate containers with a label according to the contamination level.

The gas handling units shall be suitably sized so as to enable gas evacuation and filling of the largest chamber to be carried out in not more than 8 hours.

B10.4.5.11 Accessories

Accessories for proper operation of the switchgear shall be included in the base price.

Following accessories for maintenance and repairs shall be included in the scope of supply:

- complete gas service cart, including vacuum pump, compressor and gas pressure vessel for liquefying of SF6-gas, all fittings, connections gauges and hoses
- set of special tools
- breaker withdrawal and maintenance parts
- portable SF6 gas detecting equipment
- SF6 purity (indication of O_2 content, dew point, moisture content).

The Tenderer shall describe all accessories in detail to enable an evaluation of the proposal.

B10.4.5.12 Tests of 400 kV and 230 kV SF6-switchgear

B10.4.5.12.1 Inspection and testing

In addition to General Specification Part B0, which shall be applied in relation to the general test requirements, the following requirements shall also be applied:

- All relevant documents, test plans and drawings are to be submitted and approved by the Employer/Employer's Representative before any factory test is carried out.
- Tests shall be carried out in order to determine whether the material and apparatus comply with the specifications. All tests shall be arranged to represent the working conditions as closely as possible. All test results shall be subject to the approval of the Engineer.
- All tests of the equipment both at the Manufacturer's factory and after completion of erection at the site shall be made in accordance with IEC standards if not otherwise agreed by the Engineer. If the IEC standards are not available for the particular test, the scope, standards and methods applied shall be specified by the Contractor and shall be subject of approval by the Engineer.
- Any additional tests apart from those specified below, as may be needed to confirm guaranteed data or to ensure the completeness and safety of the equipment, shall be performed as requested by the Engineer.
- Appropriate standard instruments and other measuring equipment, necessary to carry out the tests, shall be provided by the Contractor.
- A written notice of the time and place of all shop tests shall be given to the Engineer at least four (4) weeks in advance, in order to enable the latter to be present if he so desires. Contractor's records of all tests shall be furnished to the Engineer immediately on conclusion of each test.
- Following the tests at site, the Contractor shall, at his own expense and within the terms of the Contract, rectify and defect and replace any defective part, as directed by or to the satisfaction of the Engineer.

B10.4.5.12.2 Type tests and special tests

Type test certificates will be accepted for the equipment used in the similar applications if the proposed equipment does not deviate in the relevant technical characteristics and if the types tests are made in a internationally recognized test laboratory and if the reports are not older than 5 years

B10.4.5.12.3 Routine tests

At least the following measurements and tests shall be carried out on the equipment:

- gas insulated switchgear 52 kV and above Test as per IEC 62271-203
- circuit breakers Tests as per IEC62771-100.
- isolating and earthing switches Tests as per IEC62771-102
- current transformers Tests as per IEC 60186, IEC 60186-2
- voltage transformers Tests as per IEC 60186, IEC 60186-3.
- lightning arresters Tests as per IEC 60099-4.

B10.4.5.12.4 Site tests and other/special tests

Field acceptance tests after installation of the complete switchgears shall be made according to IEC 62271-203 and shall be subject to agreement between manufacturer and Employer/Employer's Representative before purchase order award. The Tenderers shall state in their offers the type of tests to be conducted on site. The dielectric tests shall comprise at least a power frequency voltage withstand test and partial discharge test according to IEC 62271-203 Procedure A for 170 kV and below and Procedure B for 220 kV and above, where partial discharge test shall include UHF or acoustic method. Voltage transformers shall also be tested, erected and assembled to GIS.

Other tests
The following checks and test measurements shall be made during erection and commissioning in accordance with agreed standards, but not limited to:

- measurement of insulation values
- verification of earthing grid neutralization conditions (e.g. step and touch voltage) in accordance with VDE 101 / IEEE80
- phase rotation
- polarity checks in the case of DC voltages
- protection circuit tests which will be not limited to CT polarity and magnetization curves
- insulation resistance tests of relays, wiring and CTs
- primary injection of all Cuts to prove CT ratio and correct connection of 50, 51, 50 N, 51 N, 67, 67 N, 87 relays
- secondary injection tests for proof of timing tests on the relays and pick-up/drop off values of important auxiliary relays shall be tested
- stability tests and in-zone fault test for differential protection schemes

- operation of tripping elements at reduced DC voltage
- measurement of the end-to-end HF teleprotection channels transmission times
- combined logic tests of HF signaling /protection /autoreclosing schemes under various simulated fault and operating conditions
- fuses, overcurrent trips, short-circuit trips, time settings, relay settings
- safety signs and warning signs
- setting indicators
- checks on wiring and cabling for conformity with the constructional circuit-drawings and plans
- high voltage test on cables and switchgear
- functional test on equipment.

All defects detected as a result of routine or on site testing shall be repaired by the manufacturer and tests repeated at his own expense.

Acceptance of any equipment by Employer's representatives shall not relieve the manufacturer from any of his performance guarantees, or from any of his other obligations resulting from this Contract.

Where no tests are detailed for items of equipment, a full program of tests shall be agreed with the Employer/Employer's Representative. The Employer/Employer's Representative reserves the right to call for such extra tests as may be necessary to prove compliance with the specification.

B10.4.26.2 Indoor local control cubicle

Functions
Each circuit-breaker bay shall be provided with a local control cubicle containing local control switches and a mimic diagram for the operation and status indication of the circuit-breaker and all associated disconnectors and earth switches together with selector switches to prevent local and remote and supervisory controls being in operation simultaneously. Closing of the circuit-breaker from the local control unit shall only be available when the breaker is isolated for maintenance purposes. Local control cubicles shall be suitable for installation in a separate place - preferably in a separate building, if present - and not attached to the switchgears.

Alternatively the local control cubicles (LCC) for the GIS shall be placed inside the GIS halls, provided that these LCC's have to be operated during maintenance only (equipments out of service).

For technical data refer to the Technical Data Sheets.

Circuit-breaker control position selector, operating control switch and emergency trip push button shall be installed in the Local Control Cubicle. In case that local operation has been selected with the control position selector, remote manual operation is excluded and vice versa if remote operation (normal kind of operation) has been selected Circuit-breaker control from this position will be used under maintenance and emergency conditions only.

Local manual release facilities shall be provided for closing and tripping the circuit-breaker. The operation of both releases shall be subject to lockout if insufficient stored energy is available. Local manual releases shall be provided with locking off facilities.

Sufficient electrical terminals shall be provided for the termination and interconnection of all cabling associated with remote and supervisory control, alarms, indications, protection and local ring main supplies.

Where control cabling between the local control cubicle and the switchgear are connected by plug and socket boxes, the plugs and sockets shall not be interchangeable.

A Mimic Diagram with circuit identifying labels on a suitable plate shall be provided in the switchgear rooms.
The color of the mimic diagram shall be "light grey" as per RAL 7055.

Circuit devices/instruments identifying labels shall be fitted at the front and rear of each individual device and on the remote/local control cubicle. A Single Line Diagram shall be marked along each bay showing location of all items of the switchgear.

There shall be at least 20% spare capacity in terminal blocks.

Design

Operating mechanism, auxiliary switches and associated relays, control switches, control cable terminations, and other ancillary equipment shall be accommodated in sheet steel vermin proof cubicles. Local control cubicles shall be provided to be free standing with front access, and shall be equipped with anti condensation heaters. A suitable thermostat shall be included in the heater circuit. The electrical apparatus so protected shall be designed so that the maximum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation. Similarly the contractor has to provide adequate cooling of the control cubicles at very high temperatures in summer. Temperature within the cubicles shall stay ≤ 40°C if electronic modules are installed unless these can cope with high temperatures that have to be expected. For design temperatures reference is made to B0.2.4.

Cubicles shall be of rigid construction, the thickness of the steel sheets shall be minimum 2 mm, preferably folded but alternatively formed on a framework of standard rolled steel sections and shall include any supporting steelwork necessary for mounting on the circuit-breaker or on concrete foundations. Access to all compartments shall be provided by either removable panels or doors. All fastenings shall be integral with the panel or door and provisions made for locking. Doors and panels shall be fitted with weatherproof sealing material suitable for the climatic conditions specified. Cubicles shall be well ventilated through vermin-proof louvers.

Taking into account the aggressive environment conditions in Asht area, all new cubicles for SS Asht shall be made in tropical export version

An interior lamp suitable for the local LVAC supply, controlled by a door operating switch, shall be fitted at the top of each section.

The arrangement of equipment within cubicles shall be such that access for maintenance or removal of any item shall be possible with the minimum disturbance of associated apparatus.

All local electrical control selector switches, together with a mimic diagram of the bay complete with semaphore indicators to show the status of each primary device shall be mounted behind a metal framed glass panel, dust proof door in the front of the cubicle.

The single bay control selector switch shall determine either local electrical or remote control of all devices and prevent simultaneous operation from both points. Local electrical operation of devices shall be for maintenance purpose only.

The voltmeter, where required, associated voltage selector switch and a circuit-breaker electrical emergency trip button shall be mounted on the front of the cubicle and not behind the hinged door. Arrestors shall be provided for bus section and bus couples cubicles. The emergency trip

button must be conveniently placed. It shall operate both trip coils from electrically separate contacts for local indication and remote operation alarm. The button shall be colored red, either recessed or shrouded, protected by a discrete hinged cover and be clearly labeled. A facility shall be provided to enable a wire seal to be used on the cover.

Sufficient electrical terminals shall be provided for the termination and interconnection of all cabling associated with remote and supervisory control, alarms, indications, and protection and local ring main supplies.

All connections to the supervisory system shall be wired to a separate terminal block labeled accordingly. The connections to this block shall be cabled to the marshalling cabinets.

Where control cabling between the local control cubicle and the switchgear are connected by plug and socket boxes, the plug and sockets shall be discrete for each duty and shall not be interchangeable with other plugs and sockets within the substation.

Hydraulic/spring drives and SF6 operation equipment necessary for the correct functioning of the circuit-breaker, disconnectors and earth switches shall be located in a separate rack of the SF6 circuit breaker cubicle.

B10.4.26.3 Auxiliary switches and contactors

Auxiliary bi-stable switches for purposefully actuated operation in both directions shall be provided for all circuit-breakers, disconnectors and control, interlocking and repeat relays, if necessary observable for local and for remote operation. All necessary auxiliary switches, contactors and equipment for indication, protection, metering, control, interlocking, supervisory etc. shall be supplied together with every circuit-breaker, isolating and earthing device and they have to be installed in a. dust free housing. Not less than six (6) spare auxiliary contacts shall be installed for each circuit-breaker and not less than four (4) for all other devices. All of them shall be wired up to a terminal board in the local control cubicle of the switchgear. These spare contacts shall be arranged in the same sequence for all other switchgears.

Automatic switches shall be provided to interrupt the supply of current to the actuated tripping mechanism of the circuit-breaker after completion of its operation. All such switches and mechanisms shall be mounted in accessible positions clearly separated from the operating mechanism and shall be adequately protected. The contacts of all auxiliary switches shall be strong and shall have a positive wiping action when closing.

Direct acting auxiliary switch contacts shall be used in conjunction with busbar protection schemes.

Auxiliary contactors shall be provided only where the circuit requirement cannot be met by the auxiliary switch arrangements and multiple contactors

and relays will not be accepted in lieu of auxiliary switches except as specifically approved by the Employer/Employer's Representative. In case of control, protection and interlocking circuits, where it is necessary to use more than one relay (a repeat relay) for a certain action due to the limited number of auxiliary contacts for one relay their operation shall be carefully monitored particularly related to the operation of in parallel working relays and their contacts. It is stressed that such construction shall be an exceptional solution.

Bi-stable devices for approval of the Employer/Employer's Representative may be accepted, but only where it can be shown that extra contacts are not required on critical circuits and direct contacts are not available.

Related to current auxiliary switches shall be designed to prevent undue heating of this associated circuit. In addition to that a current of 2 A at 220V DC shall have a circuit time constant of not less than 20 ms in order to limit peak current after switching on the system.

B10.4.26.4 Interlocking

An interlocking scheme shall be provided on the lowest control level which takes into account the following basic requirements:

a) Safeguard maintenance personnel who may be working on one section of the equipment while other sections are live. This may be a mechanical detent in combination with a table "Danger! Electricians at work. Do not switch any switch or circuit breaker!" in the national language.
b) prevent incorrect switching sequences which could lead to a hazardous situation to plant, equipment and personnel.

Interlocking shall be done by electrical systems I for all operational interlocks, but preferably be of the mechanical/key type for maintenance safety interlocks, Interlocking for maintenance purposes shall be effective when the equipment is being controlled locally under emergency off condition or from a supervisory position.

All mechanical interlocks shall be applied nearby the point at which manual operation will be performed, so that stress cannot be transferred to parts remote from that point.

All electrical interlocks shall function in that way that power supply for normal operation will be interrupted. A system of interlocks shall be provided, which shall cover the manual emergency off operation of apparatus, which are normally power-operated. Failure of supply or connections to any electrical interlock shall not produce or permit faulty operation.
Electrical bolt interlocks shall be energized only when the control levers to operate the appropriate mechanism is set to its working position. Visible indication shall be provided to show whether the mechanism is locked or

free. Means, normally padlocked, shall be provided. So the bolt can be operated in the emergency case of a failure of interlock supplies.

As long as key interlocking is engaged tripping of the circuit-breaker shall be prevented as consequence of pulling the key from the lock. Any local emergency tripping device shall be kept separate and distinct from the key interlocking.

Interlocking of Circuit-breakers shall be designed, that a circuit-breaker cannot close, unless the associated busbar and circuit disconnectors are in closed position, except under controlled maintenance conditions with deenergized adjacent systems. In addition to that it shall not be possible to close a circuit breaker unless all trip relays of the concerned circuits are reset.

That means as well disconnectors stay interlocked and not operable unless the associated circuit-breaker is open.

In cases with double busbar arrangements on-load transfer of a feeder from one busbar to another with the associated circuit breaker shall be made possible by interlocking which ensures that the associated bus-coupler and its relevant disconnectors are closed.

The bus-coupler circuit breaker shall be interlocked in such manner that opening the bus-coupler circuit breaker shall not be possible while on-load changeover on the relevant side of the breaker is in progress.

Both busbar disconnector pairs of a circuit that are affected by the load switching shall not remain closed after completion of load transfer. Only the new circuit shall stay to be a closed loop. The other disconnector to the busbar shall be opened. An alarm shall provide a warning if both busbar disconnectors of a transferred circuit are left closed.

Earthing switches shall be interlocked in that way that they cannot be operated unless the associated disconnector is open.

All busbar isolators and earthing switches shall be interlocked with the associated circuit breakers (standard safety interlock).

For double busbar configurations where on-load change-over of feeders is foreseen, the closing of busbar isolators of individual feeders, if the related CB is closed, shall be prevented, unless the bus-coupler breaker and associated isolators are closed. Interloading scheme, subject to detailed design, will be approved by the Employer.

B10.4.26.5 Locking facilities

Locks and locking facilities shall be provided for all safety relevant parts of the switchgear as detailed below and shall be additional to the mechanical interlocking devices specified in the above clause.

If a mechanism is to be locked in a specific position, preferably the power supply of this mechanism shall be considered.

The following interlocking functions shall be provided:

- circuit-breaker mechanism in the open position and any associated manual operating device in the neutral position
- isolating switches in both positions open and closed position
- control position selector switches in all positions as specified
- operating cubicle access doors
- air or gas system isolating valves in inacceptable positions (open/closed)
- It shall not be possible to open the bus-coupler during the process of feeder transfer from one busbar to the other.

The following locking facilities shall be provided:

Synchronizing selector switch:	Cylinder lock such that switch can be operated by inserting and turning the key. Key removal in off-position only.
Protection on/ off switch:	Key removal in either position

Locks shall be designed, constructed and located on the equipment so that they will remain serviceable in the climatic conditions specified without operation or maintenance for continuous periods of up to two years and with suitable maintenance shall be fit for indefinite service.

B10.4.30 Representative earthing system, power and lighting installations

B10.4.30.1 Earthing and lightning protection

General
In addition to General Specification (B0) the following requirements shall be considered.

For outdoor installations, the Contractor shall install a meshed earthing system. The earthing system shall be calculated according to IEEE 80. For the construction of the earthing system approved standards, such as VDE 0141, will be applied. A uniform stranded conductor cross-section is to be used for the entire installation. For potential grading and to offer protection against excessive contact potentials, ring earths made of stranded copper cable shall be installed around the building and these shall be connected to the mesh earth conductors.

At maximum distances of 10 m, the ends of the stranded conductors of the mesh earth are to be taken into the inside of the buildings and connected to the internal earthing system.

The earthing and lightning protection system shall include but not be confined to:

- the necessary stranded copper ropes for the indoor earthing installations and mesh system
- the necessary bare copper strips for the earthing ring inside the building
- connection of PVC single core cables being laid out of the concrete to the earthing ring inside the buildings
- the necessary compression connectors or connections by Cadweld system (or similar) for the earthing conductor crossing point connections and junctions
- all connections to the housings of the electrical apparatus, steel frames, pipes, steel strips etc.
- all necessary disconnecting points for measuring purposes which must be readily accessible
- all the necessary lightning protection equipment for the protection of persons and structures such as lightning collectors, roof bushings, lightning rods, potential equalizing systems, spark gaps, lightning arresters etc.
- the required connecting and fixing material such as plugs, screws, angle pieces, expansion strips, conductor support, isolating terminals, earthing and rain gutter clamps, jumper outfits, earthing clamps etc.

Material
Whenever dissimilar materials are to be joined, the necessary transition plates are to be inserted as required to make sure that electrolytic action is avoided.

- Earthing material
  Stranded copper conductor is to be used as earth conductor for laying on cable trays and for the earthing of electric equipment, steel structures and frames etc. Bare copper strips should be used for the internal earthing ring inside the buildings.

- Lightning protection material
  Round copper rod of 8 mm diameter is generally to be used as the material for the lightning protection system. The conductor supports of the lightning protection system must be copper or bronze. Nuts and bolts at isolating or other points which are to remain detachable must be made of coppernickel silicon bronze.

Earthing system
Installations above and below 1000 V shall be made safe by protective earthing. This is required to prevent the occurrence of excessive touch potentials on conducting parts of the installation which are not part of the electrical circuit.

The earthing installations must be designed and constructed in accordance with approved standards.

Generally, underneath the substation building a grid earth of stranded copper cable must be installed. The size of the stranded copper conductor shall be minimum 70 mm2, but the Contractor has to check this diameter by an earth fault calculation. The size of the mesh shall be in accordance with the maximum occurring earth leakage current to meet the requirements for earthing aceording to IEEE 80 and IEC 60621. The size of the stranded copper conductors used must be uniform throughout the area under Contract as far as possible.

Inside the buildings encircling, bare copper strips must be installed on the walls. From the inner earthing ring the connections to the switchgear, and other electrical apparatus, cable trays, vertical cable runs, steelwork etc. are to be made using bare copper conductor. All the electrical equipment, frames and mechanical apparatus must be fitted with earthing screws and studs.

The copper conductors can be laid and fixed on the cable trays and vertical runs for AC power cables. Where this is not possible, earthing conductor supports shall be provided and fixed in concrete or masonry by means of plugs. The bare copper strips must be fixed with earthing support on walls.

Cable trays and vertical runs shall be connected to the earthing conductor at intervals of 10 m max. in such a way as to give good connection. This earthing conductor must likewise be connected to the earthing ring.

Inside the concrete of buildings a separate round iron (reinforcement bar) mesh in walls and ceilings for earthing purposes must be provided. The size of this mesh should not exceed 8 m x 4 m. The connections of this earthing reinforcement bar should be welded. The reinforcement bar shall be connected via a flexible PVC single-core cable every 8 m to the inside earthing ring.

At a maximum distance of 8 m the inside earthing ring of the buildings must be connected with the outdoor earthing system. These connections must be provided with flexible PVC single-core cables which are to be laid through the concrete walls above the ground water level.

In buildings without a basement the internal earthing ring is to be connected by the Contractor to the outer earthing ring at maximum intervals of 10 m.

The crossing point connections of the earthing cables underneath the buildings and outside the buildings must be made by compression connectors. Connections, e.g. by Cadweld system, will also be acceptable. All other earthing conductor connections and junctions must be made in the same way to ensure secure, lasting connections having good contact.

The interconnections between the earthing installations of the buildings must be provided with an accessible isolating point in order to be able to measure the earthing resistance. All isolating points must be numbered consecutively in the drawings and clearly marked in the field.

All facilities shall be securely connected, with minimum practicable resistance, to the common ground system. The maximum resistance to ground from the connection point in any facility shall not exceed 0.5 Ω, when measured by standard ground resistance measurement techniques.

The lightning installations must also be connected to the central earthing installation.

The effects of lightning strikes on the control and monitoring systems vary from faulty pulses in control and measurement to the destruction of electronic sub assemblies and cables and must therefore be prevented by the earthing of screens. To this end the screens of the control cables leading from the signal transmitters, actuators etc. must be taken to the central earthing points and from there to the indoor earthing installation.
They must be insulated and laid via the screen bars in subsidiary distribution boxes, intermediate terminal boxes, marshalling racks, control cabinets and DC main distribution boards.

Further requirements in General Specification Part B0 and Electrical and Associated Works Part B7 shall be followed.

The earthing system shall fulfill the following requirements:

- maintain a low overall resistance of the earth mass to limit the plant potential rise and ensure protective relay operation in the event of an external fault
- provide ground connections to all electrical apparatus enclosures and structural steelwork adequate to carry prospective ground faults without excessive heating or fire risk
- limit potential differences within the power plant site in the event of earth current, originating from within or outside the station. To ensure the safety of personnel and eliminate interference or damage to sensitive electronic circuits
- The contractor shall provide a potential gradient control system for all locations where dangerous surface voltage grandients can occur, the step and touch voltage shall be less than the permissible values according VDE 0101- 2 Figure 4 or IEEE 80.

The Bidder shall be entirely responsible for the earthing system and connections to cover the whole area and for ensuring that all apparatus is securely and safely connected to this system. The overall resistance of the earthing system shall be 0.5 Ohm or less.

The earthing system shall be interconnected with the earthing system provided for the 400/230 kV kV substation.

B7.3.8.2 Common earthing system

The earthing system is common for:

- protective earthing for equipment at all voltages
- transformer neutral points earthing
- equipment equipotential earthing and bonding
- lightning protection system, etc.

The main parts of common earthing system are:

- indoor earthing system (above-ground earthing system)
- outdoor/external earthing system (under-ground earthing system)
- foundation earthing
- lightning protection system.
- Screening.

B7.3.8.3 Indoor earthing system

The indoor earthing system shall form one ring inside the building on the walls of each building floor. Encircling bare copper bars shall be used inside

the building. From the inner ring the connections to the bus, panels and other electrical apparatus, cable trays, conduits, doors, steelwork, etc., shall be made using tinned stranded copper conductor or copper bars. All the electrical equipment, frames and mechanical apparatus shall be provided with designated earthing points with at least two connections to the earthing inner ring.

Large plants situated in buildings shall each be enclosed by an earth ring connected to the main earth grid at two or more points, at least every 20 m. The copper conductors may be laid and fixed at the cable trays. Where this is not possible earthing conductor supports shall be provided fixed in concrete or masonry. The copper bars shall be also fixed with earthing support on walls.

B7.3.8.6 Screening

The effects of lightning strokes on control and monitoring systems can lead to the destruction of electronic sub-assemblies and cables and shall therefore be prevented by adequate "screening"

B7.3.8.7 Fences

All internal fences shall be bound to the main earth grid by a buried earth conductor (0.3 m deep) outside the fence to reduce touch voltages to a safe value.

The perimeter fence shall be provided with a separate earth not connected to the main earthing grid provided the two systems have a minimum separation of not less than two and a half meters. Where the systems approach closer than two and a half meters, they shall be bonded together.

B7.3.8.8 Cable trenches, tunnels, raceways and risers

A main copper earthing conductor shall be provided for each cable route to which all steelwork shall be bonded.

B7.3.8.9 Pipelines

Pipelines entering the site shall be fitted with a length of electrical insulation over the pipe on each side of the fence, and an insulating flange at the boundary. This prevents dangerous potentials occurring between the pipe and earth, both within and outside the site.

B7.3.8.10 Communication circuits

If it is not possible to limit the rise of station earth potential to the maximum of 650 V rms typically required by communication authorities isolating devices shall then be applied to the incoming lines as part of the communications installation.

B7.3.8.11 Material

Earth Electrodes
Earth electrodes shall consist of a network of horizontally buried conductors with vertically buried rods connected to the horizontal conductors.

Tinned stranded soft copper conductor shall be used for earth electrodes (grid conductors).

The cross-section of earth electrodes shall be chosen by the Bidder in accordance with the technical data but not less than 240 mm^2.

The size of tinned stranded soft copper conductors shall be uniform throughout the plant.

Earthing Conductors
Bare copper bars shall be used for the ring inside the buildings on the walls at each operational level

Tinned stranded soft copper conductor or copper tape shall be used for connection of the equipment to the ring inside buildings.

Tinned stranded soft copper conductors or PVC insulated copper conductor shall be used for all connections to earthing grid.

Single connections between the equipment and the earthing system shall carry the total fault current but the cross-section area of branch connections may be reduced to 60 percent of corresponding single conductor to provide for the current distribution in two or more conductors.

The earthing conductors shall be sized to carry for 1 sec the max. earth fault current.

The minimum cross sectional area of any earthing conductor shall be 16 mm^2.

Earthing Connections
All equipment within the station area shall be connected to the main grid including but not limited to the following: steel structures, hoist and motors, cranes and motors, control boards, generator frames, generators neutral point, generator cubicles, excitation cubicles, MV switchgear, transformers neutral point, transformer tanks, 400/230 kV GIS, fences, cables armour, cable trays and conduits, bus ducts, overhead shield wires, AC switchboards, DC switchboards, control panels, control desks, relay racks, motor frames, lighting fixtures, lighting poles, housing of small equipment, ladders, steel reinforcing bars where it is applicable or where it is used in ground slabs for equipotential grading, etc.

All joints and connections welding shall be of cad weld technique.

The location of all buried joints shall be identified on a drawing.

Whenever dissimilar materials are to be joined the necessary transition plates shall be inserted as required to ensure that electrolytic action is avoided.

All electrical equipment shall be equipped with earthing hooks of sufficient size and shall be earthed at the earth system by means of heavy-duty tinned copper compression lugs.

Earth Pits and Earth Rods

Earth pits shall be provided for connecting copper bond earth rod with earth grid.

Earth rods shall be minimum 16 mm diameter and of a length sufficient to penetrate 3 m below the water table. Tinned copper shall be used for earth rods

Earth rod shall be completed with a rod to cable clamp.
Earth link pits shall be provided at all interconnection points with the earthing system provided for the 400/230 kV Substation.

Finishes: the control room shall be of noble appearance and receive e.g. sound absorbing metal wall cladding. The lighting shall be adequate and in accordance with the arrangement of the individual working places. Windows to be double glazed aluminium PVDF coated.

The design of finishing works will comply with the requirements of the code of procedures with regard to the mirroring effects, lighting of working places, shadowing etc.

B9.3.2.22 400/230 KV GIS building

The GIS buildings shall consist of a steel structure with trapezoidal metal panels for external walls and roofs. The floor shall be a concrete foundation.

Description of the building

- structure: steel structure
- floors: one
- flooring: reinforced concrete
- foundations: according to the soil investigation report and Special Technical Requirements of Foundations
- walls: single skin metal sheet cladding
- roof: single skin metal roofing
- doors:
  - external: self closing sandwich steel doors with insulation
- windows: double glazed aluminum
- ventilation: natural/mechanical.

B9.3.2.23 HCSD - building

The building shall accommodate the equipment for high concentrated slurry disposal, as described in **Section B04**.

Building description

- structure: reinforced concrete
- floors: one floor
- flooring: reinforced concrete
- foundations: according to the soil investigation report and Special Technical Requirements of Foundations
- external wall: 230 mm thick brick walls or autoclave aerated concrete blocks with metal cladding
- internal wall: 230 mm thick brick walls or autoclave aerated concrete blocks or autoclave aerated concrete blocks with plaster finish
- roof: double skin metal sheet roof
- doors:

B9.3.3.2 400/230kV GIS

The GIS buildings shall consist of a steel structure with trapezoidal metal panels for external walls and roofs. The floor shall be a concrete foundation.

SECTION-3

3.0 GENERAL

This section stipulates the General Technical Requirements under the Contract and will form an integral part of the Technical Specification. This shall include but shall not be limited to: engineering, manufacturing, shop testing, supply, supervision of erection, testing at site, commissioning, performance testing, training Employer's personnel.

The requirements stated in this Section of General Technical Requirements are valid for all sections of the specification, except only where additional and/or special requirements are specified.

In case of a contradiction between different Sections of this specification or mentioned standards, the more stringent requirements shall be applicable to Bidder/ Supplier.

The Equipment shall be new and clean, and designed, manufactured and arranged so that it will have a functional design and a pleasant appearance. All parts of the Equipment shall be arranged in such a manner as to facilitate surveillance by the operator and to ease maintenance, operation and control.

The parts of the Equipment shall be designed and arranged so that they can be easily inspected, leaned, erected and dismantled without necessitating large scale dismantling of other parts of the Equipment. They shall be designed, manufactured and put into operation in accordance with the latest recognized rules of workmanship, modern engineering practice and with good standards of prudence applicable to the international electricity generation industry which would have been expected to accomplish the desired result at the lowest reasonable cost consistent with reliability, safety and expedition.

The regulations, standards and guidelines listed in the Specification as well as all applicable laws and governmental decrees, regulations, orders, etc. shall be observed in the design, calculation, manufacture, erection, installation, testing, commissioning and start-up of all parts of the Equipment. The following shall be considered in the design and engineering of the Equipment facilities:

- All parts of the Equipment shall be suitable in every respect for continuous operation at maximum output as well as part loads and expected transient operating conditions peculiar to the site and shall be able to safely withstand the stresses arising from the operating conditions without any reduction in its planned life.

- The Supplier shall familiarize himself with the conditions on site.

- Suitable and automatically acting protection and safety measures shall be provided for automatic load reduction or shut down of equipment in case of abnormal operating conditions.

- Switchover to stand-by units shall be automatically, as far as required for continuous Plant operation without interruption of Plant operation.

- In case of equipment and/or system shut down process conditioned drainage of components (such as pipelines, tanks, etc.) shall be performed automatically from the control room.

- Minor equipment which, in case of failure would cause a failure of a power generation unit and/or the Plant is to be provided with a stand-by facility in order to ensure further operation of the power generation unit or the Plant.

- All live, moving and rotating parts shall be provided with appropriate effective protection in order to avoid danger to the operating staff. All metal parts shall be electrically grounded.

- All equipment shall be designed to ensure start-up from any condition, i.e. from long term shut-down, cold, warm or hot condition without necessitating special or preparatory measures.

- The project language shall be English.

- Material and personnel costs for tests and inspections which are mandated in legislation
- Material and personnel costs for site inspections
- Declaration of conformity with requirements from Bangladesh and markings for all machines
- Engineering design of complete supplied equipment including interface coordination
- All as-built documents (on data carriers; data formats as requested by the Employer)
- Quality control plan and safety plan
- Complete documentation as set out in the tender specification
- Operating manual (5 hardcopies and 3 electronic copies)
- Detailed operating and maintenance instructions/manual (5 hardcopies and 3 electronic copies)
- A maintenance program for all equipment of the Plant instructions (5 hardcopies and 3 electronic copies)
- For all documents softcopy format shall be searchable pdf, however in addition all drawings, diagrams like P&IDs shall be supplied in ACAD or other editable format, and all lists in Excel format.

Terminology:
Owner/ Employer: BIFPCL/ BHEL
Contractor: Supplier/ Bidder

3.1 PROJECT INFORMATION AND SYSTEM PARAMETERS

Site conditions

The following information on local conditions is investigated or compiled by the Owner. The Contractor is hereby in no way relieved from his duties of carrying out all investigations required for satisfactory performance of his equipment/ works. The Contractor shall perform his own Site visits and investigations, prior to Contract award in order to familiarize him with the existing conditions of the Site and the surrounding area.

Location, accessibility and present condition of the Site

The site for the Maitree-STPP Project is geographically located between 22° 370'0'' N to 22°34'30''N and 89°32'0''E to 89°34'5''E, approximately 14 km northeast of the Mongla Port

and 14 km northwest of the Sundarbans, is infringed by the Passur and Moidara Rivers to the west and south east respectively.
The topographical survey indicates a natural ground level of +1.15 to + 1.35 meters above sea level. A severe cyclone in 2009 raised the level to 4.47 meters and it was decided to raise the Plant level to +5.00 meters.
Politically, the site is located in Rampal Upazila of the Bagherat District in the Rajnagar Union.

Currently, the Site is accessible by boat only.

The nearest inland port is Mongla port at around 14km direct distance.

The proposed Khan Jahan Ali Airport is located at a distance of approximately 12 km from the project site.

Soil conditions
In general the subsoil conditions can be described as follows:

- top layer filled sand (with unknown silt content) in Plant area
- underlying layers of clay
- underlaying fine sand.

Seismic zone

Related to soil type as identified to Soil Investigation Report, the effect of local soils on earthquake ground motion shall be determined.

For site class "S1" and "S", as expected for the Project, site specific studies shall be carried out to determine the design acceleration response spectrum. During field study minimum the following tests shall be executed:
- Seismic cross hole test; and
- Seismic refraction test.

Based on these results (Attached as Annexure-A) a site specific Response Spectra shall be established. Peak spectral acceleration shall be determined, but shall be not less than 0.12g, as mentioned in BNBC 2012, Table 2.5.2.

Bidder to design equipment based on parameters of Seismic report (attached as Annexure-A), other relevant electrical requirements, standard codes etc. Foundation loading shall be provided as per parameters of Seismic report.

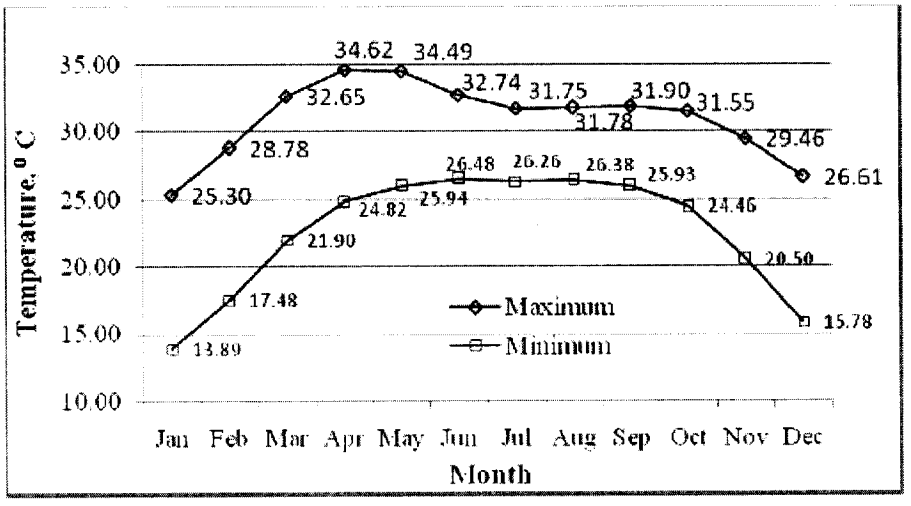
Site climatic conditions
The Plant site is from the climatic point of view under maritime tropical conditions. The assumed meteorological conditions for the Site are as follows:
The project site is located in the country's South Central Zone consisting of three dominant seasons:

- summer season-March to May
- monsoon season-June to October
- winter season-November to February.

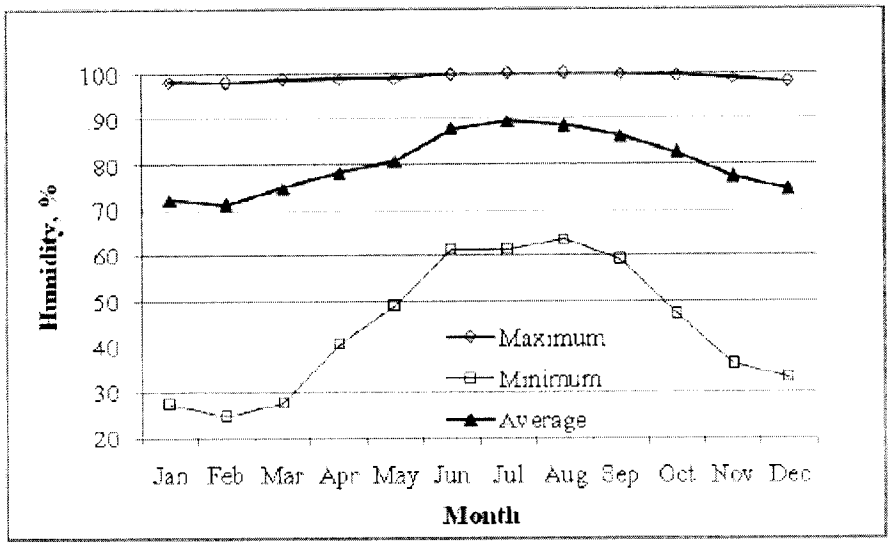
During the Monsoon Season occasional cyclonic storms can occur.

The climatic conditions in the area are continuously monitored by the Bangladesh Meteorological Department (BMD) at the Mongla Meteorological Station.

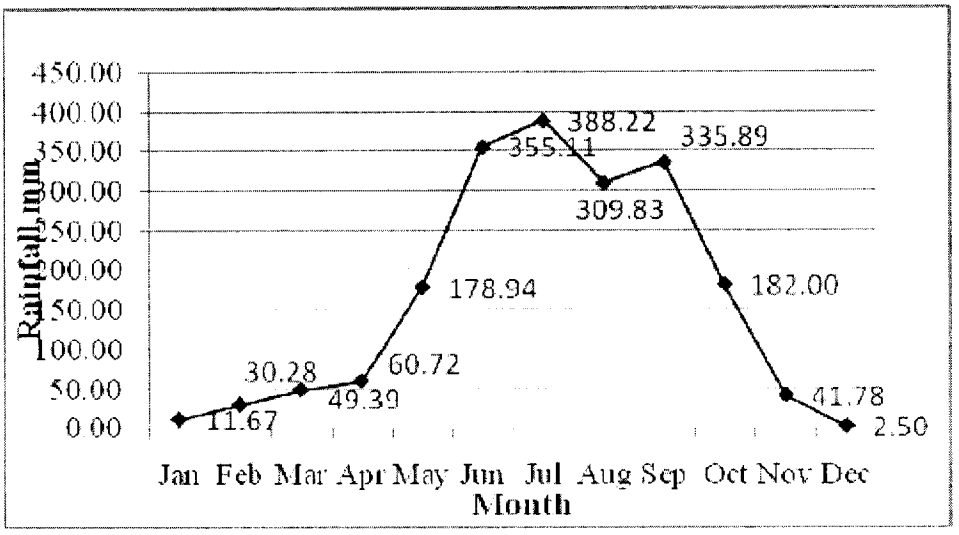
The temperature varies only slightly throughout the year with the highest temperature of 36.9°C and the lowest temperature of 12.2°C recorded in the period from 1989 to 2008. This distribution is depicted in figure below.



The relative humidity varies drastically during the Monsoon Season with 80% to 90% and the lowest levels of 20% to 30% during the Summer Season. The humidity profile recorded in the same period as the temperature is visualized in below figure.



The maximum rainfall occurs during the Monsoon Season by varying between 300 mm and 350 mm with almost no rainfall during the Winter Season.
The average evaporation in the project area varies between 3 - 5 mm/day with its peak of 16 mm/day during July. The average rainfall for the period between 1991 and 2008 is depicted in below figure.



Below definitions are to be used as typical data for the different climatically seasons at the site.

Average Site Condition ASC
Ambient Temperature: 27.3 °C
Ambient Humidity 87 %
Ambient Pressure 1007.6 mbar
River Water Temperature: 29.8 °C

Summer Site Condition SSC
Ambient Temperature 36.9 °C
Ambient Humidity 60 %
Ambient Pressure 1007.9 mbar
River Water Temperature: 33 °C

Winter Site Conditions WSC
Ambient Temperature 12.2 °C
Ambient Humidity 100 %
Ambient Pressure 1017.2 mbar
River Water Temperature: 20°C

Reference Site Conditions RSC
Ambient Temperature 31 °C
Ambient Humidity 88 %
Ambient Pressure 1007 mbar
River Water Temperature: 32°C
Wind speed 1 m/s
Design ambient conditions for Electrical Systems

- Maximum design temperature (outdoor) 45°C
- Maximum daily average ambient shade temperature 38°C
- Maximum monthly average temperature (in the shade) 34.6°C
- Maximum annual average temperature (in the shade) 27.3°C
- Maximum design temperature of the electrical equipment installed indoors in air conditioned rooms 40°C
- Maximum design temperature of the electrical equipment installed indoors non in air conditioned rooms 45°C
- Minimum design temperature 0°C

Marine conditions
Two tides (e.g. flood and ebb) are regularly observed in the Passur River, which enters into the project site through numerous connected creeks.

The tidal range varies between 1.2 and 3.1 meters. The mean water level (CD) is about 0.87 meters (PWD=CD −1.17 meters). The mean high water level varies due to spring-neap tide conditions between +1.60 m and +2.6m PWD. The Highest High Water Level (HHW) is about +3.1m PWD and the Lowest Low Water Level (LLW) is about −1.4m PWD.

The salinity of the Passur River system varies with the amount of fresh water entering the system which is highly seasonal dependent. The surface water temperature ranges between 22.9°C and 33.0°C.

The marine conditions as recorded at Mongla Port Gauge Station (approx. 14 km south-east to the site) are as follows:

- Highest High Water Level (HHW) + 2.642 MSL
- Lowest Low Water Level (LWL) - 1.858 MSL

The Power Plant shall be designed for 100 years flood condition based on data provided by relevant Organization in Bangladesh and taking into account the Highest Astronomical Tide (HAT), the maximum wave conditions (including storm surges) and the potential event of Cyclone. The Contractor is responsible to verify the worst conditions.

These reference data are with respect to LAT, which corresponds to the Chart Datum (CD). The site land data is however with respect to the Bangladesh Land Survey Datum (BLSD), which corresponds to approx. +1.55 m CD (hence the MLSD corresponds to MSL).

Design Wave Height 2.0 m
Design Wave Period 6.0 sec
Sedimentation and Siltation: Soft to stiff clay and alternations of very sandy and stiff clay.

A water analysis from the area adjacent to the site giving salinity and water quality is shown below:

Location	Date	Temp.	pH	EC	Cl	T. Alkalinity	Turbidity	TS	TDS	SS	DO	BOD	COD	Salinity
		°C		µS/cm	mg/l	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	7-Jan	27.4	7.74	3910	879	36	68.7	1565	1510	55	5.1	0.8	55	1.6
2	7-Jan	27.1	7.72	3920	878.8	36	68.5	1570	1510	60	5.1	0.8	55	1.6
3	7-Jan	27.8	7.71	3930	879	36	68.8	1565	1510	55	5.1	0.8	55	1.6
1	11-Feb	29.8	7.65	4590	1285	36	182	2300	2190	110	4.7	1	75	2.3
2	11-Feb	29.2	7.63	4580	1268	36	178	2290	2190	100	4.7	1	75	2.3
3	11-Feb	29.1	7.67	4580	1285	36	179	2290	2190	100	4.7	1	75	2.3
1	9-Mar	32.6	7.56	11780	2944.4	38	175	6080	5890	190	4.7	1.2	75	6.7
2	9-Mar	32.6	7.57	11780	2945.2	38	178	6080	5890	190	4.7	1.2	75	6.7
3	9-Mar	32.1	7.55	11780	2945.4	38	177	6090	5890	200	4.7	1.2	75	6.7
1	17-Apr	32.6	7.59	25300	8273	36	184.6	12950	12700	250	4.6	0.7	135	13.5
2	17-Apr	32.6	7.59	25300	8273	36	185.2	12950	12700	250	4.6	0.7	138	13.5
3	17-Apr	32.6	7.59	25300	8273	36	184.8	12950	12700	250	4.6	0.7	136	13.5
1	5-May	32.6	7.58	29200	9430	36	195.6	14900	14600	300	4.5	1.2	177	17.6
2	5-May	32.6	7.54	29200	9430	36	195.6	14900	14600	300	4.4	1.2	177	17.6

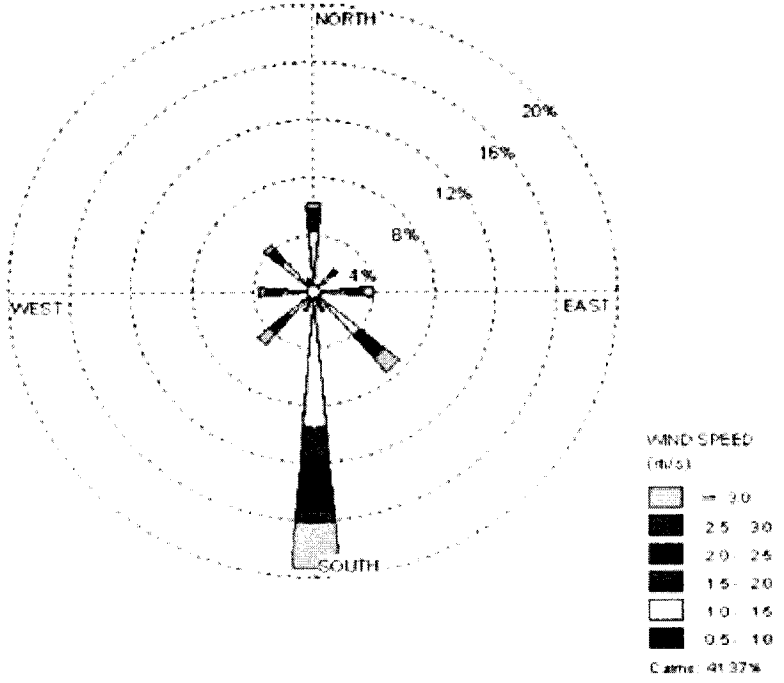
Figure 1 Water quality of the Passur River at Mongla point (Source: EIA-Report)

Location	Date	Temp.	pH	EC	Cl	T. Alkalinity	Turbidity	TS	TDS	SS	DO	BOD	COD	Salinity
		°C		µS/cm	mg/l	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
3	5-May	33.2	7.57	29200	9470	36	199.6	14900	14600	300	4.5	1.2	177	17.6
1	13-Jun	31.6	7.69	18500	5930	36	112.6	9300	9000	200	4.7	1.1	97	10.8
2	13-Jun	31.6	7.69	18500	5930	36	113.2	9300	9000	200	4.7	1.1	97	10.8
3	13-Jun	31.6	7.69	18500	5810	36	112.4	9300	9000	200	4.7	1.1	97	10.8
1	1-Jul	31.6	7.69	440	32.6	36	76.6	285	220	65	5.2	0.8	26	-
2	1-Jul	31.6	7.69	440	32.6	36	76.6	285	220	65	5.2	0.8	26	-
3	1-Jul	31.6	7.69	440	32.6	36	76.6	285	220	65	5.2	0.8	26	-
1	5-Aug	31.6	7.69	273	15.6	36	68.6	192	137	55	5.3	0.7	22	-
2	5-Aug	31.6	7.69	273	15.6	36	68.6	192	137	55	5.3	0.7	22	-
3	5-Aug	31.6	7.69	273	15.6	36	68.6	192	137	55	5.3	0.7	22	-
1	8-Sep	31.6	7.74	270	15.6	36	65.6	190	135	45	5.5	0.7	22	-
2	8-Sep	31.6	7.76	270	15.6	36	65.6	190	135	45	5.5	0.7	22	-
3	8-Sep	31.6	7.74	270	15.6	36	65.6	190	135	45	5.5	0.7	22	-
1	12-Oct	30.6	7.79	290	25.6	36	62.6	192	145	47	5.6	0.7	22	-
2	12-Oct	30.6	7.78	290	25.6	36	62.6	192	145	47	5.6	0.7	22	-
3	12-Oct	30.6	7.78	290	25.6	36	62.6	192	145	47	5.6	0.7	22	-
1	5-Nov	24.6	7.79	340	35.6	36	56.6	210	170	40	5.6	0.7	22	-
2	5-Nov	26.6	7.79	340	35.6	36	56.6	210	170	40	5.6	0.7	22	-
3	5-Nov	25.6	7.79	340	35.6	36	56.6	210	170	40	5.6	0.7	22	-
1	12-Dec	21.3	7.72	520	62.6	36	72.6	320	260	60	5.1	0.9	25	0.4
2	12-Dec	20.9	7.71	520	62.6	36	73.6	320	260	60	5.1	0.9	25	0.4
3	12-Dec	21.1	7.72	520	62.6	36	71.6	320	260	60	5.1	0.9	25	0.4

Figure 2 Water quality of the Passur River at Mongla point (Source: EIA-Report)

Wind data

The project region is characterized by southerly winds from the Bay of Bengal during the Monsoon Season and north-westerly winds from the Himalayas during the Winter Season. During the Summer Season, the wind blows from south-southwest to north-northeast. The annual average wind speed amounts to 1.7 meter/second and the wind rose for the entire year is shown in Figure 5.5.



The wind load calculation for the buildings and structures shall be as per Bangladesh National Building Code -2012. Part 6. Chapter 2.4.

Basic wind speed, V, shall be taken as 73m/s. Three second gust at 10m above ground in exposure C, having a return period of 50 years.

3.2 Design requirements

The main design features (basic design reports, drawings, PFD, P&IDs, design data etc.) and the main vendors and subcontractors shall be subject to the approval by the Owner/ BHEL.

The Owner/ BHEL has the right to refuse design features and vendors or subcontractors, if the supplier cannot verify the reliability of the suggested design, vendor or subcontractor.

The Plant is expected to operate in base-load mode with high plant load factor. The design lifetime of the Plant shall be of not less than 30 years of operation or 200,000 full load operating hours, whichever is longer. The Plant and all its auxiliaries shall be designed to operate for the complete lifetime under the site conditions as described in this section and dedicated other part of this FTS.

All Plant equipment and material must be suitable for the range of ambient site conditions. In particular the saline atmosphere has to be considered.

Redundancy concept

All equipment shall be implemented with (n+1) redundancy – unless otherwise stated -, where n is the number of equipment required to maintain the maximum capacity of a unit. N+1 means that even in case of outage of the biggest component sufficient capacity is available to maintain the maximum capacity of the Power Plant unit.

For all components which are not redundant, the supplier shall provide a maintenance and spare part concept to ensure that outage times are minimized and to ensure that the required availability is met.

Each equipment whose unavailability due to a failure could result in damages to another equipment shall be backed up by a stand-by equipment, one of them being fed by an emergency source in case of external black out.

Failure of any single item of auxiliary equipment including the Power Plant's DCS and electrical systems shall not result in a reduction in power evacuated from the Power Plant.

Replacement and repair of redundant components shall be possible without interrupting Plant operation.

Note: The Power Plant shall be designed for 100 years flood condition based on data provided by relevant Organization in Bangladesh and taking into account the Highest Astronomical Tide (HAT), the maximum wave conditions (including storm surges) and the potential event of Cyclone. The Contractor is responsible to verify the worst conditions.

3.3 SYSTEM PARAMETERS

NOMINAL VOLTAGE (kV)	**400 kV**	**230 kV**
HIGHEST SYSTEM VOLTAGE (kV)	420 kV	245kV
RATED FREQUENCY (Hz)	50	50
RATED SHORT CIRCUIT CURRENT (1 SEC)	50	50
RATED PEAK WITHSTAND CURRENT /(kAp)	125	125
CREEPAGE DISTANCE (mm/Phase Voltage in kV)	53.7	
CREEPAGE DISTANCE (mm/Line Voltage in kV)	31	

3.4 Latent Defects:

Notwithstanding the issue of the Take Over Certificate, the Contractor shall be responsible for making good with all possible speed any Latent Defect in any Works /equipment of the plant which appears at any time before the expiry of defect liability period. And shall remedy such defect at its own cost and expense. The latent defect liability period shall be a minimum of 5 years from the end of defect liability period. The defects to which this applies are defects in design, materials or workmanship or defects arising from any act or omission of the Contractor done or omitted prior to Take-over of the portion of the Plant affected by the defects or during the Warranty Period which a reasonable examination at the end of the Warranty Period would not have disclosed.

3.5 PACKING FOR SHIPMENT

The equipment complete with its accessories, spares, special tools and tackles shall be suitably protected by respective packing for shipment considering handling during transit, distance and weather conditions involved. The Contractor shall submit the packaging method for shipment to be adopted by him, if so desired by the Owner / Purchaser.

Each consignment shall be marked with Equipment name, Owner /Purchaser's name & address, Project details, handling instruction etc. It shall be complete with part list and identification details. The copies of the part list of each consignment shall also be furnished to the Owner / Purchaser after dispatch.
Equipment shall be packaged for transportation so as to meet the space and weight limitation of transport facilities. The contractor shall obtain approval from concerned authorities for transportation of over dimensioned consignment/package, if any, before starting manufacture of such equipment.

3.6 TROPICAL PROTECTION

All electrical equipment, accessories and wiring shall have fungus protection involving special treatment of insulation and metal against fungus, insects and corrosion.

Fine mesh screen of corrosion resistant material shall be furnished on all ventilating openings to prevent entry of insects.

3.7 HANDLING, STORING AND INSTALLATION

Contractor may engage manufacturer's Engineers to supervise if required for unloading, transportation to site, storing, testing and commissioning of the various equipment being procured by them separately. In case of any doubt/misunderstanding as to the correct interpretation of manufacturer's drawings or instructions, necessary clarifications shall be obtained from the purchaser. Contractor shall be held responsible for any damage to the equipment consequent to not following manufacturer's drawings/instructions correctly.

Where assemblies are supplied in more than one section, contractor shall make all necessary mechanical and electrical connections between sections including the connection between buses. Contractor shall also do necessary adjustments/alignments necessary for proper operation of circuit breakers, isolators and their operating mechanisms. All components shall be protected against damage during unloading, transportation, storage, installation, testing and commissioning.

Contractor shall be responsible for examining all the shipment immediately of any damage, shortage, discrepancy etc. for the purpose of Purchaser's information only. Any demurrage, pilferage and other such charges claimed by the transporters, railways etc. shall be to the account of the Contractor. The Contractor shall be fully responsible, for the equipment/material until the same is handed over to the purchaser in an operating condition after commissioning.

The minimum phase to earth, phase to phase and section clearance along-with other technical parameters for the various switchyard voltage levels to be maintained shall be strictly as per the approved drawings.

The design and workmanship shall be in accordance with the best engineering practices to ensure satisfactory performance throughout the service life. If at any stage during the execution of the Contract, it is observed that the erected equipment(s) do not meet the above minimum clearances, the Contractor shall immediately proceed to correct the discrepancy at his risks and costs.

Common equipment and services

The following supplies and services are to be included in the corresponding Section prices:

3.8 DOCUMENTS TO BE SUBMITTED ALONGWITH OFFER

1) Drawings
2) Guaranteed Technical Particulars
3) Type Test Reports
4) Manufacturing Quality Plan

3.8.1 DOCUMENTATION SCHEDULE

S. No.	DESCRIPTION	TENDER STAGE	CONTRACT STAGE FOR APPROVAL	FINAL DOCUMENTATION	
			Prints	Prints	CDs
1	Drawings and Data Sheets	1	6	6	3
2	Drawings "As Built "	-	-	6	3
3	Type Test Reports	1	6	6	3
4	Erection Manuals	-	6	6	3
5	Operating manuals, maintenance and service manuals, component documentation, assembly documentation, drawing and listing etc.	-	-	6	3
6	Operation and Maintenance Manuals (shall be translated into Bangla and provided as paper copies in electronic format).	-	6	6	3
7	Manufacturing Quality Plan	1	6	6	3
8	Field Quality Plan	1	6	6	3
9	Inspection Test Reports	-	-	6	3

Electronic copies shall be submitted in primary original data format (e.g. DOC, XLS, DWG) as well

as in printable non-proprietary document format (e.g. PDF).

Final Documentation shall be submitted in bound volumes with Customer & Project etc. written on top.

3.8.2 AS-BUILT DRAWINGS

The Contractor shall furnish drawings and document in as-built condition as stipulated in the specification.
On completion of the project, contractor should submit Three Sets of As commissioned drawings, Three Sets of as Installed Bill of Materials and Three Sets of As Commissioned Data/ Specification /Parameter Sheets Duly Signed by the Competent Authority.

3.8.3 DRAWINGS, DATA, INFORMATION AND MANUALS

Drawings, data, information & manuals shall be submitted as indicated below:
To be submitted after award of the Contract.
a) Single line diagram giving rating of each equipment.
b) Design calculations in support of selection of equipment rating and system design.
c) Technical Date sheets, characteristic curves.
d) Equipment layouts, layout of switchyard with sections.
e) Grounding & lightning protection drawings and details.
f) Cabling, cable trench and tray layouts with section and details with cable sizing calculation.
g) Dimensional general arrangement drawing along with cross- sections for equipment.
h) Foundation plan and loading data : design calculation and detail drawing of foundation.
i) Design calculation and detail drawing for civil work related to this specification.
j) Design calculation, GA drawing for GI structure and equipment supporting structure, and subsequently detailed drawings.
k) Mounting details of equipment and structure.
l) Fire fighting and sump arrangement.
m) Control & operation write up/Block logic diagrams.
n) Control schematic and wiring diagram.
o) Cable schedule and interconnection and cable routing.
p) Relay co-ordination.
q) Civil & structural analysis, design calculations and working drawings including bar bending schedule and fabrication.
r) Erection and maintenance manual.
s) Any other drawings & data as required for satisfactory installation, operation & maintenance.

3.8.4 OPERATING MANUALS AND MAINTENANCE INSTRUCTIONS

(i) The Contractor shall provide at least six (6) months before the time of commissioning and before taking over of the plant and equipment, all necessary maintenance manuals and operating instructions. The instruction manual shall be submitted in the form of one (1) soft copy in CD and 15 hardcopies.

(ii)The information provided, which shall be contained in loose leaf stiff backed covers, shall include :

a) A complete inventory of all main items of plant, with identification details.

b) Service manuals for all plant and equipment giving full descriptions of the main items and auxiliary items such as power packs, hydraulic equipment, actuators, lubricating pumps, etc.

c) A separate electrical manual covering items such as switchgear, cabling, instrumentation, controls, cabling layouts and wiring diagrams.

d) A schedule of recommendations for routine maintenance of all electrical and mechanical equipment, recommended inspection point, information on detection, cause and rectifications of troubles & faults.

e) A lubrication schedule with all necessary drawings diagrams to identify the lubrication points.

f) Manufacturer's literature.

(iii) The instruction manual shall be subject to the approval of Owner.

3.9 Electrical network connection conditions

The electrical equipment shall be designed according to the IEC standards (if not specified otherwise) and

The Plant shall comply with:

a) the Essential Electrical Requirements of the Power Purchase Agreement (PPA);
b) the latest edition of the Electricity Grid Code of the Bangladesh Energy Regulatory Commission; and
c) The Great Britain Grid Code.

The Contractor shall familiarize himself with such requirements. In case of contradictions or discrepancies the order of precedence shall be as follows:

a) Essential Electrical Requirements of the PPA
b) Electricity Grid Code of the Bangladesh Energy Regulatory Commission
c) Great Britain Grid Code.

Any other requirements of the Bangladesh Power Development Board (BPDB) or Power Grid Company of Bangladesh (PGCB) shall also be considered. The bidder shall list all those grid connection requirements which cannot be met by the proposed Plant.

3.10 Electromagnetic Field (EMF)

In accordance with the EHSG-TPP the occupational EMF exposure shall be prevented or minimized. All technical measures and the required equipment necessary to fulfil the EHSG-TPP shall be provided by the Contractor. Inter alia areas with expected elevated EMF levels shall be indentified and marked.

Fire and explosion, electrical and chemical hazards
In accordance with the EHSG-TPP all technical measures to prevent, minimize and control physical, electrical and chemical hazards shall be include in the bidderr's scope of services and supplies.

3.11 Standards and codes

The work must be performed according to the most recent relevant codes, standards, accident prevention regulations and local rules and legal regulations.

All materials and equipment supplied and all work carried out as well as calculation sheets, drawings, quality and class of goods, methods of inspection, specific design features of equipment and parts and acceptances of partial plants shall comply in every respect with the applicable standards, codes and regulations to be chosen from the following:

- American Association of State Highway and transportation Officials AASHTO
- American Concrete Institute ACI
- American Gear Manufacturers Association AGMA
- American Institute of Steel Construction AISC
- American Iron & Steel Institute AISI
- American Moving and Conditioning Association AMCA
- American National Standards Institute ANSI
- American Petroleum Institute API
- American Public Health Association APHA
- American Society for Testing and Materials ASTM
- American Society of Civil Engineers ASCE
- American Society of Heating, Refrigeration & Air Conditioning Engineers ASHRAE
- American Society of Mechanical Engineers ASME
- American Water Works Association AWWA
- American Welding Society AWS
- American Wire Gauge AWG
- Anti-Friction Bearing Manufactures Association AFBMA
- Architectural Institute of Japan AIJ
- Association Francaise de Normalisation AFNOR
- British Standards Institute BS
- Chlorine Institute CI
- Crane Manufacturers Association of America CMAA
- Deutsches Institut für Normung DIN
- Diesel Engine Manufacturers Association DEMA
- European Norm EN
- Expansion Joint Manufacturer Association EJMA
- Fédération Européene de Manutention FEM
- Heat Exchanger Institute HEI

- Hydraulic Institute HI
- Illuminated Engineers Society IES
- Institute of Electrical and Electronics Engineers IEEE
- Instrument Society of America ISA
- Insulated Power Cable Engineers Association IPCEA
- International Electrotechnical Commission IEC
- International Standards Organization ISO
- Japanese Architectural Standard Specification JASS
- Japanese Electrical Manufacturers Association JEMA
- Japanese Electrotechnical Institute JEC
- Japanese Industrial Standards JIS
- Manufacturers Standardization Society MSS
- National Association of Corrosion Engineers NACE
- National Electrical Code (USA) NEC
- National Electrical Manufacturer's Association (USA) NEMA
- National Electrical Safety Code NESC
- National Fire Protection Association NFPA
- National Structural Code for Building NSCB
- Occupation Safety and Health Administration OSHA
- Portland Cement Association PCA
- Properties of Water and Steam IFC
- Scientific Apparatus Manufacturers Association SAMA
- Society of Automotive Engineers ASE
- Standards of Japanese Electrotechnical Committee JEC
- Steel Structures Painting Council SSPC
- Technische Vereinigung der Grosskraftwerksbetreiber VGB
- Tubular Exchanger Manufacturers Association TEMA
- Underwriters Laboratory UL
- Uniform Building Code UBC
- Verband Deutscher Elektrotechniker VDE
- Verein Deutscher Ingenieure VDI
- Vereinigung Deutscher Elektrizitätswerke (Association of German Power Plants) VDEW
- Water Pollution Control Federation WPCF

Generally, all internationally and nationally recognized standards as above will be applied, except if specific standards called for by:

a) Occupational Safety Board of Bangladesh
b) Department of Inspection for Factories and Establishments, Bangladesh
c) Department of Environment, Bangladesh
d) Bangladesh Power Development Board
e) Bangladesh Energy Regulatory Commission
f) Ministry of Power, Energy and Mineral Resources

g) Bangladesh Fire Service and Civil Defence Ministry
h) All relevant Bangladesh National Statutory Regulations
i) Bangladesh National Building Code
j) Bangladesh Standards
k) Local Authorities.
All steam boilers and unfired pressure vessels together with associated pipework and fittings shall comply with the Bangladesh Boiler Act, 1923 with amendments.

All pressure parts shall be designed in accordance with applicable ASME codes.

All services, supplies and works shall comply with the requirements of the relevant laws of Bangladesh and the IFC/World Bank Group Standards and Guidelines in their latest edition, including but not limited to:

- Environmental Conservation Rules
- Bangladesh Energy Regulatory Commission Act;
- BERC Licensing Regulation
- BERC Technical Quality Standards;
- Bangladesh National Building Code;
- other applicable laws in Bangladesh;
- IFC Performance Standards on Environmental and Social Sustainability;
- IFC / World Bank Group Environmental, Health and Safety (EHS) General Guidelines;
- IFC / World Bank Group EHS Guidelines for Thermal Power Plants;
- IFC / World Bank Group EHS Guidelines for Electric Power Transmission and Distribution.

It is the Contractor's responsibility to provide sufficient evidence that any national or other standard the Contractor proposes (other than those mentioned above) will ensure an equivalent or higher standard.
Immediately after effective date of the Contract the Contractor shall supply an indexed list of all standards, codes and associated standards referred to, to which the work is to be performed. A copy of all applied standards shall be forwarded to the Employer. The Contractor shall supply preferably two (2) searchable softcopies, else two (2) hardcopies each.

3.12 Plant and equipment identification

All design submissions shall include a detailed labelling list indicating the label text, size of the lettering and fixing details for the approval of the Employer or its representative.

The identification and numbering of equipment, systems, items, etc. of supply, as well as of all documents and drawings shall be in accordance with the VGB guideline RDS-PP (Reference Designation System for Power Plants - KKS system).

There is to be only one approved description for any one item of Plant and this must be used consistently for Plant, electrical and instrumentation designations throughout.

The supplier shall supply all labels (Equipment Identification Plates), nameplates, manufacturer's equipment nameplate, instruction and warning plates necessary for the identification and safe operation of the Plant, and all inscriptions shall be in the English language and Bangla language.

All labels, nameplates, instruction and warning plates shall be securely fixed to items of Plant and equipment with stainless steel rivets, plated self-tapping screws or other approved means. The use of adhesives will not be permitted.

Nameplates for Plant and equipment identification and record purposes shall be manufactured from stainless steel or aluminium with a mat or satin finish, and engraved with black lettering of a size which is legible from the working position.

Warning plates shall be manufactured from stainless steel or aluminium engraved red lettering on a white background and sited in the position where they afford maximum safety of personnel.

All equipment within panels and desks shall be individually identified by satin or mat finish stainless steel or aluminium labels.

Each circuit breaker panel, electrical control panel, relay panel, etc. shall have a circuit designation label on the front as well as on the rear panels engraved with black lettering in accordance with the circuit designation system. Circuit designations must be precise and convey complete information. There should be no doubt whatsoever for the operation as to which area of the Plant a particular feeder is supplying with power. Labels such as interconnector 1 or feeder 2 are not acceptable. Corridor type panels shall in addition have circuit designation labels within the panels.

Pipework systems shall be identified with a colour identification systems in conformity with the colours according to the Employer's specification, with colours at the nameplates and, if necessary by colour bands and with KKS numbering and plain language. The direction of flow shall be shown.

Each valve/instrument shall be fitted with a stainless steel or aluminium nameplate indicating the valve/instrument service and reference number in accordance with the approved equipment coding system.

Where possible valve nameplates shall be circular and shall be fitted under the hand-wheel captive nut. They have to be of such a diameter that there is no danger for persons operating the valve or that they do not prevent lock-off of this valve; on check valves and small valves the Contractor may provide rectangular nameplates fitted to brackets on the valve or attached to a wall or steelwork in a convenient position adjacent to the valve.

Marking and labelling

Each crate or package is to contain a packing list in a waterproof envelope. All items of material are to be clearly marked for easy identification against the packing list.

All cases, packages, etc. are to be clearly marked on the outside to indicate the total weight, where the weight is bearing and the correct position of the slings and are to bear an identification mark relating them to the appropriate shipping documents.

All stencil marks on the outside of cases are either to be made in waterproof material or protected by shellac or varnish to prevent obliteration in transit.

3.13 Corrosion protection, coating and galvanizing

This specification shall be used for the corrosion protection of steel structures, components, piping and equipment in general which are installed in confined areas (indoors) or outdoors.

Surface preparation, as well as protective coatings and coating systems are based on this specification in order to assure that structural parts of different suppliers will get a corrosion protection of similar and high quality.

Coating material shall only be supplied by manufacturers with international experience and their products can be obtained internationally.

Regarding maintenance work (storage), application and supervision of coating work, choice of coating suppliers should be minimized. At any rate, similar parts of structures/components (such as structural steel, containers, piping, etc.) shall only be coated with products of one individual Manufacturer.

The materials and equipment used, the methods of application and the quality of work shall at all times be subject to the inspection and approval of the Employer or his Representative.

To mitigate crevice corrosion, the designs and construction of structures and equipment shall ensure that no collection of water occurs in crevices which could lead to crevice corrosion. It is the responsibility of the Contractor/Supplier to ensure that, for all supplied equipment (including that from sub suppliers):

- The protection system is perfectly suitable for the Site conditions and for the specific purpose.
- The shop paints provide a sufficient protection during transport, storage and erection.
- The shop paints are suitable for handling and erection conditions (slinging, Site welding works etc.) and are compatible with the Site finishing coats
- All necessary precautions are taken in order to prevent damage to paints during storage, handling, welding.
- The necessary repairs are carefully executed as soon as possible.
- The colour RAL number of the finishing coat has been approved by the Employer, including identification code for piping.
- Standardised equipment will be painted according to the manufacturer's standard.

• All corrosion protection and coating on site shall be done in a workshop specifically for the purpose of the application of corrosion protection and coating.

Codes and standards

Applicable standards are:

• Product data of coating manufacturer
• DIN 2403 Indication of pipe-lines according to flowing material
• DIN 4762 Surface roughness
• ISO 8503 Surface roughness
• DIN 8201 Part 1-9 tight blasting agents
• DIN 50976 Corrosion protection, hot dip batch galvanizing of single parts, requirements and testing
• DIN 55928 Part 1-9 corrosion protection of structural steel work through protective coatings and topcoats
• ISO 8501 Preparation of steel substrates before application of paints and associated products
• ISO 12944 Paints and varnishes – corrosion protection of steel structures by protective paint systems
• RAL Colour card
• ISO 8501-1 Preparation of steel substrates before application of paints and related products
• SSPC Vol. 1 and 2 Steel structure painting council

SURFACE PREPARATION AND CLEANING OF SURFACES IN THE SHOP

Prior to blasting, areas have to be cleaned from oil, grease, paint residues, splatters, welding splashes and welding slag using a suitable aqueous degreaser, or solvent for more severe grease contamination. The cleaning should be to provide a "water break free surface".

Sharp edges have to be rounded off.

Contaminations caused by salts, acids and alkali solutions shall be eliminated by rinsing with water up to a pH value of 6-8. Soluble salt contamination is to be tested using the Weber Reilly test method (or similar approved) and pH is to be tested using universal indicator paper strips prior to continuation with the blasting.

The preparation of substrates shall be carried out on the basis of the specifications of ISO 12944 part 4 and ISO 8501. The preparation of steel before application of paint and related products shall be in line with ISO 11124 for metallic blast cleaning abrasives and ISO 11126 for non-metallic blast cleaning abrasives. No recycled blast grit may be utilised.

After blasting, an anchor profile of 25 - 50 µm shall be achieved. Blasted surfaces have to be provided with a prime coat of the approved coating system immediately within 4 hours of blasting. All blasting and priming must take place outside of the high humidity periods of the day (i.e. maximum relative humidity of 80%).

Cleaning of prime and intermediate coats (if required)

To prevent contamination by mineral oil products, areas with prime and intermediate coat have to be treated with suitable cleaning agent. Cleaning has to be done free of residues, e.g. with alkaline detergents and thorough washing done with fresh water. Rusty spots have to be removed according to required purity. Metallic areas which are provided with temporary corrosion protection have to be cleaned. No oxidation products shall remain on the surface. Further care shall be taken that on hot components, no destructive or reaction products will be released when heating which could injure insulation.

Application procedure

When using the provided coating material, strict adherence to all application instructions given in product data of coating manufacturer is necessary. To obtain the maximum performance, technical data as well as application instructions for the individual coating material have to be strictly followed. For a multi-layer coating system each layer has to have a different colour shade in order to clearly identify number of coats applied.

The last finish coat has to be applied in the specified colour shade.

All paintings shall be performed according to ISO 12944. The durability of all paintings shall be "high" which corresponds to 15 years.

The interval between applying the different coats has to follow according to supplier's precautions. Each layer has to be cleaned and released from spray dust before the next layer will be applied. Prior to applying a further layer, the last one has to be repaired. All coatings have to be applied without retarding.

Following application procedures are allowed:

- prime coats by airless spray
  areas like disconnections, angles, corners, etc. which are difficult to be reached can be applied by brush or roller
- repair of prime coat by brush
- finish coats
  - at works by airless spray, roller or brush
  - at site by roller or brush or airless spray.

When applying coating systems by roller, rollers have to be of kind and quality which make an appropriate application possible.

Control areas in accordance with the coating supplier's instructions have to be applied. For this procedure, a schedule for control areas has to be prepared by the Contractor and coating supplier which corresponds with the requirements of the warranty agreement.

Number and performance of the control areas have to be done in accordance with ISO 12944 part 7 and have to be documented in writing.

No application shall take place either in the condition of the relative humidity not within the given limit or in case of poor weather conditions such as fog, dust, rain, snow, hail or when it can be assumed that such conditions of poor weather will arise within 2 hours after application.

Temperature of the coated parts has always to be above 5 °C and 3 K above dew point.

All specified dry film thicknesses (DFT) are minimum thicknesses.

Welding seams executed at site have to be taped with an adhesive tape of about 30-50 mm after surface preparation (blasting or manual derusting) and prior to application in the manufacturing plant and to be coated with stripping coat.

Chequered plates, nap plates, etc. have not to be covered with adhesive tape, but have to be coated with stripping coat in a dry film thickness of at least 150 µm.

Edging lines on steel structure have to be taped prior to application and after blasting in sufficient width or have to be protected with varnish before application. Thickness of prime coat may be 50 µm maximum.

During repairing works at site on shop-primed structures, it is important that different coats will have different colour shades. Numbers of layers have to be the same as the original coating system to be used.

Application of temporary primer on structures which have to be insulated has to be in accordance with a sufficient corrosion protection for the period of storage respectively erection time.

Galvanizing

Galvanizing work shall conform in all respects to ISO 1461 or equivalent standards and shall be performed by the hot dip process unless otherwise specified.

It is essential that details of steel members and assemblies which are to be hot-dip galvanized should be designed to suit the requirements of the process. They should be in accordance with ISO 12944.

Vent holes and drain holes shall be provided to avoid high internal pressures and air locks during immersion and to ensure that molten zinc is not retained in pockets during withdrawal.

Careful cleaning of welds is necessary before welded assemblies are dipped. All defects of the steel surface including cracks, surface laminations, laps and folds shall be removed in accordance with BS 4360. All drilling, cutting, welding, forming and final fabrication of unit members and Assemblies shall be completed, where feasible, before the structures are galvanized.

The minimum coating thickness shall be as specified in Table 1 of BS 729. Structural steel items shall be first grit-blasted to BS 4232, second quality, (Sa 2 1/2) or pickled in a bath, and the **minimum average coating weight on steel Sections 5 mm thick and over shall be 900 g/m², on steel Sections 2 – 5 mm thick 600 g/m².**

Galvanized contact surfaces to be joined by high-tensile friction-grip bolts shall be roughened before assembly so that the required slip factor is achieved. Care shall be taken to ensure that the roughening is confined to the area of the mating faces.

Protected slings must be used for off-loading and erection. Galvanized work, which is to be stored at the works or on site shall be stacked so as to provide adequate ventilation for all surfaces to avoid wet storage staining (white rust).

Small areas of the galvanized coating damaged in any way shall be restored by:

- cleaning the area of any weld slag and thorough wire brushing to give a clean surface
- The application of two coats of zinc-rich paint, or the application of a low melting point zinc alloy repair rod or powder to the damaged area, which is heated to 300 °C or the treatment with suitable cold galvanizing paint, such as ORAPI n.z.a.b 706. All zinc rich paint used for such repairs must contain a minimum of 81% by mass of zinc in the dry film.

Connections between galvanized surfaces and copper, copper alloy or aluminium surfaces shall be protected by suitable tape wrapping.

Coating Systems

System-No.	Surface location	Temp. °C	Surface preparation	Coating systems	No. of coats	Generic type	Dry film thickness (DFT) per coat µm	Total DFT µm
1	Structural steel works, piping, vessels, tanks INDOOR	up to 120	SA 2.5	Primer Finish	1 1	Zinc-Epoxy Epoxy High Solid	80 80	80 80 **160**
2	Structural steel works, piping, vessels, tanks OUTDOOR	up to 120	SA 2.5	Primer Intermediate Finish	1 1 – 2 1	Zinc-Epoxy Epoxy High Solid 2-Comp.Polyurethane	80 160 50	80 160 50 **290**
3	Piping, tanks, etc. INDOOR and OUTDOOR, Insulated	up to 120	SA 2.5	Primer	1	Zinc-Epoxy	50	50
4	Pumps, motors, other equipment OUTDOOR	up to 120	SA 2.5	Primer Intermediate Finish	1 1 1	Zinc-Epoxy Epoxy High Solid 2-Comp.Polyurethane	80 110 50	80 110 50 **240**
5	Pumps, motors, other equipment INDOOR	up to 120	SA 2.5	Primer Finish	1 2	Zinc-Epoxy Epoxy High Solid	80 50	80 100 **180**
6	Piping, reactors OUTDOOR Insulated	> 120	SA 2.5	Primer	1	Zinc Ethysilicate	75	75
7	Stacks OUTDOOR	< 120 < 200	SA 2.5	Primer Finish	1 2	Zinc Ethysilicate Silicone Acrylic	75 50	75 100 **175**
8	Steel surfaces Uninsulated	200 - 450	SA 2.5	Primer Finish	1 2	Zinc Ethysilicate Silicone Aluminium	75 25	75 50

								125
9	Galvanized surfaces	up to 120	Mechanical cleaning from contaminants and zinc salts by means of washing or steam jetting or sweep-blasting with fine sand	When Finish Coat is required, such as sea climate with chloride exposure	1	Epoxy High Solid*	125	125
10	Steel surfaces permanently in contact with water, also river water splash zone	Medium temp. °C up to 60	SA 2.5	Prime and Finish Coat in One	1	Glassflake reinforced High Solid Epoxy	500	500
11	Plant / Cooling water pipes	GRP, or steel lined concrete pipes with cathodic protection and coating according to AWWA C 203						

* Additional 1 x Finish Coat 2-Comp. Polyurethane, 50 µm, when exposed to UV or weathering conditions and colour retention is required.

3.14 Training

The bidder shall provide comprehensive training for Owner's engineering, operating and maintenance staff (Employer's staff) covering all aspects of the Power Plant equipment and systems and operation and maintenance.

The supplier shall train, instruct and supervise the Employer's staff to an adequate standard of knowledge and capability for good trouble shooting, repair and of the plant equipment as well as to an adequate standard for safe and efficient commercial operation of the Plant.

The training shall at least include:

- training at manufacturer's works during the assembly of the major plant items
- classroom and hands on training
- on the job training during erection, commissioning and reliability test run; and
- simulator training.

The supplier shall submit the training plan for the classroom, on the job and simulator training including schedule, place, content of lectures etc. for the Owner's approval.

Post training assessment shall be carried out and documented. In case the results are below expectations (to be agreed upon by both Contractor and Employer before training) the respective training modules shall be repeated in an improved way.

3.15 Spare parts, tools, appliances, and consumables

Spare parts

The bidder shall elaborate a maintenance and spare part concept which ensures that outage times are minimized and that the required availability is met, in particular considering all those components which are not redundant.

An "Initial Spare Part List" shall be provided with the Bid. The "Initial Spare Part List" shall contain all those parts which are required to operate, maintain and repair the Plant efficiently and which are necessary to achieve the guaranteed availability during the warranty period (that means, 24 months from the date of PAC/COD). The "Initial Spare Part List" shall comprise therefore:

- the "Mandatory Spare Parts", which are required for the normal operation and scheduled maintenance / repairs of the Plant - that means, mainly the "wear and tear parts";

- the "Recommended / Strategic Spare Parts", which are in Tenderer's opinion and from Tenderer's experience required to minimize the outage of the Plant - that means, parts which are supposed by a Tenderer to breakdown during the Warranty Period, which may be required for unscheduled repairs, which will lead to outage of the a Unit or the Plant and which will have a longer delivery period.

The Tenderer shall provide details and prices for the "the Initial Spare Parts" by using the provided price breakdown. "The Initial Spare Parts List" shall be contained twice in the Bid: (i) un-priced in the techno-commercial bid, but comprising all technical details, and (ii) priced in the financial bid.
The cost of the "Initial Spare Parts" shall be considered for the financial Bid Evaluation.
In case a Tenderer fails to submit the "Initial Spare Part List" or if the "Initial Spare Part List" is consider by the Employer as non-compliant or insufficient, the Employer shall decide at its sole discretion either to reject the entire Bid as non-compliant or to apply the highest price for spares from the competitive Bids for the financial Bid Evaluation.
A "Final Spare Part List" (segregated as the "Initial Spare Part List") including all details, such as vendor's / original equipment manufacturer's (OEM's) name and location, drawings, normal delivery period, quantity, life time / service life, vendor's/OEM's serial numbers and price etc., shall be submitted by the Contractor to the Employer for approval not later than eighteen (18) months prior to the scheduled Commercial Operation Date (COD) / Issuance of the Provisional Acceptance Certificate (PAC) of the 1st unit.

The Contractor shall name three (3) vendors / OEMs with complete address for each of all required spare parts.

The Spare Parts Lists shall:

- specify fixed unit prices for the Spare Parts ("Initial Unit Prices"), and such fixed pricing shall remain valid until twelve (12) months prior to the COD of 1st Unit (the "Initial Spares Period"); and

- include an agreed indexation mechanism that shall be applied to the "Initial Unit Prices" following the expiry of the "Initial Spares Period", for the Employer's consideration and approval.

The Employer may order spare parts at the Initial Unit Prices at least twelve (12) months prior to the COD of the 1st Unit, and such Spare Parts shall be delivered in due time before the COD of the applicable unit. Spare Parts shall remain available for order anytime during the first three (3) years commencing from the COD of each unit, at the Initial Unit Prices as adjusted pursuant to the indexation mechanism approved by the Employer.

However, the Employer shall have the freedom to decide at its sole discretion to purchase spare parts either from the EPC Contractor (according to the agreed unit prices as stated above) or directly from vendors/OEMs.

All spare parts before COD belong to the Contractor. That means, all spare parts required for commissioning, testing etc. of the Plant up to COD form part of the principal scope of supply and shall be not included in the spare parts lists.

Each item shall be labelled in English and be separately packed against damage and sealed to prevent deterioration from corrosion. The protection shall be sufficient for a minimum of 10 years storage in a dry weatherproof building.

If during warranty period the Contractor is allowed to use spare parts from the spare part stock, the Contractor has the obligation to order new spare part at short notice and to replenish the spare part stock.

The Contractor shall not use any of the spare parts without written permission from the Employer.

Tools and appliances
The following tools and appliances shall be supplied under this Contract for use by the Employer:

a. two (2) sets of all special tools and gauges required for the operation and maintenance of the Plant
b. one (1) set of special lifting and handling appliances required for the operation and maintenance of the Plant
c. suitable storage bins/racks/shelves for the above.
d. Standard tools according to the relevant Technical Schedules.

Each tool or appliance is to be clearly marked with its size and/or purpose.

Each set of tools and appliances under category (a) and (d) shall be suitably arranged in fitted boxes of mild steel construction, the number of boxes being determined in relation to the layout of the Plant and equipment in question. If the weight of any box and its contents should be such that it cannot conveniently be carried, it shall be supported on steerable rubber-tyred wheels.

Each cabinet and box shall be painted, fitted with a lock and clearly marked in white letters with the name of the item of equipment for which the tools and appliances contained are intended.

Suitable lifting lugs, ears or ring bolts, or tapped holes for lifting rings shall be provided on all equipment items where the weight exceeds 15 kg. All lifting tackle shall be stamped with a unique identification number and safe working load. A test certificate from an approved authority shall be supplied for each item of lifting tackle.

The Contractor shall provide a schedule of all lifting tackle and tools and appliances being supplied, for the approval of the Employer/Engineer.

Where the Contract includes site erection, any special tools or appliances required solely for erection shall be provided by the Contractor for his own use and shall remain the property of the Contractor.

3.16 Documentation after Award of Contract

The documents required for design, construction, installation, operation and maintenance of the equipment t shall be submitted by the bidder in good time so as to permit the Plant as a whole to be erected in compliance with the specified time table.

All documents, including the installation and operation and maintenance manuals as well as the related software shall be in fluent, legible English. In addition, operation and maintenance manuals shall be translated into Bangla and provided as paper copies and in electronic format.

The bidder shall list all the drawings and submission schedule for the Employer's approval. These documents shall be submitted sufficiently in advance, so that corrections and amendments desired by the Employer as well as resubmission of the documents will not result in any delays with respect to the guaranteed time schedule. The Employer reserves the right to request from the Contractor additional drawings, documents, etc. as may be required for proper understanding and definition of the design and engineering of the Plant.

The overall responsibility with regard to completeness, correctness and suitability for the permit application process remains with the Contractor. In no case any comment, correction, amendment and approval (if any) by the Employer shall relief the Contractor from this responsibility.

The drawings and documents to be submitted during this stage shall be listed. They shall be submitted within the specified time scale calculated in weeks after Award of Contract.
Details shall be agreed according to the approval procedure for drawings and documents above.

The Contractor may propose modifications to the list, in order to ensure timely completion of permit application documents and performance of the works according to the project's requirements and in accordance with the specified project time schedule. Any modification to
this list shall be submitted for Employer's review and approval.

The Employer reserves the right to require detailed information on the progress of drawing and document preparation from the Contractor at any time during this stage.

Approval procedure for drawings and documents

The Employer reserves the right to ask the Contractor to submit drawings and other documents for approval to the Employer or to its representative.

Before submittal of any such drawing or other document, the Contractor shall submit a detailed list comprising all drawings or other documents the Contractor will produce. Based on this list the Employer will decide which drawings or other documents will have to be submitted for approval, information or other purpose.

When submitting drawings or other documents for approval, including any prepared by subcontractors, the Contractor shall certify in each case that he has examined such drawings or documents and that they comply with the requirements of the Contract.

The Contractor is requested to provide Third Party Verification of structural documents, e.g. structural analysis, drawings and connecting details prior to submission for approval. These documents must contain all information necessary for the execution of the works.

Approval of a drawing or other document will imply that:

- They have been examined and appear to be in accordance with the basic design concept of the project and meet the requirements of the specification.

- They have been examined in relation to compatibility of the items and equipment with the specification and respect of interconnections with other items, equipment or systems.

- The Contractor is not relieved of his responsibility under the Contract. The Contractor is to arrange for the revision history of drawings and other documents as follows. The first revision shall be indexed by the letter "A" followed up by the respective letter in alphabetical order.

Once the drawing or document is approved for construction by the Employer or its representative the document shall be indexed with the number "0" followed up by the respective number in chronological order. Hence, the sequence of the revision index of a design document shall be as follows: A -
B - C - [...] - 0 - 1 - 2 - [...]. Each revision is to be listed in the revision history with the respective date and a short description of the modification(s). In addition, all modification(s) shall be highlighted and/or marked up as specific and detailed as possible.

Furthermore, each drawing/document shall be indicated with a unique document number according to the following standard:
Maitree – Unit – KKS – DCC - 12345 – XYZ – REV
Where:
Maitree Project-Denomination
Unit - 00 (for common), 01 (for unit 1), 02 (for unit 2)

KKS - Function Key as per KKS system (1 to 3 letters)
DCC - DCC code according to EN/IEC 61355
12345 - Document number
XYZ - Sub-/Contractor number
REV - Revision index
For each comment, the Employer will allocate a priority in the TCS (Technical Comment Sheet). The priorities range from 1 to 3 as follows:
1 - High Priority
2 - Medium Priority
3 - Low Priority
The TCSs are to be named with the above described identification key and the supplementary ending "... - RI" ("Revision Income") for TCSs being sent from the Contractor to the Employer and "... - RO" ("Revision Outcome") vice versa.
The Contractor shall be responsible for any discrepancies, errors or omissions in the drawings and other documents supplied by him, whether such drawings or other documents have been approved or not.

3.17 Quality control procedure

A comprehensive **quality control procedure / quality assurance programme** for all aspects of the products/works shall be prepared by the Supplier/Contractor and shall be submitted to the Employer for approval.
The Supplier/Contractor shall adopt suitable quality assurance programme (QAP) to ensure that the equipment and services under the scope of Contract whether manufactured or performed within Contractor's works or at his subcontractor's premises or at the site or at any other place of work are in accordance with the specifications. Such QAP shall be outlined by the Supplier/Contractor and shall be finally accepted by the Employer or his authorized representative after discussions before the start of work. The QAP shall be generally in line with ISO Systems.
The quality assurance program shall consist at least of the following:

- testing during manufacturing
- workshop inspections and testing
- factory acceptance tests (FAT)
- testing at site
- construction inspections and testing
- erection / mechanical completion
- pre-commissioning and commissioning tests (cold and hot commissioning)
- optimization of overall Plant
- final inspection and testing
- Bench mark testing
- completion test
- performance tests
- reliability test run.

An outline of the proposed comprehensive quality assurance programme is to be provided with the Tender and is subject to review by the Employer.

The Supplier/ Contractor shall provide complete laboratory facilities and staff to perform the required tests. The facilities could be fully or partially on site. Arrangements could be made with an experienced testing laboratory to support the site laboratory, all subject to the approval of the Employer.

Only approved fully qualified and experienced staff shall carry out the quality control all in accordance with the approved quality control procedure.

The Supplier/Contractor shall appoint a dedicated, experienced and competent QA&QC in-charge at site, preferably directly reporting to the project manager, supported as necessary by experienced personnel, to ensure the effective implementation of the approved QAP. An indicative structure of Contractors QA&QC manpower required to be deployed at site shall be submitted with the Tender.

The results of the tests shall be made available to the Employer within 24 hours of obtaining the relevant test results. Acceptance of the relevant part of the work shall be subject to the performed tests showing satisfactory results. Individual construction completion certificates shall be issued by the Contractor to certify the readiness for equipment erection.

The Employer may instruct tests at no cost provided either the overall frequency governed by the specification is not exceeded and the notification given to the Contractor is equal to that currently being provided by the Contractor for his normal testing in formality and warning, or the Employer has due cause to suspect a change in the quality, such concern having been advised to the Contractor. The Employer may instruct sampling, testing or both which satisfy only some or none of the above criteria.
The Employer shall have the right to carry out independent inspections and testing either using his own resources or those of a third party. Should the Employer require the results to determine the conformance with the specification then he shall notify and inform the Contractor.

As far as is practicable the Employer shall have free access to the site, fabrication areas and suppliers work at all times without notice. Should he discover unsatisfactory work then he will invite a formal joint inspection. Either after such an inspection or if the Contractor declines the invitation the Employer shall issue instructions with regard to the faults and their reparation.

Should any materials, items or complete parts of the equipment/works fail to comply with the requirements of this specification when tested in accordance with this Section the Employer may reject such materials or items, or condemn complete parts of the equipment/works, and demand of the Supplier/Contractor such replacement or modification as may be necessary to ensure their compliance.

Should modification or adjustment be deemed a satisfactory alternative to demolition and /or removal, the Contractor shall submit full details in writing such modifications to the Employer for approval, and should such approval be forthcoming carry them out without undue delay.

If however, the Supplier/ Contractor is required to demolish and /or remove any such items or materials this shall be carried out quickly and with as little disruption to the works as possible.

No claims of any sort whatsoever will be entertained arising from the rejection of any part of the products/works through failure to meet this specification, and repairs, demolitions, removals, additional testing etc. Such modifications, removal, demolitions etc, shall be entirely at the expense of the Supplier/Contractor. No extension of the Contract period shall be granted for such a reason.

If for any reason materials or other items are received or made on site before approval of them has been granted, these shall be transported, handled and stored separately or labelled in such a way in order to, wherever possible, prevent them being incorporated into the works or, should such prevention not be possible, to accurately define the part(s) of the works in which such materials or items were used.

Approvals previously granted for any materials etc. shall be withdrawn if they are not properly transported, handled which may adversely affect their properties and subsequent performance. The Supploer/Contractor has the option of removing such materials or having them retested for approval.

The Contractor shall submit to Employer, the quality plans and field welding schedules (for field weld of pressure parts only), along with test procedures and WPS endorsed by designer wherever applicable, for checks to be done during manufacturing and erection, for review and approval by Employer.

Interfaces

The Supplier/Contractor shall actively clarify all interfaces with the Employer, the Operator, PGCB and all companies, authorities and any other entity participating in the project.
All mentioned equipment, connections, connection materials, counter flanges, shut-off valves, safety valves, seal up material and works are included in the scope of supply.

3.18 Units of measurement

The Contract shall be conducted in the Systems International d'Units (SI) system of units in accordance with the provisions of ISO 31 and ISO 1000. In all correspondence, technical schedules, drawings and instrument scales, the following units shall be used:

Quantity	Name of Unit	Symbol
Length	Millimeter	mm
Mass	Kilogram	kg
Time	Second	s
Temperature	Degree Celsius	°C
Temperature Difference	Kelvin	K
Electric Current	Ampere	A
Luminous Intensity	Candela	cd
Area	Square meter	m^2
Volume	Cubic meter Liter	m^3 l
Force	Newton	N
Pressure	Bar	bar
Pressure below 1 bar	Millibar	mbar
Stress	Newton per square millimeter	N/mm^2
Velocity	Meter per second	m/s
Rotational speed	Revolutions per minute	rpm
Flow	Cubic meter per day Cubic meter per hour Kilogram per hour Liter per second metric ton per hour	m^3/d m^3/h kg/h l/s t/h
	For gaseous substance: standard cubic meter per hour	Nm^3/h
Density	Kilogram per cubic meter	kg/m^3
	Kilogram per standard cubic meter	kg/Nm^3
Torque, moment of force	Newton meter	Nm
Moment of inertia (mr^2)	Kilogram square meter	kgm^2
Work, energy or heat	Joule	J
Heat capacity, entropy	Joule per Kelvin	J/K
Specific heat capacity, specific entropy	Joule per kilogram Kelvin	J/kgK
Calorific value	Joule per cubic meter Joule per gram	J/m^3 J/g

Quantity	Name of Unit	Symbol
Power, radiant flux	Watt	W
Heat release rate	Watt per square meter	W/m^2
Thermal conductivity	Watt per meter Kelvin	W/mK
Dynamic viscosity	Newton second per square meter	Ns/m^2
Kinematic viscosity	Meter squared per second	m^2/s
Surface tension	Newton per meter	N/m
Concentration	Parts per million	ppm
Electrical conductivity	Microsiemens per meter at 25 °C	µS/m
Frequency	Hertz	Hz
Electric charge	Coulomb	C
Electric potential	Volt	V
Electric field strength	Volt per meter	V/m
Electric capacitance	Farad	F
Electric resistance	Ohm	Ω
Conductance	Siemens	S
Magnetic flux	Weber	Wb
Magnetic flux density	Tesla	T
Magnetic field strength	Ampere per meter	A/m
Luminous flux	Lumen	lm
Illuminance	Lux	lx
Thermal resistivity	Kelvin meter per Watt	Km/W
Energy	Kilowatt hour	kWh

3.19 Hazardous areas, firefighting & prevention systems

Hazardous areas

The Contractor shall take full account of any special requirements concerning the nature, handling and storage of all fuels, flammable gases and chemicals etc., and provide plant, equipment, buildings and other services accordingly, including all facilities to ensure the safety of the operating and maintenance personnel.

The Contractor shall provide drawings to define all the hazardous zones taking account of all sources of hazards under normal and abnormal operating conditions (regardless of whether or not these areas are specifically listed in the specification). The zoning philosophy shall be subject to the approval of the Employer. All equipment necessary for mounting in these areas shall meet the requirements of BS 5345 or equivalent.

In particular, equipment directly concerned with Plant which may give rise to a hazardous situation shall be designed to IEC 60079 Zone 1 or 2 requirements with electrical connection safety barriers or intrinsically safe equipment equivalent to VDE 0171 Type Exi. Where required by the Employer/Engineer, certification shall be provided to confirm the suitability of the equipment and devices.

The Contractor shall be responsible for ensuring that all electrical equipment installed in any hazardous zone is designed and tested to suit the relevant zone classification and shall be to the approval of the Employer. Cables shall not be laid in trenches etc. with fuel pipe work.

Maintenance isolation

All major equipment shall be arranged to facilitate safe isolation from all hazards for maintenance purposes. In addition all valves must be capable of being locked either in the open or closed position by means of a chain and padlock.
Non return valves are not acceptable as a means of isolation.

3.20 Materials

General material requirements

All materials shall be new and of the best quality for use in the conditions and the variations in river water quality, the temperature and pressure that will be encountered in service without undue distortion or deterioration or the setting up of undue strains in any part that might affect the efficiency and reliability of the Plant.

All materials shall correspond either to the approved standards and the respective code number or to exact analysis data, and full information concerning properties and applied heat, chemical and mechanical treatment shall be submitted.

Special attention must be paid to eliminating the possibility of corrosion resulting from galvanic effects. Design, selection of materials and all methods of erection shall be such as to keep these effects to a minimum. Materials complying with codes and standards listed below shall be used for the design and construction work.

Unless the materials meet these codes and standards the equivalent ASME/ASTM standard shall be used.

Materials and standards

Materials and standards

(A)	a.	Structural Steel Built-up Members	DIN EN 10 027-1	all steel brands S235 and S355
			Formerly DIN 17100 and EN 10 025	Formerly St, USt & RSt37-2, St37-3, St52-3 or Fe360B, BFU, BFN, C & D1, and Fe 510
	b.	Structural Steel Hot Rolled Members	DIN 1024 Series DIN 1025 Series	all steel brands S235 and S355,
			DIN 1026 Series DIN 1027 Series DIN 1028 Series	Formerly St, USt & RSt37-2, St37-3 and St52-3; or Fe360B, BFU BFN, C & D1, and Fe 510
			DIN 1029 Series	
	c.	Structural Steel Tubes	DIN EN 10 210-1,2	S235 and S355
	d.	Crane rail	DIN 4132	
(B)	a.	Bolts and Anchor Bolts	DIN ISO 898, DIN 18 800-1	4.6 (fy ≥240 N/mm²) 5.6 (fy ≥300 N/mm²)
	b.	High Strength Bolts	DIN ISO 898, DIN 18 800-1	8.8 (fy ≥640 N/mm²) 10.9 (fy ≥900 N/mm²)
	c.	Stud Bolts	DIN 32 500, Part 1 & DIN 18 800-1	4.8 (fy ≥320 N/mm²)
			DIN 32 500, Part 3 & DIN 18 800-1	St 37-3 per DIN 17 100, (fy ≥350 N/mm²)
(C)	Electrodes for Arc Welding		DIN 1913/ DIN EN 499	
(D)	Ordinary Portland Cement		DIN 1164-1 / 1164-2 EN 197-1	
(E)	Reinforcing Bars		DIN 488-2 / 488-4	

Structural steel

DIN 18800 / DIN 18801 / DIN 18807 shall be followed.

For all above mentioned material standards, the equivalent standards as per BS, ASME/ASTM are also accepted.

Structural steel works

Materials

All ferrous materials, their dimensions, forms, weights, tolerances, chemical and mechanical properties, shall be the best of their kind, complying with relevant international Standards.

All structural steel material shall be minimum S235 for rolled steel shapes, angles, tees, plates, etc. having a minimum yield stress of 235 N/mm².

In the case of structural steel work, care shall be taken that all parts in the assembly fit accurately together and corresponding parts shall preferably be interchangeable.

The supplier shall submit to the Employer for approval the country of origin and manufacturer of the steel he proposes to supply.

The structural steelwork and testing shall comply with the relevant clauses of BS 4, BS EN 10162, BS 4360 and BS 6323 or equivalent standards.

Each steel part shall be marked with the manufacturer's name or trademark.

The steelwork shall be manufactured by a specialist firm approved beforehand by the Employer. As much of the work of manufacturing of the steelwork as is reasonably and technically practicable shall be executed in the manufacturer's works, and facilities for inspection by the Employer shall be provided.

All steelwork before and after manufacturing shall be smooth, un-deformed, straight and free of cracks, twist and burrs. All steelwork shall be cut and fabricated to a tolerance of ± 1.5 mm in its length. All plates shall be truly at right angles to the longitudinal axis of the section. No work shall be painted, packed or dispatched from the manufacturer's works until it has been inspected and complies with or has been certified to comply with all the tests and requirements of the standard applicable to the material specified and until it has been inspected and approved.

Tests

The manufacturer's test certificate for all steelwork shall be supplied to the Employer. The certificates shall state the manufacturing process and shall include a test sheet giving the results of the mechanical tests and the chemical composition. The supplier shall provide free of charge any supplementary tests reasonably required by the Employer. Steel which do not conform to the specified standards shall be rejected at the expense of the supplier. No steelwork shall be delivered from the manufacturer's works until it has been tested and the results comply with the requirements of the relevant standards.

Workmanship

Tolerances

Care shall be taken to ensure that the tolerances specified on the drawings or the relevant standards are worked to. The erection tolerance for cleated ends of members connecting steel shall be not greater than 2 mm at each end. No work shall be painted, packed or dispatched from the manufacturer's works until it has been tested and complies with all requirements of the standards.

Cutting

Cutting may be by shearing, cropping, sawing or machine flame cutting. Hand flame cutting shall be avoided. If rolled products for steel structures under predominantly static loading are cut by flame-cutting or shearing there will generally be no need for a finishing operation if the cut surface is free of defects.

Bolting

The threaded portion of each bolt shall project through the nut by at least one thread. Approved high strength friction grip bolts, preferably the type with indicated load, shall be used where specified and shall be tightened strictly in accordance with the manufacturer's instructions and the relevant regulations. The surfaces in contact shall not be painted and shall be free of oil, dirt, loose rust, burrs and other defects, which would prevent proper seating of the parts or interfere with the development of friction between them.

When connections are made using high strength friction grip bolts the relevant standards shall be observed.

Welding

The execution and testing of welding shall be in accordance with BS EN 1011-1, BS EN 1011-2 or equivalent standards.

All welds, unless otherwise stated shall be continuous minimum 6 mm fillet weld and shall be dressed smooth, free of porosity, cracks, holes and finished to match adjacent surfaces. When welding operations are completed, all welding flux shall be removed without delay. Cooling of welds shall not be accelerated by any special measures.

Site welding shall be restricted to the absolute minimum. Site welding is subject to approval by Employer. The examination of welded work and the inspection of welds during and after manufacture shall be carried out by responsible specialist welding engineers. Welding shall be carried out by expert trades men and in strict accordance with the current code of practice.

Painting

Surface treatment and painting before and after delivery to site shall be done.

Parts to be encased in concrete shall not be painted or oiled. Surfaces inaccessible after shop assembly shall receive the full-specified protective treatment before assembly.

Erection

The Contractor shall supply all suitable plant, hoisting gears and tackles for the erection of the steelwork and shall provide all temporary baulks, struts, shores, etc.

Steelwork damaged due to inadequate precautions being taken during the storage, transport and erection of the steelwork shall be made good to the satisfaction of the Employer at the Contractor's expense.

All shop connections shall be made by electric welding. All site connections shall be bolted unless otherwise specified in drawings or directed by the Employer.

Encased steelwork and steel in foundations shall be solidly encased in concrete with a minimum cover of 100 mm. Anchors of the required structural strength shall be used as holding down anchors in concrete foundations for columns. Sole plate of the column shall be grouted with low shrinkage grout of 50 mm nominal thickness.

The grout shall be shaped with an inclination of 45°from the lower edge of the sole plate to avoid stagnant water.

Rejection

Any steelwork, which in the opinion of the Employer is not in accordance with the requirements of the standards or with the specifications, shall be mandatory rejected and removed from the site at the Contractor's expense.

Small non-structural steel parts

General

This Clause refers to the specifications covering the provision of all materials and labor in relation to supply and manufacture on site of articles made of steel or cast iron.

All steel structures and parts specified under this clause shall be hot dip galvanized and painted.

The list of small items to be furnished shall contain but not be limited to the following:

- steel sections, bent plate sections and square bars for construction of:
    - metallic stairs, platforms and walkways

- railing for stairs, platforms, walkways and protective around floor openings
- corner and edge protection for concrete steps and concrete
- Structural parts such as columns, beams, removable cover slabs, etc.
- support of any equipment foundation
- joint covers
- Anchors, ties, hangers, inserts, slots, embedded steel parts, etc.

- steel pipes and plain round bars for making guardrails and ladders
- steel plates, chequered and/or flat, for fabrication of removable covers
- Open steel grating for metal steps, platforms, and walkways.

Materials

The requirements for materials of structural steel specified herein are applicable to all steel sections, bars, plates, pipes and any sections as far as their quality, source, dimensions, mechanical characteristics and their delivery, handling, storage and tests on site are concerned.

Specific requirements for high temp./high pressure part materials

The purpose of this part is to provide the additional requirements for the purchase, manufacturing and fabrication of:

- austenitic stainless steels used for high temperature superheater and reheater tubing,
- ferritic/ martensitic steels used for high temperature pressure parts.

All manufacturers and suppliers of the base metals, from raw materials until finished products, shall be ISO 9001:2000 certified for the duration of the contract or being renewed during the duration of the contract as appropriate. Only seamless tubes and pipes are acceptable for power piping. For low pressure systems (< 6 bar (g) welded pipes will be accepted. The welded pipes provided shall be of certified source.

All materials and manufacturing procedures shall be certified by an independent 3rd party. The approval shall be part of the quality documentation.

The use of SA213-T24 material for membrane walls is not accepted.

The material SA213-T23 is known for cracking sensitivity. It shall be demonstrated and documented in the final data package that all such materials are free from any cracks and that all hardness values are within the required limits.

For SA213-T23 the Contractor must provide a detailed procedure for the calculation, design, purchase, manufacturing, erection, cleaning and pressure testing of this material. The relevant ASME code cases must be respected. For SA213 T91 and SA335 P91 the latest stress values and the latest information according to ASME code cases must be used. Also the EPRI „Guidelines and Specifications for High-Reliability Fossil Power Plants Best Practice Guideline for Manufacturing and Construction of Grade 91 Steel Components“ shall be respected.

For SA335 P92 the Contractor shall provide a detailed procedure for the calculation, design, purchase, manufacturing, erection, cleaning and pressure testing of this material. The relevant ASME code cases must be respected. SA213-T92 may be used for header nipples outside of the flue gas pass, while meeting the above mentioned requirements for quality control. The details on preheating for welding and PWHT shall be stated in detail. Special consideration shall be given to record the metal temperatures during manufacturing, erection and operation.

In case of any repair of any of such materials at site the 3rd party engineer must be involved concerning the proposed repair method.

Pre-service cleaning and protection of plant equipment

This clause covers mechanical and pre-service cleaning and protection of the plant items and equipment at the Manufacturer's workshop and at site that are not subsequently to be painted.

Cleaning of fabricated component items shall be carried out after fabrication and final heat treatment or welding at manufacturers' works or at site, as appropriate.

In the event of the surfaces not being cleaned to the Employer's satisfaction, such parts of the cleaning procedures or agreed alternatives as are deemed necessary to overcome the deficiencies shall be carried out at the Contractor's sole expense.

Mechanical cleaning as opposed to alternative chemical cleaning is the preferred method for workshop cleaning except where this is precluded by design or access considerations.

Machined surfaces shall be protected during the cleaning operations. For recleaning small areas, hand cleaning by wire brushing may be permitted. Wire brushes used on austenitic materials shall have austenitic steel bristles. Austenitic stainless steels, copper and aluminium alloys, cast iron, bimetallic and metallic/plastic items, and components fabricated by spot welding or riveting shall not be chemically cleaned. All weld areas shall be suitably stress-relieved before chemical cleaning.

At an appropriate time, the Contractor shall submit drawings of temporary pipework necessary to carry out the pre-service cleaning simultaneously with a list of works to be carried out on the pipelines, heaters, feedwater tanks, vessels etc. to connect the temporary pipework with the parts of equipment to be cleaned.

Further, the Contractor shall submit at the same time the basic draft of the cleaning procedure and of the treatment of wastes.

Not less than six months prior to the commencement of any site cleaning, the Contractor has to submit programs covering all procedures, lists of chemicals, calculations which quote the velocities, temperatures handpipework forces and movements imposed during site cleaning.

All necessary equipment, provisions, chemicals etc. are to be provided by the Contractor.

All tests, analyses, etc. as required are to be performed by the Contractor.

Besides this, the Contractor shall take over all responsibility for the treatment and disposal of wastes according to the local law and to the satisfaction of the Employer.

The date at which cleaning of plant equipment will be carried out at site shall be notified to the Employer at least 20 days in advance.
The Contractor shall take all necessary precautions to ensure that the internal surfaces of all plant are kept clean and free from injurious matter during erection.

When all plant has been erected and lagged or at such other time as may be agreed with the Employer for sub-assemblies, the installation shall undergo a procedure for site cleaning proposed by the Contractor and subject to the approval of the Employer.

Welding

All pressure part welding must follow the requirements of ASME and connected standards.

Welding work and related heat treatment as well as inspections and test shall be performed in accordance with the specific and approved welding procedure specifications (WPS) and the respective material specifications.

WPS shall be prepared in accordance with relevant ASME standards, endorsed by 3rd party / inspector and submitted to the Employer.

Welding plans have to be prepared by every manufacturer for his scope of work.

No welding shall be undertaken until the applicable WPS and Procedure Qualification Record (PQR) are approved by the Employer.

The PQR shall be qualified in accordance with relevant ASME standard. Welding procedures must be qualified by a qualified independent testing authority engaged by the manufacturer.

Welding procedures shall be qualified in accordance with the requirements of the construction code/specification for the Item of plant concerned and in the case of critical plant items the tests shall be witnessed by an internationally recognized inspection authority.

Welders shall be qualified in accordance with the requirements of the construction code/specification for the Item of plant concerned for all types/positions of welding he may perform.

Welder tests shall be carried out in accordance with the approved standards within Contractor's scope. Test results are available for review in the workshops.

If at any time in the opinion of the Employer the work of any welder appears questionable, such welder is required to pass additional qualification tests to determine his ability to perform the type of work on which he is engaged. Any welder failing the retest may, at the discretion of the Employer be disqualified from further welding on items under this Contract.

The 2 first production welds of every welder shall be 100% examined by volumetric NDE and only when the results are acceptable, shall the welder be released for production welding.

A system of positively identifying the work of each welder shall be maintained and any welder whose work is the subject of multiple rejections shall be required to undergo a requalification test. Any welder failing the retest may, at the discretion of the Employer's Representative be disqualified from further welding on items under this contract.

Welded fabrications shall be stress relieved when specified by the applicable standard or for dimensional stabilization prior to machining.
Copies of temperature charts referenced with load items shall be included in the test certification supplied for the relevant items.

All welds shall be visually examined and shall be of smooth contour, free from cracks, undercut and other significant defects. Wherever possible the interior of tubes etc. shall be examined using a suitable optical device where necessary. The manufacturer shall make every effort to avoid any contamination of the tube interior during the manufacturing process. To ensure the tubes are free from obstruction and debris the tubes shall be cleared with a sponge being blown through.

Fillet welds shall be checked for size using suitable gauges which shall be available for use on request by the Employer's Representative during an inspection visit.

For single side butt welds, all root passes shall be welded using a TIG welding process.

Preheating shall be in accordance with the applicable WPS and the respective material specification. The preheat temperature shall be in function of welding process, wall thickness, type of welding consumables, ambient temperature and climatic conditions.

Welding performed outside a workshop is authorised if an approved wind and rain protection (welding bay) is installed around the working place. Anyway, when ambient temperatures falls below 5°C, preheat is required for all ferritic materials and thicknesses. Gas burners or oxy-fuel torches can be used for pre-heating. Preheat shall be maintained over a distance of not less than 4 times the nominal thickness with a minimum of 75mm on either side of the weld. If the material required pre-heating, the same pre-heating shall be done for oxy-fuel or plasma cutting.

Welding consumables such as TIG-rods, electrodes, wires shall be clearly marked in order to avoid any mix-up of material grades. Positive Material Identification to be carried out on where a doubt for mix-up exists.

Any post welding heat treatment (PWHT) shall be performed in accordance with an approved procedure. The procedure shall describe the method, the heat treatment parameters (e.g. holding temperature and time, heating/ cooling rates, heated/insulated band...), the number and location of thermocouples, records and calibration. The procedure shall be available on Site and or in the workshops.

Before welding and/or heat treating valves, valve-manufacturer instructions shall be taken into consideration.

In the case of sensitive materials, grinding of the welds or other grinding work may only be carried out with special grinding wheels so as to avoid overheating or an increase in the hardness of the material.

Welding defects of all kinds must be documented and be available to the Employer on Site or in the workshop.

The Contractor maintains and makes available to the Employer or his representative, both at works and Site, adequately indexed records of all welds, weld inspections, weld controls and repair.

3.21 Electrical equipment and works

Standards

The design and manufacture of all electrical equipment shall comply with the latest editions of the IEC Recommendations if not specified otherwise elsewhere in the specification. Compliance with ANSI/IEEE/NEMA, BS, EN or VDE standards will only be accepted in case no applicable IEC standards are available and subject to approval by the Employer/Engineer.

The Plant shall comply with:

a. the Essential Electrical Requirements of the PPA
b. the latest edition of the Electricity Grid Code of the Bangladesh Energy Regulatory Commission; and
c. the Great Britain Grid Code.

In case of contradictions the order of precedence shall be as follows:

a. Essential Electrical Requirements of the PPA;
b. Electricity Grid Code of the Bangladesh Energy Regulatory Commission;
c. Great Britain Grid Code.

Any other requirements of BPDB/PGCB shall also be considered (if available).

Voltage levels

The following voltage levels shall apply:

• 240/415 V + 10%, 50 Hz	standard voltage for power supplies to small electric power consumers and motors below 160 kW lighting and domestic power outlets
• 240/415 V + 10%, 50 Hz	voltage for power supply of essential electric power consumers - the system shall be operated with un-grouded neutral
• 220 V DC + 10%/-15%	voltage for emergency users of electricity, like turbine emergency oil pumps, circuit breaker control, inverters
• 240/415 V ± 10%, 50 Hz	uninterrupted voltage supplies to consumers, which require uninterrupted infeed like DDCMIS components, control actuators, burner control panels, VDUs.
• 24 V DC ± 15%	for power supplies to the DDCMIS system components
• 24 V ± 10%, 50 Hz	for erection work in enclosed plant items of metal

Insulation levels

• The 400 kV system shall be designed to limit the switching surge overvoltage to 2.3 p.u. and the power frequency over-voltage for the 400 kV system and the 230 kV system to 1.5 p.u. The lightning arrestors associated with the 400 kV reactors shall be of 336 kV.

• Following insulation levels shall be considered:

.	Description	400 kV	230 kV	Generator *	11 kV	3.3 kV
1.	Highest voltage for equipment	420	245	24 or 36	12	3.6
2.	Power frequency withstand voltage	650	460	50 or 70	28	10
3.	Lightning impulse withstand voltage	1425	1050	145 or 170	75	40
4.	Switching impulse withstand voltage (phase to earth)	1050	-	--	-	-

* According to manufacturer standard

• The creepage distance of the outdoor insulators shall be minimum 31 mm/kV.

3.22 Installation conditions and protection class for electrical operational equipment and control and monitoring equipment

If not specified otherwise the electrical operational equipment must be designed to meet protection classes stated below.

Switchgear, housings for electrical equipment and electrical equipment itself must be designed according to IEC 60529 at least to:

- Class IP 41 if located indoors in air-conditioned/ventilated areas
- Class IP 42 for ventilated enclosure of DDCMIS equipment if located indoors in air-conditioned/ventilated areas with suitable cannope ontop to prevent ingress of dripping water
- Class IP 22 for non-ventilated enclosure of DDCMIS equipment if located indoors in air-conditioned/ventilated areas with suitable cannope ontop to prevent ingress of dripping water
- Class IP 54 if located indoors
- Class IP 65 for all I&C field devices
- Class IP 55 for motors located outdoors and in indoor areas with high dust and humidity
- Class IP 65 for other outdoor electrical and control system equipment such as cubicles or panels with additional measures) if located outdoors in accordance with IEC 60529 (degrees of protection provided by enclosures (IP Code) or equivalent). The additional measures shall consist of sunshades, protection covers against splashing water, additional sealing, special acid resistive coating etc., depending upon the particular site conditions at the place of installation, subject to the approval of the Employer.
- Class IP 21 if located indoors with open doors.

The lamps for external lightning and internal lighting of not completely closed buildings must have protection class IP 55W. Furthermore for dust prone areas the lamps shall have protection class IP 65.

Electrical operational equipment which must be installed in areas exposed to danger from explosions must have the required explosion-proof design appropriate to the flash-point group classification of the explosive mixture as laid down in IEC 60079. Attention must be paid with respect to the use of electrical operational equipment in workshops and storage premises exposed to the risk of explosions.

In all rooms and areas where the local and operational conditions and surroundings can lead to the accumulation of gases, vapors, mists or dusts which, in combination with air, form explosive mixtures, the operational equipment and installations to be used in these circumstances must be of explosion-proof design. All operational equipment must be designed to comply with the class of protection dictated by the ignitable mixture (e.g. compression-proof casing, external ventilation, inherent safety, etc.).

Electrical operational equipment should be located indoors in adjoining buildings rather than inside buildings or other structures exposed to the risk of explosion. Whenever operational equipment has to be installed within areas liable to the risk of explosion, protection against explosion must, in general, be applied wherever explosive mixtures can arise. In this connection, the ignition of explosive

mixtures must be reliably prevented by adopting the correct choice of design and construction of the operational equipment and the incorporation of supplementary safeguards where applicable.

Electrical, chemical, thermal and mechanical influences must on no account impair, in any way, the protection afforded against explosion. In particular the high ambient temperatures and the influence of nearby heat sources at the installation point must be taken fully into account.

Protective measures, earthing and lightning protection

In view of the potential dangers of electrical power, the following measures are required for the protection of life, equipment and materials. Basically, all 'live' parts, i.e. all parts of electrical, operational equipment at an electrical potential above or below earth potential when in operation, and with a rated voltage over 24 V, must be insulated or covered so that they cannot be touched accidentally.

In addition, measures must be taken by the Contractor to prevent the occurrence or persistence of excessively high contact potentials on conductive parts of electrical operational equipment (frames etc.) brought about by faults in insulation.

For installations up to 1000 V, voltages over 50 V are considered to be excessive contact voltages. Within enclosed electrical installations, with voltages over 1000 V, the contact potential shall be according to the values given in EN 50522 (VDE 0101-2) Earthing of power installations exceeding 1 kV: enclosure B.

The following rules and regulations are to be observed in carrying out protective measures and in earthing procedure:

- IEC 60079 and 60364 for installations up to 1000 V,
- EN 50522 (VDE 0101-2) Earthing of power installations exceeding 1 kV.

In areas exposed to the hazard of explosion, the protective measures outlined in IEC 60079 and IEC 61241are to be adhered to in the erection and installation of electrical plant and equipment.

Protective measures for installations up to 1000 V

Protection against direct contact

All 'live' parts of electrical operational equipment that can be reached by hand must be protected against direct contact either by means of insulation or through constructional design, position or arrangement, or by means of special devices. If, in the case of enclosed switchgear or control cabinets, access is required in the course of normal operation (e.g. for replacing fuses), protection against direct contact must still be ensured when the switchgear or control cabinet has been opened up.

Protective insulation

Protective insulation is to be provided by means of additional insulation over and above the insulation provided for operational purposes. This measure must prevent the occurrence of a dangerous contact potential.

Use of low voltages as a safety measure

This safeguard applies to all equipment, which is required to operate in metal enclosures, boilers, tanks etc. The operational voltage of tools and lighting equipment must not exceed 24 V AC. Isolating transformers shall be provided by the Contractor for the purpose of producing the protective low voltage. A separate 24 V system will not be provided.

Connection of the neutral

The LV network shall be of the TN type, i.e. the LV neutrals of the auxiliary transformers are earthed directly.

Neutralization (protective multiple earthing) is intended to prevent the persistence of an excessively high contact potential on conductive parts of the installation which do not form part of the actual operating circuit.

Protective multiple earthing as a protective measure requires the neutral to be earthed close to the transformer. However, wherever possible the neutral shall be earthed at the main LV board. In this case the connection transformer to LV main board shall be carried out as TN-C type, i.e. three phases plus PEN:

The LV system for symmetrically as well as unsymmetrical connected power consumers shall generally be of the TN-S type, i.e. a five wire system. The separation of N and PE shall be carried out at the main LV board. Because of the clear demarcation between the neutral conductor N, carrying operational current, and the protective earthing conductor PE, which - under non-fault conditions - carries no current, NO connection between either N and PEN or N and PE is permissible beyond the point of separation of the PEN conductor into PE and N.

The neutral conductor is to be insulated in the same manner as the phase conductors. The use of constructional parts of the switchgear as a neutral conductor is not permitted.

All earthing conductors have to be rated depending on the value of earthfault current (see EN 50522 (VDE 0101-2) enclosure D). Separate installed earth conductors must be at least 16 mm^2 for copper and 100 mm^2 for galvanized flat-iron.

The earth electrode resistance shall ensure that potential contact will not be higher than 50V (see IEC 60364 - 4 -41).

Protective measures for installations over 1000 V

Protection against contact

At least the following measures are to be taken for all parts that are 'live' when in operation:

- Protection outside of closed electrical operating areas:
- complete protection from all sides against contact, the degree of protection shall be at least IP23D according IEC 62271-202 and IEC 60529
- protective devices may only be removed by means of tools.
- Protection inside closed electrical operating areas:
- protection against contact with 'live' parts within reach of personnel,
- protection against accidental contact outside the reach of personnel.

The above-mentioned measures for protection against contact are also to be applied to 'dead' parts of the Plant where, in the case of a fault, a dangerous contact potential might arise, however, where the parts must not be connected to the protective earthing system for operational reasons.

Protection against contact voltages

Protective earthing is to be used as a safeguard against excessively high contact potentials for conductive parts of the installation, which do not form part of the operational circuit. Here, all normally 'dead' parts equipment and apparatus shall be earthed if it is possible for them to come into contact with 'live' parts as a result of faults due to the occurrence of surface leakage paths, arcs or direct connections to a 'live' part of the equipment.

In considering the dimensioning of the protective earthing system, the thermal loading and voltages on the earthing equipment are decisive factors and these should be based on the maximum possible earthing current, which can arise.

3.23 Earthing and lightning protection

Earthing and potential equalization system

The earthing system and potential equalization shall comply with the following standards:

• IEC 60364-4-41:	Electrical Installation of Buildings – Protection for Safety: Chapter 41: Protection Against Electric Shock
• IEC 60364-5-54:	Electrical Installation of Buildings – Part 5-54: Selection and Erection of Electrical Equipment - Earthing Arrangements, Protective Conductors and Protective Bonding Conductors
• EN 50522 (VDE0101-2) :	Earthing of power installations exceeding 1 kV
• VDE 0845, Part 1:	Protection of Telecommunication Systems Against Lightning, Electrostatic Discharges and Over-voltages from Electric Power Installations; Provisions Against Over-voltages
• IEC 61643:	Low-voltage Surge Protective Devices

For earthing, protective earthing, functional earthing, potential equalization and lightning protection-potential equalization, a common system shall be established.

No framework parts or other structural components shall be used for the ground bus.

An earthing cable shall be included in all main cable runs.

3.24 Technical conditions for low voltage motors

If not specified otherwise all motors must be designed to meet IP 55 enclosure according IEC60034-5.

All motors with rated power (referred to 40 °C ambient temp.) less than 160 kW must be designed as LV motors with premium efficiency class IE3.

Constructive features

The same features as for high voltage motors shall apply.

Anti-condensing heating shall be provided for motors of 55 kW and above.

Electric features

All motors shall be designed as 3-phase squirrel-cage motors suitable for direct on line starting.

The motors must be capable of being switched on to a large and stable network and with phases in opposition.

The electric features:

a. Motor rating to be at least 110% of the maximum required electric power consumption of the driven machine.
b. Continuous delivery of rated power at voltages of 90 - 110% of the rated voltage and allowable frequency range within the limits of thermal class F.
c. Rated power output at ambient temperatures existing at the particular site of installation and under continuous running conditions.

Motors starting current must not exceed 7.0 times rated current (referred to the motor rating and 40 °C ambient temp).

Protective features

An earthing clamp inside the terminal box has to be provided.

Other features

Cable leads

All cable connecting boxes are to be designed to meet the requirements of IP 55 or IP 58 protection class respectively.

The cable connecting boxes are to be installed easily accessible on the motor. The connecting boxes must be capable of being turned by 90° or 180° and of being opened up longitudinally. The connection boxes are to be fitted with a terminal block.

Shafts
Where not otherwise specified, motors must be fitted with a free shaft end.

Protection against explosion hazards
Low-voltage motors, which are to be installed in areas exposed to the risk of explosion, must comply with the rules laid down in VDE 0165/0170/0171 for explosion-proof design in relation to the flash-point group classification for the particular explosive mixture.

DC motors
The use of DC motors is to be avoided and must be agreed by the Employer. The maximum starting current must not exceed 1.8 of the rated motor current (referred to the motor rating at 40 °C ambient temperature).

3.25 General cable construction requirements

The low voltage cables shall be of Fire Retardant Low Smoke (FRLS) with XLPE insulation. For cables that are exposed to ambient temperatures above 60°C, teflon or silicone cables are to be provided.
For safety related equipment fire surval cables shall be provided.

The cables must be suitable for laying indoors, in the open (direct or indirect sunlight), in ducts, on trays, in the ground and in water. The cables must be resistant to solar radiation, the effect of oil, seawater, bacterial action, insects and rodents. Outer sheaths are to be manufactured from non-combustible or flame retardant low smoke material.

Low voltage (LV) power cables
The low voltage power cables shall be standard single and multi-core cables of FRLS with copper conductor and XLPE insulation.

To ensure the elimination of excessive contact potentials on any object, effective earthing must be carried out as a safety measure and suitable 3- core, 4-core and 5-core low voltage power cables must be provided. The minimum conductor cross-section of the low voltage power cables is 2.5 mm^2. If 3 1/2-core cables are used, the reduced conductor for protective neutral must have a cross-section of at least 16 mm^2. In lighting systems (especially discharge lighting circuits) the use of a reduced conductor for the protective neutral is to be avoided.

Depending on the site conditions the DC cables must be single-core, 2-core or 4-core. Between batteries or rectifiers and the DC switchgear single-core power cables should in general be used.

The LV power cables must be designed for the dynamic and thermal characteristics of the electrical system and for continuous operation.

Measuring and control cables above 60 V/ instrument transformer cables

For voltages above 60 V the cables shall be of Fire Retardant Low Smoke (FRLS) with PVC insulation and a mini-mum conductor cross-section of 1.5 mm2. If they lead to outlying buildings, cables with a common core screen and protection against induction must generally be used.

For instrument transformer cables inside buildings the minimum conductor cross-section must be 2.5 mm2.

Instrument transformer cables leading to outlying buildings must have a minimum size of 4 mm^2 and must generally have a common core screen.

The maximum voltage drop shall not exceed 2%.

Fiber optic cables (FOC)

All fiber optic cables as well as their deployment and the entire test procedure shall comply with IEC 60794. The cables shall be able to operate continuously in temperatures up to 70°C. The fiber optic cables shall be loose tube type with the fibers fed into tubes. The tubes shall be sufficiently strong to hold their shape and provide protection for the fibers against deformation and friction. Each fiber shall be colour coded acc. to IEC 60304.

Buried fiber optic cables shall always be laid inside adapted conduits. Installation shall ensure rodent protection and be water tight. The conduits system shall supply all equipment necessary for the deployment acc. to FOC manufacturer's specification. Occupancy shall allow future cable installation.

For out-door applications cables shall be suited for out-door deployment, longitudinally water tight, filling material standardized for all cables, yield minimum 3,000 N.

The fiber optic cables shall be complete with non-metallic strain relief elements. Fiber optic cables that are installed outdoors shall be armored. Cables used indoors shall be reinforced with a steel wire braid.

Graded index fibers cables and monomode fiber cables shall comply with IEC 24702:

Graded index fibers cables shall consist of always 24 fibers
- fiber - type 50/125 µm, OM-3.

Monomode fiber cables shall consist of always 24 fibers
- fiber - type 9/125 µm, OS-1.

19" patch panels shall be used for termination, connectors shall be LCDuplex as standardized by IEC 61076-3-106 var. 4. All fibers shall be terminated / connected.

Each fiber of all FOC shall be deployed and tested according to IEC 60794. Resulting test protocols of all single fibers of all FOC shall be handed over to the Employer, stating all details in written.

3.26 EMC measures

All EMC measures shall ensure that during subsequent operation, no impermissible malfunctions or damage to equipment occurs due to violating electromagnetic compatibility.

The description of the measures is not limited to this section, but also forms a part of other sections, in particular "Protective measures", "Earthing and lightning protection" and "Cabling".

The EMC requirements are set out in the following.

Under consideration of the conditions and constraints, the equipment used shall emit the lowest interference signals and exhibit the highest immunity to interference.

All equipment items shall operate properly when connected to networks with a power supply corresponding to the maximum permissible tolerances as laid down in EN 50160 (as regards, harmonics, voltage fluctuations etc.).

Priority is given to reducing sources of interference.

Additionally, by means of high-capacity screening, generation of overvoltages due to inductive or capacitive coupling shall be reduced. Influencing by electrical and magnetic fields shall be reduced.

Earthing and potential equalization systems designed for low-impedance shall reduce generation of overvoltages due to ohmic coupling. If EMC resulting from the measures named above is still not adequate, further measures shall be taken within buildings, for example by isolation and suppressor circuits.

Thanks to the lightning protection and screening measures taken at the buildings, within them an EMC protection zone is formed.

All installations penetrating this protection zone, that is where they pass through the external walls of buildings, shall be incorporated into a lightning protection-potential equalization system as close as possible to the points of entry and exit of the building. This applies also for conductors carrying a potential. At entry or exit, these shall be included in the lightning protection potential equalization system by way of suppressor circuits.

Cable runs to outdoor plant components and between buildings may also be screened by appropriate measures, and so form a part of the protection zone. If this is done, the suppressor circuit can be dispensed with.

A suppressor circuit shall be provided at all low-voltage main distribution boards.

Overvoltage protection shall be foreseen within the power supply for both central and distributed power supplies to electronic cubicles.

All conductive parts of the structures and installation within the scope of the contract must be connected to the main earthing system.

All steel Sections or frames must be provided with at least two earthing straps for every frame or Section that is fabricated from parts welded together. The earthing straps shall be located at the ends of the beam Section or frame Section in every case.

The Contractor must provide earthing straps in front of and behind the screwed connection in every case and these straps must be interconnected, using stranded copper, and connected, at least at one point, to the main earthing system, except the Contractor verifies that the type of screwed connection applied is a permanent electrically conducting one. Tanks and vessels containing flammable liquids or gas shall be earthed by a connection to the earthing grid or by bonding to earthed metal structures.

Each pipe shall have a minimum of one connection to the earthing system. In areas where flammable vapor-air mixtures may exist, electrically isolated Sections of metallic piping shall be connected to the earthing grid.

All flange connections in these lines shall be bridged by flexible stranded copper. Earthing tabs shall be provided at each flange.

When connecting differing materials together the required material transition plates must, in general, be inserted. All connecting materials must be corrosion-proof and suitable for the conditions prevailing at the installation point.

3.27 Requirements for local cubicles and local housings for e.g. switchgear, control, measurement and signaling equipment

Steel-clad cubicles and enclosures with fixed, integral switchgear and apparatus must be provided.

The switchgear cubicles must be partitioned off and incorporate a busbar system, the necessary instruments, control switches, switch panels of the individual switch and apparatus chambers. The main busbars are to be installed on the rear face, top side of the switchgear cubicle in a lockable shuttered compartment.

Connections to switching devices, MCB's fuses etc. are to be made from these busbars. The lower part of the cubicle will house the terminal strips and connecting blocks, the clamps for the cable terminals and, if required parallel connection copper straps for the connection of more than 2 cables in parallel. An adequate number of ball studs must be provided within the switchgear cubicle suitable for earthing the main and distribution busbars as well as the switchgear itself by means of portable earthing and short circuiting equipment (to be provided once per switchgear panel row).

The space in the interior of the cubicles must be divided into a Section with 'live' parts, 'live' switching elements etc. and a Section with control and measuring equipment. The Sections are to be separated by reinforced sheetsteel.

Care must be taken that in the event of arcing hot gases will not escape to the front of the cubicles (the operational side).

Ammeters are to be provided on the cubicle front panel for the cubicle feeders and the supply outlets for motors higher than 55 kW or motors of lower rating, but particularly important for the process. A single voltmeter with 4-position voltmeter changeover switch must be provided for measurements of busbar voltage between each phase and neutral. Measuring instruments should, in general, be square in shape.

All cubicles, cabinets, panels, etc. shall be designed for an ambient temperature of 40 °C (outside the enclosure) in non-air conditioned areas. Special precautions shall be taken in the design of electronic devices for protection and control systems housed in the cubicle in order to allow for these conditions.

Heating elements are to be provided generally in each local cubicle or cabinet and shall be humidity controlled.

It must be possible to disconnect power supplies to the cabinets by means of manually operated power circuit-breakers (MCBs).

For easy monitoring and a rapid grasp of the operational state, collared mimic diagrams with the required switch position indicators, apparatus symbols and pilot lamps must be provided in every case on main process cubicles and switchgear cubicles. Lamp test facilities for all signed lamps connected shall be provided. All cubicles shall be provided with the required earthing screws.
Plastic-insulated, stranded conductors must be used for wiring within the switchgear cabinets, which must be numbered at each end with special tabs so that change by mistake is impossible.

Preferably plug-in type auxiliary relays are to be used. Apparatus being sensitive to impact must be protected against shock and vibration.

The cubicles must contain at least 5% of fully fitted spare terminal capacity and 5% of spare space for the future installation of extra equipment. It shall be possible to replace indicating lamps on the front panels of cubicle feeders and motor-supply outlets without isolating the equipment concerned. Furthermore the control system must be designed in such a way that lamps operate at less than their rated voltage in order to avoid their being overheated.

Incoming and outgoing cables have to be fixed by suitable metallic cable glands.

Terminal boxes and terminal cabinets

In order to minimize the amount of cables and distribution of signals and to centralize connections in the Plant, terminal boxes or, wherever necessary, by larger amounts of terminals, terminal cabinets shall be fitted on all the necessary

- cable crossover terminal points
- central collecting points for individual analog and binary signals and local transmitters
- signal collecting and distribution points for fire alarm, telephone, loudspeaker and clock system

- central distribution points for local signals.

Terminal boxes and cabinets must at least have class of protection IP 54 if installed indoors and IP 55W if installed outdoors and must be equipped with the necessary terminal strips, cable glands and fittings components for the connection of the cables.

The necessary earthing terminals are to be provided for the earthing of the boxes and cabinets.
In any area subject to the danger of explosion, the necessary explosion protected terminal boxes and cabinets are to be provided in accordance with IEC 60079 and IEC 61241 and VDE 0165/0170/0171.

3.28 Instrumentation and control equipment

Main design criteria
This Section applies to the design of the general Instrumentation and Control equipment. The following general requirements shall be strictly observed with regard to design and execution. In the event of contradictions the Contractor shall be responsible for obtaining written clarification from the Employer/Engineer.

Reference within this Section does not automatically indicate that the particular form of instrumentation is required on this project or will be acceptable for a particular application. The particular requirements for control and instrumentation shall take preference in the event of any disagreement between the two Sections.

Only requirements for technical performance of the equipment are stated herein, whilst the detailed requirements of the tasks to be performed by the control systems and the scope of delivery for each individual item of plant is stated in the relevant Sections of this specification.

This specification does not however relieve the Contractor of his responsibility for the basic design and execution of the instrumentation and control system per scope of supply in relevant Sections of this specification. The rules of good engineering practice and the relevant approved standards and regulations shall be observed.

A consistent instrumentation and control philosophy shall apply throughout the Plant and shall be implemented in terms of a range of equipment exhibiting a minimum diversity of type and manufacture. The objective shall be to standardize all measurement and control equipment throughout the Plant in order to rationalize operation, maintenance and reduce spares holding.

Generally equipment shall be supplied from one composite range of measurements and control equipment as marketed by a reputable manufacturer of international standing and shall have a minimum of three years operational use on similar projects. Where particular equipment is not included in the products of the manufacturer thus necessitating diversity of supply, this equipment shall be identified by the Contractor. The equipment shall be of modern, compact design incorporating the latest developments in proven technology. All instruments whether for local indication or remote transmission shall be of good quality and shall have an accuracy and repeatability appropriate to their duty. All fittings shall use metric threads.

Measurement and control instruments shall be matched to the main plant equipment ratings in all aspects. Instrument ranges, installation codes of practice and precautionary measures for safety of the Plant and the operating and maintaining personnel shall be observed.

Special attention shall be paid to the Plant safety. As a general rule, measuring points and measuring equipment for critical protection shall be separate from and not combined with measuring equipment for the automatic control equipment.

The material of all equipment installed in pipes, tanks, etc., shall correspond to the material of the relevant pipes, tanks etc. and shall fully meet the requirements regarding safety and operational conditions of the media to be measured. All the equipment shall be suitable for the location in which it is to be mounted and in particular all outdoor equipment shall be suitable for the prevailing climatic conditions.

The diversity of makes and types shall be kept to a minimum. The Employer/Engineer reserves the right to stipulate make and type following award of contract.

Any equipment to be installed within potentially explosives atmospheres shall comply with the requirements of international standards and codes, e.g. IEC-60079, NEC 500 etc.

The instrumentation and control equipment shall have high electro-magnetic and radio frequency interference immunity and shall not be affected by portable radio transmitters operated in the vicinity of the equipment. Any limitations shall be stated.

All instruments shall be protected by cases. The cases shall have enclosure classification not less than IP 42 according to EN 60529 when mounted indoors in totally enclosed rooms with provision for limited ingress of dust, IP 54 else in a enclosed building and IP 55W for mounting outdoors.

Electronic instruments shall not be located close to hot lines, vessels or other hot equipment. Ambient sun temperatures exceeding 80 °C shall not result in calibration difficulties or rapid deterioration of electronic components.

Distributed Digital Control, Monitoring and Information System (DDCMIS)
The Plant will be controlled generally through a DDCMIS. The DDCMIS contains of process stations, operator workstations, engineering workstations, archiving facilities and signal exchange to management and third party systems. In general the DDCMIS will be DCS based hardware only in some exceptions PLC based systems may be applied.

3.29 Programmable logic controllers

Programmable logic controllers (PLC) shall be deployed in subsidiary installations and systems of higher complexity and shall provide a more open access for operation. Standard products of PLC manufacturers shall be used for which software developed by the process suppliers and proven for the specialized process is available.

The diversity of makes and types shall be kept to a minimum. The Employer/Engineer reserves the right to stipulate make and type following award of contract.

The use of auxiliary packages with PLCs or local controls for ancillary plants or systems shall be limited and minimized. Only some special cases can be considered subject to the Employer/Engineer's approval. Typical and acceptable reasons for a specialized control system can be high speed of response or special safety requirements, which may require a separate safety-related system.

For signal exchange with the main DCS, PLCs shall be compatible with this system. Depending on the amount of information to be exchanged, parallel or serial interfacing shall be considered. The sequence of events signals should be directly physically connected to Sequence of Events Recording System (SER).

If only few signals are to be exchanged, parallel interfacing is preferred. Binary signals shall be exchanged via volt free signals. Analogue signals (4 - 20 mA) must be suitably decoupled.

If serial interfacing is used, the interface equipment between the PLC and the DCS must be capable of communication using an industrial standard protocol. The transmission baud rate shall be selected dependent on the application (minimum 19200 baud or higher). If commands are issued from the DCS to the PLC, the time between operator command input and PLC signal output shall not be more than 1.5 seconds. The same requirement goes for answer back signals from the PLC and updating of displays of analogue values coming from the PLC on the DCS monitor displays.

As a minimum requirement, the offered serial link shall have a data integrity checking and retransmission facility in case of error detection, independent of the DCS or external system software. Hardware and software failures during data transmission shall be monitored and alarmed onto the DCS.

The communication link shall be redundant. In case of failure in the communication, quick manual automatic switch-over to the standby communication link shall be possible with automatic switchover and fault reporting and diagnostic facilities.

The functions realized in the PLC and the method by which they are invoked shall be represented graphically similar to IEC 61131-3.

Additionally, a verbal program description supported where required for easy understanding of complex functions with functional diagrams according to IEC 60848 shall be provided.

Programming devices with keyboard, VDU and printer for ease of programming, effective on-line monitoring and diagnostic functions, together with the necessary equipment to write in and to erase EPROMs shall be provided.

The Contractor shall guarantee that spare parts for the offered PLC system will be available for at least 15 years after commissioning of the Power Plant as well as upward/forward compatibility for

future upgrades of the system. If necessary, the Contractor shall provide successive system upgrades to ensure spare part compatibility for that time span.

For local operation and monitoring a panel or desk mounted Human Machine Interface (HMI) unit, operable by keypad or touch screen with LED-displays shall be provided. Protection class of panel mounted HMI (front side) shall be IP 22 according to IEC 60529.

3.30 Control cubicles

DCS, PLC hardware and other associated control equipment shall be installed in suitable control cubicles. The cubicles shall be set up in local switchgear/ electronic rooms (CER or LER) or in local control centers (LCC).

Outdoor installed cubicles shall be provided with thermostatically controlled heating elements in order to prevent the formation of condensate which may occur due to large variations of ambient conditions, if necessary. Adequate lighting and sockets for hand tools protected by 30 mA Residual Current Differential Switch (RCDS) shall also be provided for cubicles and panels, if necessary.

The cubicles shall be secured in such a way that failure of one node cannot cause the failure of the whole system.

The required control elements and displays (annunciation and status lights, analogue displays, switches etc.) shall be so configured that as far as possible they can be viewed from the associated secondary system. Should it be necessary to place the control and monitoring elements in the field, these shall be installed in separate, robust housings (protection class IP 55W). All alarms/ annunciations shall as well be available in DCS.

In preference LED displays shall be used. Ease of access and operation of the equipment shall be ensured.

Visual display unit (VDUs) will be employed for field operation and monitoring.

All cubicles shall be adequately ventilated in order that the heat generated by the equipment mounted there shall remain within the specified limits, even in the case of high ambient temperatures that may occur in the event of failure of the air-conditioning system.

Locally installed cubicles shall be suitable for the location in which they are situated and shall provide adequate protection against dust, moisture or mechanical damage for the equipment mounted therein. Cubicles shall be designed in such a way that vibrations of the building shall be absorbed to a large extent. Sunshades shall be provided for all cubicle located outdoors. Cable connections to cubicles, panels and desks shall be made via suitable seals so as to prevent the ingress of dust, vermin or the propagation of a possible fire. During installation period, a provisional sealing of cable penetrations shall be ensured.

3.31 Racks, junction boxes

Marshalling racks
Open type racks constructed of angle steel may be used for the marshalling and termination of low voltage control cables within the Central Electronics Rooms (CER & LER). Cubicle type marshalling racks may also be considered.

For voltages exceeding 60 V, a suitably separated Section with isolation cover shall be provided.

Instrument racks
Wherever possible, instruments and devices, e.g. transmitters, thermo element cold junctions, terminal boxes, located in the field, shall be mounted on local instrument racks. The instrument racks shall be installed with due regard to control engineering needs, material-saving assembly and easy accessibility for maintenance and checking work, and shall be constructed of standard angle Section steel.

Junction boxes
In order to simplify local collection of cables and distribution of signals and to centralize connections in the Plant the junction boxes shall be fitted on all the necessary:
- cable crossover terminal points,
- electrical actuators,
- central collecting points for individual analog and binary signals and local transmitters,
- central distribution points for local signals.

The necessary intermediate terminal boxes must at least have degree of protection IP 55 in accordance with EN 60529 and must be equipped with the necessary terminal strips and attachment components for the connection of the cables. The necessary earthing terminals shall be provided for the earthing of the boxes. In hazardous areas, terminal boxes shall be in accordance with EN 50019 or 50020, depending on zone classification. After commissioning, the junction boxes, marshalling racks, instrument racks, etc. must contain at least 10% of spare space. The Contractor shall furthermore provide at least 10% of fully fitted spare terminal capacity.

3.32 Mimic diagrams

Mimic diagrams shall be offered where specified or alternatively where their presence would assist Plant operators in assimilating the operational state of the Plant.

Where used, the mimic diagram shall harmonize with the other equipment in the control room. Mimic diagrams shall be of the mosaic type.

On mimic diagrams for electrical systems, the different voltage levels shall be distinguished by the use of mosaic elements having an inlaid colloured strip. These elements shall be fitted together to show the location of the different busbars. The operational position of circuit breakers and isolators shall be indicated by semaphore indicators, and the operation of switchgear from the mimic diagram shall be by means of discrepancy switches or pushbuttons designed to operate in a similar manner.

On process mimic diagrams, methods shall be used to clearly indicate the path of the various media, the preferred technique being by means of raised plastic strips which shall have a distinctive colour. Also a uniform scheme of colours for different media shall be adopted.

Where pushbuttons are proposed for operation, enabling pushbuttons shall also be provided and it shall require the operation of both the pushbutton actuating the device and the enabling pushbutton to operate the device.

The Contractor shall propose the mimic colour code for process and electric system identification of the P&ID and electric single line mimics in the VDU or mimic panel.

3.33 Power supply and fusing

The supply voltages for the control cubicles within the central electronic rooms (CER & LER) shall preferably be 24 V DC and must be arranged as separately fused double infeeds. The individual feeders can serve either a single cubicle or several cubicles combined as a logical group.

All equipment shall be adequately protected against overcurrent by means of fuses or other current protection devices. The main power supply fuses shall be located in functional groups within separate power distribution cubicles. Fuse ratings and time characteristics shall be such that in all cases, a fault within an individual item will cause the fuse associated with that item to rupture and thus disconnect that item from the power supply, before the main fuse is affected.

Failure of a main fuse shall affect the overall operation of the Plant as little as possible and shall be indicated in the central control room (CCR) by means of an alarm. This alarm shall state the identity of the failed main fuse.

Failure of an individual cubicle, module or component fuse shall be indicated by a general alarm and a detailed diagnostic message. The Section of the control cubicle in which the fuse is located shall be indicated. It shall also be possible to locate visually the fuse that has failed.

The design of the electrical power supplies and fusing system must ensure that any faults in modules or other devices, which may block sequence logic interlocks, automatic control systems or other control systems, are restricted to the system in which the fault has occurred.

All electronic devices shall be protected against transient voltage levels which would otherwise damage the device.

3.34 Transmitters

All transmitters shall have an impressed output signal of 4 - 20 mA corresponding to zero to full range input. However, digital communication shall also be acceptable.

Generally, 2-wire transmitters shall be used. If for some special purposes (e.g. analyzers) 230 V AC power supply is required, the output circuit shall be isolated.

As far as possible, all transmitters shall be of the SMART-type. This applies also to field mounted temperature transmitters.

All transmitters shall be fitted with a local analog indicator displaying appropriate physical units which may be read clearly from an easily accessible position.

Transmitters with accuracy class "0" or better must be used. The repeatability shall be within a range of ± 0.1% of full span.

The output signal of all transmitters must be independent of the burden of the transmitter output circuit including cable resistance over a wide range.

The removal of connected devices must not open the transmitter output circuit or cause malfunction of this circuit. In the case of failure and return of the supply voltage within a measuring circuit, no false signals endangering the system shall be issued. All transmitters shall be individually fused. If not specified otherwise, local parameterization at the transmitter or via modem and PC/laptop or hand held communicator using HART protocol shall be possible.

For the continuous remote position indication of valves, dampers etc. also transmitters with impressed output signal of 4- 20 mA shall be employed.

All transmitters shall be suitable for field installation and shall have strong, moisture and dustproof cases of IP 65 or better according to EN 60529. This applies also for temperature transmitters when installed in the field.

Diaphragm seals shall be provided to serve as a barrier for corrosive process fluids, slurries or highly viscous oils. The seal shall be of the flanged type, suitable for the same conditions as those for the transmitter. The material selection shall be according to the requirements of the fluids to be measured. The seal shall be provided with a flushing connection.

Transmitters to be used in hazardous areas shall be explosion proof. Suitable intrinsically safe circuits are to be provided in accordance with EN 60079- 11.

All transmitters potentially subjected to vacuum shall be capable of withstanding 100% vacuum without damage.

No stress shall be imposed through the connections between Plant and the transmitter. As far as possible, the transmitters shall be grouped together into enclosed racks or panels for easy access. Sunshades shall be provided for all outdoor panels.

Individually installed transmitters shall have their own weather proof enclosure of robust construction and be suitable for the proposed environment. All field equipment terminals shall be wired to a terminal box using screwed connections.

Transmitters shall be provided with all necessary isolating, vent and blowdown valves and facilities shall be provided for the connection of test instruments at the input and output of each transmitter, to enable calibration to be carried out.

In general limits (for alarms or switching actions) shall be derived from the analogue measurement value in the DCS (use of switches shall be avoided). Where binary signals cannot be derived from an analog value, **binary transmitters** e.g. temperature switches, pressure switches etc. may be used. Indicators with integrated limit switches are allowed within package units. Preferably limit switches shall be of the proximity type. All switches shall be of robust design and reliable performance. Temperature switches, pressure switches, level switches, and etc. shall be of the snap-action and change over type. The switches shall have an adjustable switching hysteresis. Parity checks shall be supplied for switches. The set point and the deadband (reset point) of each switch shall be adjustable from inside the case, over the full range specified. The set point and reset point shall be indicated on the adjusting mechanism. For the sensing of level in tanks, vessels or bunkers float switches, vibration level switches or other suitable switching devices with conductive or capacitive electrodes shall be provided. For monitoring of machine coolant or lubricant flow (dry running protection) suitable flow or level sensors shall be employed. The switches shall be housed in robust, dust and moisture proof cases having glanded cable entries and shall be suitable for the ambient conditions local to the equipment on which they are mounted.

3.35 Temperature measurements

Glass thermometers, bi-metallic and capillary remote thermometers are to be used for local temperature measurement. For both, class 1.0 shall be provided.

Glass thermometers are to be inserted into pockets provided for the purpose. The use of mercury is forbidden.

Capillary remote thermometers shall be with a case diameter of preferably 160 mm and must be mounted on fixtures or instrument panels in such a way that they are protected from vibration, jarring and sprayed water. The capillary tube must be laid in a protected position.

If possible, resistance thermometers (Pt-100) in accordance with IEC 60751 shall be used for remote measurements. All resistance thermometers shall be wired according to the four-conductor principle.

Otherwise, thermocouples with appropriate heat resistance in accordance with DIN IEC 60584-1 or equivalent may be used for remote measurements.
All thermocouples shall be of the quick response type, ungrounded and preferably of double element type.

Thermocouples shall be arranged in such a way that the ambient temperature of the head is lower than 100 °C, and that the measuring inserts can easily be exchanged.

All thermocouples and extension leads shall be terminated with a suitable gland and the conductor to sheath resistance shall be greater than 100 MOhms when tested after termination.

Thermometers and thermocouples shall generally be fitted in protective wells. They shall be provided with weatherproof terminal heads and shall be installed so as to totally prevent the ingress of foreign matter.

High speed response pockets shall be provided for all applications involving control of critical process temperatures.

Where more than one temperature measurement e.g. for redundant loops, recording, indication, automatic control is to be made at one location, individual protective wells with sensors shall be provided at the common place of measurement. Protective wells for unoccupied test measuring points shall be arranged with the opening inclined downwards wherever possible and shall be provided with a screw-on protection cover.

Insofar as local conditions or extreme temperature do not require otherwise, screw-in immersion wells for exhaust gas and air shall meet the following requirements:

- nominal length not less than 0.5 m
- attachment of the well in the wall of the exhaust gas channel or air duct must be gas-proof.

For the measurement of temperature of other media the following requirements shall be observed:

For all pipework a minimum immersion depth of 55 mm in the internal pipeline cross-section and a minimum distance of 15 mm from the opposite pipe wall must be provided. If the diameter of the pipeline does not allow the thermometer to be inserted perpendicular to the pipe axis while still maintaining the above mentioned measurements, another solution must be found in cooperation with the Employer/ Engineer. When determining the lengths of the insertion and connecting tubes the insulation thickness is to be taken into consideration.

For all remote temperature measurements (i.e. for RTDs and TCs) transmitters shall be installed locally in a transmitter protecting box on a DIN rail.

3.36 Pressure measurements

Pressure gauges of class 1.6 or better must be used. The standard measuring ranges must be selected with regard to the maximum operating pressure.

A pressure instrument installed for measurement of steady pressure at varying pressure shall operate in a band centered on 60% of its maximum range.

When the pressure impulse line is liquid filled the measuring unit shall be compensated for static head. The head correction shall be stated on the unit.

Pressure gauges shall have a dial size of 160 mm and shall be located in such a way that they can be easily observed or shall be combined in groups on local gauge boards or cubicles.

Pressure gauges shall be resistant against vibrations. Furthermore, pressure gauges shall be designed in such a way that the measured value may reach the end of the indicating range without affecting the calibration of the gauge. Pressures to be remotely indicated, recorded or used for automatic control loop inputs shall be measured by means of pressure transmitters (refer to relevant part of **Section**).

Pressure measurement tapping points shall generally be in accordance with the specification for the pipeline in which they are installed and shall be equipped with one, and for high pressure installations (45 bar) two, isolating valves arranged directly at the tapping point. Excluded from this stipulation are measuring points for vacuum and measuring points for combustion air and exhaust gas.

Piping shall be of approved quality and sized for the particular service. In all cases the pipe size shall be chosen to ensure strength and freedom from blockage. Instrument impulse pipework shall be manufactured from a suitable grade of stainless steel to the approval of the Employer/Engineer.

Pressure transmitters for remote measurement shall not be mounted directly at the tapping point, but shall be arranged at a distance from the tapping point by means of enclosures. The impulse line between tapping point and transmitter shall be arranged in such a way as to form a siphon loop, when steam pressure measurements are involved.

A valve combination or multiway cock shall be provided directly on each pressure gauge or transducer connection. They shall be equipped with a connection for test gauges, and it shall be possible to shut off the test connection without isolating the service pressure gauge at the same time.

Open blowdown / drain connections shall not be arranged within panels and local equipment. Instead it shall be led to a drain external to the panel. All valves shall be installed so that they are accessible for in-situ maintenance from a floor or permanent structure landing.

Transmitters are to be protected from the measuring media, if required.

In addition to the above requirements, special valve block equipment shall be provided, where differential pressure is to be measured. Alternatively, differential pressure type transmitter can be considered.

3.37 Inspection and Testing

General

This Section contains general requirements for inspection of material, parts, equipment and workmanship of the Plant during manufacture, assembling and erection and upon completion to demonstrate compliance with specification, codes and standards and to ensure overall reliability of Equipment operation and performance.

Development and implementation of test procedures for the construction inspection, start-up and performance testing and capacity demonstration of the Plant shall be the responsibility of the Contractor.

The Contractor shall be responsible for providing all supplies required for carrying out such tests.

The overall testing program for the Project shall consist of the following:
- workshop inspections and testing
- construction inspections, and testing

The Employer shall have the right to have their representatives present during inspections and tests of Plant equipment and systems in the workshops and during construction. The presence of the Employer's representatives during any inspection or test shall in no way relieve the Contractor of its responsibility for supplying the equipment or systems in accordance with the milestone dates.

The Employer will be notified by the Contractor in writing at least ten (10) days prior to such testing and inspection at workshop and two (2) days for test at site.

The Contractor shall submit to the Employer all relevant test documents, which shall include:
- inspection and test program
- test standards
- type of inspection and tests
- tests which are to be witnessed by third parties.

The results of all tests shall be certified by the manufacturer, Contractor or independent agency as appropriate.

Document files containing material certificates, welding procedures, test report etc. shall be compiled for each item of plant and shall be suitably identified (including equipment classification reference) and bound.

Welding tests

Non-destructive examination of pressure and vacuum containment welds

Welds shall be non-destructively tested in accordance with the construction standard applicable to the item of plant. In addition the requirements of the following Table 1 shall be observed. Table 1 shall also apply in cases where the standards used for design and construction of an item of plant does not specify the quality requirements for welds. Fault limitations to be subject of agreement with the Employer's Representative prior to fabrication.

Hardness testing shall determine the hardness for welds and heat affected zone according to Vickers (HV10).

The test procedure ISO 6507-1 or equivalent shall be used. Minimum 3 hardness locations shall be tested for the weld. On circumferential welds the test locations shall be located at 120° distance. Hardness tests shall be conducted after PWHT.
Following percentages of welds shall be hardness tested.

Carbon steels or low allow steels (<2%Cr)	10%
2.5% Cr steels	50%

9 - 12% Cr steels	100%
Austenitic steels	-

TABLE1

Type of Steel	Design factor	Wall thickness	Inside diam	Type and Extent of non destructive testing			Remarks
	(shell)	(mm)	(mm)	Butt	Nozzle	Fillet	
C and C-Mn steels with C content not exceeding 0.25%	≤ 0.85	≤ 10	all	-	-	-	Only applicable to: Atmospheric systems (excluded systems, which handle chemicals, toxics or inflammable media).
		40≤	all	20% R	-	-	
		> 40	all	100% R	10% M	10% M	
	> 0.85	≤ 40	≤ 100	20% R	-	-	
			> 100	100% R	10% M	10% M	
		> 40	all	100% R	100% M	100% M	Test after stress relief
C-Mn steels with C content 0.25 to 0.35%, CrMoVsteels, C 1/2 Mo steels, low alloy steels, and CrMo steels except 12% Cr steels		≤ 30	all	20% R	10% M	10% M	
	all	> 30	all	100% R	100% M	100% M	Test after stress relief
Low alloy steels except CrMoV and 2 CrMo	all	all	all	100% R	100% U**	100% M	Test after stress relief
12% Cr ferritic/martensitic steels	all	all	≤ 100 > 100	100% R 100% R* 100% U	100% M 100% M 100% U	100% M 100% M	Test after stress relief Test after stress relief

* Radiographic examination may be omitted if done on as-welded joint
** If feasible, otherwise 100% M.

Type of Steel	Design factor	Wall thickness	Inside diam	Type and Extent of non destructive testing			Remarks
	(shell)	(mm)	(mm)	Butt	Nozzle	Fillet	
Austenitic Stainless Steels	≤ 0.85	≤ 15	all	-	-	-	Not applicable to: Butt welds made from one side only Operating temperatures exceeding 200 °C
		≤ 30	all	20% R	-	-	
		> 30	all	20% R	10% D	10% D	
					-	-	
	> 0.85	≤ 30	≤ 100	20% R			
			> 100	100% R	10% D	10% D	
		> 30	all	100% R	100% D	100% D	

Legend: R = Radiographic examination
U = Ultrasonic examination
M = Magnetic particle examination
D = Dye penetrant examination

Note:

1. Where 10% examinations are shown for pipework under 100 mm diam bore this shall be the circumference of 10% of the welds by each welder selected at random with a minimum of one per welder.
2. Where 10% examinations are shown for vessels or large diameter pipework this shall be 10% of each weld length and must include all intersections of longitudinal and circumferential welds.
3. Where partial examinations reveal rejectable defects, adjacent welds or areas of weld shall be examined. In the event of rejectable defects being found welds shall be subject to 100% examination.
4. Welds in clad materials shall be tested in accordance with the requirements of the base material and the surface of the overlaid welds shall be dye penetrant tested throughout their length.

Non-destructive examination of structural welds

Welds shall be non-destructively tested in accordance with the construction standard applicable to the item of plant. Where appropriate, the following requirements shall also be observed:

- magnetic particle testing of the tension side welds in major fabricated girders and Sections,
- ultrasonic examination of heavily restrained welds (e. g. cruciform joints) where there is a risk of lamellar tearing in the parent material.

Weld Repairs

Unacceptable defects observed by visual examination or indicated by non-destructive testing shall be completely removed by chipping or thermal gouging and grinding. The resulting excavation shall be crack detected prior to rewelding.

Details of the original defects and repair shall be recorded.

Repaired welds shall be subjected as a minimum requirement to the same inspection requirements as the original welds and test records should indicate that a repaired weld is referred to.

3.38 Electrical equipment

Electrical equipment and material which is not covered by the tests specified elsewhere in this document shall be inspected and tested in accordance with the latest edition of standards listed hereafter. Alternatively, equivalent standards approved by the Employer's Representative may be used.

Type tests shall be carried out if type test certificates certified by an independent test authority are not available.

Installation Material

IEC 60130	Connectors for frequencies below 3 MHz
IEC 60364	Low voltage electrical installations/ Electrical installations of buildings
IEC 60423	Conduits for electrical purposes

Materials for earthing and lightning protection

IEEE 80	Guide for safety in AC Substation Grounding
IEEE 81	Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface potentials for Ground system
NFPA 780	Installation of lightning protection systems

Insulators and Bushings

IEC 60383	Insulators for overhead lines with a nominal voltage above 1000 V
IEC 60507	Artificial pollution tests on high voltage insulators to be used on AC systems
IEC 60137	Insulating bushings for AC voltages above 1000 V

Surge Protection Equipment

The surge protection equipment shall be tested in accordance with IEC 60099.

AC Switchgear for voltages above 1 kV

IEC 62271	High-voltage switchgear and control gear
IEEEC37.013	IEEE standard for AC-High-Voltage generator circuit breakers on a symmetrical current.

At least the following tests shall be performed in the manufacturer's workshop on the individual apparatus and on the complete installation, respectively, all in accordance with IEC Standards:

- Visual inspection
- Power frequency HV tests
- Dielectric tests of the auxiliary circuits
- Measurement of the main contacts resistance with dc
- Temperature rise test on circuit breakers (type test certificate)
- Test of mechanical endurance (type test certificate)
- Measurement of the contact opening period (type test certificate)
- Functional tests of the control circuits
- Check of the operational sequence
- Measurement of the instrument transformer's angle and ratio errors (according to IEC-standards 60044)
- Check of the denominations.

Note 1: All MV switchgear shall be type tested according IEC 62271-1, IEC62271-100 and IEC 62271-200 including internal arc classification IAC = AFLR. Related type test certificates shall be provided with the Tender. If the test has already been carried out on similar type switchgear, type test certificates may also be accepted.
Note 2: All GIS above 52 kV shall be tested according IEC 62271-1, IEC 62271-203.
Note 3: Generator circuit breakers shall be tested according IEEE Std C37.013.

High voltage fuses

IEC 60282	High voltage fuses
IEC 60644	Specification for high voltage fuse links for motor circuit applications

Dry type transformers

The following routine tests in accordance with IEC 60076 shall be carried out on all transformers:

- Measurement of winding resistance
- Measurement of voltage ratio and phase displacement
- Measurement of short circuit impedance and load loss
- Measurement of no-load loss and current
- Separate source AC withstand test
- Induced AC voltage test
- Lightning Impulse test

- Partial discharge measurement.

The following tests in accordance with IEC 60076 to be carried out as type tests (type tests shall not be repeated if type tests certificates of an identical transformer issued by a recognized test laboratory are available):

- Temperature rise test
- Measurement of sound level
- Short circuit test
- Environmental Test according Class E2
- Climatic test according Class C1
- Fire behaviour test according to Class F1.

Fault withstand (fault versus time) curve for all transformers shall be submitted by the Contractor. Separate type and routine tests shall be carried out for all accessories like bushings, bushings CTs, tap changers, etc.

Current and voltage transformers

The current and voltage transformer shall be tested in accordance with IEC 61869

Motors

IEC 60034, ISO 1680, ISO 10816

- Type tests (each motor type) as far as type test certificates are not available
- measurement of starting (locked rotor) current and torque
- power factor and efficiency measurement
- heat run test
- noise measurement
- temperature rise measurement
- Routine tests (each motor)
- measurement of winding resistances
- measurement of shaft current
- no-load and current measurement
- no-load short circuit measurement
- open circuit secondary induced voltage test at stand still (wound rotor)
- dielectric test (high voltage test)
- measurement of insulation resistance
- overspeed tests (120% for 2 minutes)
- check of motor vibrations
- oscillographic measurement of starting current.

Low voltage switchgear

The following standards and regulations or equivalent shall be used:

IEC 60947	Low-voltage switchgear and control gear
IEC 61439	Low-voltage switchgear and control gear assemblies
IEC 60529	Degrees of protection provided by enclosures (IP Code)

IEC 60898	Specifications for circuit-breakers
IEC 60079	Electrical apparatus for potentially explosive atmospheres
IEC 60947	Regulations for low-voltage switchgear

The "Design Verification" of all low voltage switchgears/ motor control centers shall be carried out by following methods:

- "Testing" for the Pos. No. 1., 2., 3., 4., 5., 9., 10., 11., 12. and 13 of IEC 61439-1/Annex D, Table D.1
- "Assessment" for the Pos. No. 6., 7. and 8 of IEC 61439-1/Annex D, Table D.1

In addition to the above tests for which certificates shall be submitted, at least the following tests shall be performed in the manufacturer's workshop on the individual apparatus and on the complete installation, respectively, all in accordance with IEC Standards:

- Visual inspection
- Power frequency HV tests at main circuit
- Dielectric tests of the auxiliary and control circuits
- Functional test of the control circuits
- Check of the operational sequence.

Capacitors

IEC 60831	Shunt power capacitors
IEC 60871	Shunt capacitors for A.C. power systems
IEC 60931	Shunt power capacitors
IEC 60143	Series capacitors for power systems
IEC 60358	Coupling capacitors and capacitor dividers
IEC 60384	Fixed capacitors for use in electronic equipment

Batteries, charging equipment inverters and DC/DC converters

IEC 60086	Primary batteries
IEC 60119	Recommendations for polycrystalline semiconductor rectifier stacks and equipment
IEC 60146	Semiconductor converters
IEC 60896	Stationary lead-acid batteries
IEC 61204	Low voltage power supply devices DC output

Chargers and batteries shall be tested together in the factory. Testing of chargers and batteries together at site will also be accepted. All factory tests shall be repeated at site.

Chargers

- Visual inspection (to be repeated on site)
- Functional tests (to be repeated on site)
- Heat run (type test)
- Output voltage stability measured for 25% load steps
- Ripple voltage measurement without connected battery
- Ripple measurement (voltage and current) with connected battery (at site will also be accepted.

- Insulation test (to be repeated on site).

Batteries
- Visual inspection (to be repeated on site)
- Insulation test (to be repeated on site)
- Charge test and discharge tests Fuse Box
- Visual inspection (to be repeated on site)
- Functional tests (on site)
- Insulation test (on site).

Inverters and DC/DC converters
- Visual inspection (to be repeated on site)
- Functional tests (to be repeated on site)
- Heat run (type test)
- Insulation test (to be repeated on site).

Lamps and accessories

IEC 60081	Double-capped fluorescent lamps
IEC 61347	Lamp control gear
IEC 60921	Ballasts for tubular fluorescent lamps
IEC 60155	Glow starters for fluorescent lamps
IEC 60598	Luminaries
IEC 60188	High-pressure mercury vapor lamps
IEC 60400	Lampholders and starter holders for tubular fluorescent lamps
IEC 60901	Single-capped fluorescent lamps
IEC 60662	High pressure sodium vapor lamps
IEC 60192	Low pressure sodium vapor lamps
IEC 60923	Auxiliaries for lamps
IEC 61347	Part 2-13: lamp control gear for LED Modules
IEC 62031	LED modules for general lighting – Safety specifications
IEC 62560	Self-ballasted LED-lamps for general lighting services by voltage > 50 V - Safety specifications
IEC 62612	Self-ballasted LED-lamps for general lighting services by voltage > 50 V - Perforce requirements
IEC 62471	Photobiological safety
IEC 62384	DC or AC supplied electronic control gear for LED modules - Perforce requirements
IEC 60838 Part 2-2:	miscellaneous lampholders – Connectors for LED-modules
IEC/PAS 62717	LED Modules for general lighting – Performance requirements
IEC/PAS 62722	Luminares Performance

HV-, MV- and LV-cables

All relevant routine and type tests according to:

IEC 60060	High voltage test techniques
IEC 60071	Insulation co-ordination

IEC 60230	Impulse tests on cables and their accessories
IEC 60811	Common test methods for insulating and sheathing materials of electric cables
IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV up 150 kV
IEC 62067	Power cables with extruded insulation and their accessories for rated voltages above 150 kV up 500 kV
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV up to 30 kV

LV-cables

LV cables shall be workshop tested as per IEC 60502-1 with the following tests as a minimum:
Type tests:

- electrical type tests acc. to: IEC 60502 - 1 Clause 17
- non electrical type tests acc. to: IEC 60502 - 2 Clause 18.

Also following additional type tests shall be carried by the Contractor at their own cost prior to the first shipment of all offered cable if no type test certificates of identical cables are available:

- Fire Resistant according to IEC 60331, BS 6387
- Flame Retardant according to IEC 60332
- Low Smoke Test according to IEC 61034
- Halogen Content Test according IEC 60754
- Water Tree Test of XLPE Insulation (accelerated)
- Test voltage = 3 x Uo
- Test frequency = 500 Hz
- Core environment = 400C water
- Duration of test = 4 month
- Test after 4 months: Dielectric stress withstand >14kV/mm.

Moreover, test certificates shall be provided, proving that each cable type to be used has successfully passed type tests as required by the applicable standards during the last 12 months before award of contract. Otherwise, these tests have to be repeated on sample Sections.

Routine tests: according IEC 60502 – 1, Clause 15

- measurements of electrical resistance of conductors according to Clause 15.2
- voltage tests according to clause 15.3.

Sample tests: according IEC 60502 – 1, Clause 16

- conductor examination according Clause 16.4
- check of dimensions according Clause 16.5 to 16.8
- hot set test for EPR, HEPR and XLPE insulations and elastomeric sheath according Clause 16.9.

Telecommunication installations

IEC 60215 Safety requirements for radio transmitting equipment

Aerials
IEC 60169 Radio-frequency connectors

Power installations up to 1000 V
IEC 60364 Electrical installations of buildings
IEC 61439-4 Particular requirements for assemblies for construction sites (ACS)

Power installation above 1000 V
IEC 60060 High-voltage test techniques
IEC 62271 HV switchgear and control gear (incl. Appendix AA "Internal Arc Test")

Protection equipment
Equipment for modular static protection systems (e.g. generator, distance, busbar, protection, etc.) pre-assembled in the relevant standardized boards/ cubicles etc. shall be tested in the manufacturers' workshops according to IEC 60255 as far as wiring and proper function is concerned. Simulated inputs (binary signals, current and voltage inputs from test power supplies) shall be used.

Fire alarm system
All relevant routine and type tests according to:

NFPA	National Fire Protection Association
DIN VDE 0800	Telecommunications
DIN VDE 0833	Alarm systems for fire, intrusion and hold-up

Control and monitoring equipment
All control and monitoring equipment shall be tested at the manufacturers' works before dispatch to site. Certificates shall be issued for
- synchronizing units
- flow evaluators

On request the correct operation of equipment with specified temperature and humidity limits shall be demonstrated by tests conducted within the limits.

Electrical measuring instruments
All electrical measuring instruments shall be tested in accordance with the following rules and regulations. Alternatively, equivalent standards approved by the Employer's Representative may be used.

IEC 60051	Recommendations for direct-acting indicating electrical measuring instruments and their accessories
IEC 60258	Direct acting recording electrical measuring instruments and their accessories
IEC 61036	Alternating current static watt-hour meters for active energy
IEC 61010	Safety requirements for electrical equipment for measurement, control and laboratory use

Electrical remote indication
Meters for active power, reactive power and similar remote indication equipment:

VDE 0418	Regulations for electric integrating meters

IEC 60338 Telemetering for consumption and demand

Calibration Tests

The Contractor shall conduct calibration tests of the following instruments and equipment:

- all local indicators over the full range of the indicator
- all transmitters over the full range of the transmitter
- all binary transmitters over the full range including initial setting
- all remote indicators over the full range of the indicator
- all recorders over the full range of the recorder
- one of each type of indication loop with circuit resistance of the loop increased to a value which is equal to the highest value expected, and under worst case operating conditions
- all superheated steam thermocouples
- one of each type of thermocouple or resistance element
- all kinds of analogue transmitters over the full measuring range
- all modules and subassemblies for measuring and control e.g. analogue limit monitors, flow evaluators, function generators
- all quantity meters
- all synchronizing units according to IEC standards
- the actual dimensions of all orifices, nozzles, Venturi nozzles have to be checked as per ISO5167.

Closed-loop control systems

All main closed-loop control systems shall be tested for polarity and function in accordance with the applicable standards. Control valves shall be tested in accordance with mechanical functional tests on control valves and shall be performed with the actuator mounted (open to closed position and vice-versa). Actuators shall be subject to mechanical and electrical function tests.

Sequence logic equipment

All sequence logic equipment shall be tested using simulated inputs.

Alarm annunciator and fault printing system

The alarm annunciator and fault printing system shall be tested using simulated inputs.

DCS system

The system shall be thoroughly tested at the manufacturers' workshops before dispatch to site. Test programs shall be devised and these shall subsequently be made available to the Employer's Representative. Tests shall be made to ensure that the system operates correctly within the ambient conditions as specified by the manufacturer and that if these conditions are exceeded, i.e. in the case of failure of the air-conditioning system, that the system will automatically fail safe and that neither hardware nor software will be damaged.

Further I&C equipment

Type test reports shall be provided for the following:

- UPS
- 24 V DC battery chargers

- Batteries
- Control valves
- Instrumentation cables
- Flow nozzle orifice plates
- Measuring instruments
- Local instrument enclosures
- Local instrument racks
- PLCs
- Etc.

Type test reports

The minimum type test reports for each of the major I&C systems shall be as follows:

1. Surge Withstand Capability (SWC) for solid state equipment/ systems All solid state systems/ equipment shall be able to withstand the electrical noise and surges as encountered in actual service conditions and inherent in a Power Plant. All the solid state systems/ equipment shall be provided with all required protections that needs the surge withstand capability as defined in ANSI 37.90.1/ IEEE-472. Hence all front end cards which receive external signals like analogue input & output modules, binary input & output modules, etc. including power supplies, data highway, data links shall be provided with protections that meet the surge withstand capability as defined in ANSI 37.90.1/ IEEE-472. Complete details of the features incorporated in electronic systems to meet this requirement, the relevant tests carried out, the certificates etc. shall be submitted with the proposal. As an alternative to above, suitable class of EN61000-4-12 which is equivalent to ANSI 37.90.1/ IEEE-472 may also be adopted for SWC test.

2. Dry heat test as per IEC 60068-2-2 or equivalent
3. Damp heat test as per IEC 60068-2-3 or equivalent
4. Vibration test as per IEC 60068-2-6 or equivalent
5. Electrostatic discharge tests as per EN 61000-4-2 or equivalent
6. Radio frequency immunity test as per EN 61000-4-6 or equivalent
7. Electromagnetic field immunity as per EN 61000-4-3 or equivalent Tests as listed under items number 5 to 7 as applicable for electronic cards only as defined under item 1 above.

3.39 Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AC	Alternating Current
AGC	Automatic Grid Control
ASC	Average Site Conditions
AVQR	Automatic Voltage and Reactive Power Control
BOP	Balance of Plant
BOQ	Balance of Quantities
BPDB	Bangladesh Power Development Board
CCR	Central Control Room
CCTV	Closed Circuit Television
COD	Commercial Operation Date
CT	Current Transformer

DC	Direct Current
DCDB	DC Distribution Board
DCS	Distributed Control System
DDCMIS	Distributed Digital Control Monitoring & Information System
DOE	Department of the Environment, Bangladesh
DOSH	Department of Safety and Health, Bangladesh
EHSG - TTP	IFC Environmental Health and Safety Guidelines Thermal Power Plants
EHV	Extra High Voltage (500 kV)
EIA	Environmental Impact Assessment
EMC	Electro-Magnetic Compatibility
EPC	Engineering, Procurement, Construction
FTU	Field Mounted Termination Unit
G-EHSG	IFC General Environmental Health and Safety Guideline
GJ	Gigajoule
GPS	Global Positioning System
GWh	Gigawatt hour
GSO	Grid System Operator
HART	Highway Addressable Remote Transducer
HAZOP	Hazard and Operability Study
HDPE	High Density Polyurethane
HMI	Human Machine Interface
HRC	High Ruption Capacity Fuse
HV	High Voltage
HVAC	Heating, Ventilation, Air Conditioning
Hz	Hertz
I&C	Instrumentation and Control
IOD	Initial Operation Date
IPL	Independent Protection Layer
IR	Infrared
kV	Kilovolt
kW	Kilowatt
LAN	Local Area Network
LCC	Local Control Center
LIE	Local Instrument Enclosure
LIR	Local Instrument Rack
LV	Low Voltage
LVS	Large Video Screen
MCC	Motor Control Center
MCL	Maximum Continuous Load
MCR	Maximum Continuous Rating
MLSD	Land Survey Datum
MNCL	Minimum Continuous Load
MNCR	Minimum Continuous Rating
MOV	Motor Operated Valve
MV	Medium Voltage

MVA	Megavolt Ampere
MVAR	Megavolt Ampere Reactive
MWh	Megawatt hour
NCC	Network Control Center
NDE	Non Destructive Examination
NFPA	National Fire Protection Association
NLDC	National Load Dispatch Centre
NOR	Notice of Readiness
NRV	Non Return Valve
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OHL	Over head line
PA	Public Address
PABX	Private Automatic Branch Telephone Exchange
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PQR	Procedure Qualification Record
PSS	Power System Stabiliser
PVC	Polyvinyl Chloride
PWD	Public Works Department
PWHT	Post welding heat treatment
QA	Quality Assurance
RC	Reinforced Concrete
RSC	Reference Site Conditions
SCADA	Supervisory Control and Data Acquisition
SCS	Substation Control System
SER	Sequence of Events Recording
SI	Soil Investigation
SIL	Safety Integrity Level
SOE	Sequence of Events
SSC	Summer Site Conditions
TCS	Technical Comment Sheet
UHF	Ultra High Frequency
UV	Ultraviolet
VDU	Video Display Unit
VT	Voltage Transformer
WSC	Winter Site Conditions
WPS	Welding procedure specification

3.40 Enclosures:

- Site Specific Seismic Study Report (Annexure-A) – 92 Pages
- Packing & Shipping Instructions (Annexure-E) – 2 Pages
- Seaworthy Packing – 5 Pages
- General Guideline for filling QA Plan in Customer format – 3 Pages
- Title Block – 1 Page

BANGLADESH-INDIA FRIENDSHIP POWER COMPANY (PVT.) LIMITED

2x660MW MAITREE SUPER THERMAL POWER PROJECT RAMPAL, BANGLADESH

OWNER'S CONSULTANT:

FICHTNER
M/s FICHTNER GmbH & Co KG.
STUTTGART, GERMANY

SITE SPECIFIC SEISMIC STUDY REPORT

DOC. NO. : Maitree-00-UTX-ED-421602C002PEM
REV-1

APPROVED IN CAT 1
BY BIFPCL/FICHTNER
VIDE TRASMITTAL NO.
00151 DATED:
01/06/2017

Maharatna Company

BHARAT HEAVY ELECTRICALS LIMITED
PROJECT ENGINEERING MANAGEMENT
NOIDA-201301

Seismic Hazard Estimation for BIFPCL, Maitree STPP Project site, located at Bagerhat, Bangladesh

Submitted To

Project Engineering Management,
Bharath Heavy Electricals Limited,
Noida, UP-201301

Prepared by

Principal Investigator: **Dr. S. T. G. Raghukanth**
Research Associate: Dhanya J

PROJECT No: IC1617CIE155BHELSTGR
REPORT- February 2017

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY MADRAS
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Seismic Hazard Estimation for BIFPCL, Maitree STPP Project site, BHEL, located at Bagerhat, Bangladesh

1. Introduction

BHEL has requested I I T Madras to carry out seismic hazard analysis for the proposed BIFPCL, Maitree STPP project site located in Bagerhat, Bangladesh. The proposed site lies in the zone I as per the seismic zoning map of Bangladesh National Building Code (2012).

The importance of estimating seismic hazard at constructions sites needs no special emphasis. In this exercise, one has to be not only scientific but also adopt state-of-art international methodologies to validate the procedures of estimating hazard parameters such as peak ground acceleration (PGA) and design basis response spectrum. Engineering design of a new structure has to assure safety in future. Thus, the design has to be based on future scenarios and not on a few past observations. The subject of Engineering Seismology is sufficiently advanced, so as to include the future uncertainty in hazard estimation. The seismic hazard can be estimated deterministically by considering only a particular scenario which can cause maximum ground motion or probabilistically, in which uncertainities involved in earthquake size, location and ground motion is taken into account. The uncertainties of the seismic phenomenon cannot be overlooked in arriving at a design basis spectrum. Thus probabilistic seismic hazard assessment (PSHA) has become the norm even for normal buildings in USA(IBC-2009, DOE 2024, USNRC-RG1.165). Engineering design and construction cannot be viewed in isolation from socio-economic considerations. Since the economic lifetime of a structure can be envisioned, the uncertain seismic scenario has to be tailored to match

with the design life of the structure. In the case of engineering structures, apart from a safe economic life period one can easily see the need for defining a safe social life period also. Thus, the traditional seismic coefficients have to be interpreted in terms of the future hazard that is foreseen for safety of engineering structures. This hazard in turn has to be scientifically expressed in terms of return periods.

The objective of the report is to estimate design response spectra for the BIFPCL, Maitree site, by DSHA and PSHA methodologies. This involves collection of seismicity data and seismotectonics details around the site. The uncertainities in magnitude and site to source distance are quantified from using the past data. The uncertainities in ground motion are obtained using ground motion predictions equation (GMPE). The three uncertainities are integrated to obtain the uniform hazard response spectra.

1.1 Return Period

The frequency of occurrence of a rare event is expressed in terms of return periods. This is the average time between consecutive occurrences of the specified rare event. For example, this rare event can be the ground acceleration exceeding 0.1g due to an earthquake anywhere in a control region of 500 km radius around the site. Return period is the average duration between consecutive occurrence of the desired event and is not the actual inter-arrival time, which is a random variable. Since the occurrence of an earthquake is unpredictable, the target event is equally likely to occur in any year during its return period T_R. Let us consider the ground acceleration at the site as the random variable and the rare event as $(Y>a_g)$ that is the PGA exceeding a value a_g in any year. It follows the annual probability of exceedance

$$P(Y>a_g) = P_a=1/T_R \quad (1)$$

Hence, a 1000-year earthquake would mean that magnitude which has a return period of 1000 years ocurring in a catchment region of 500 km radius around the site. This is same as that magnitude which has annual probability of exceedance P_a of 0.001. In engineering problems it is more appropriate to characterize the future earthquake in terms of its PGA and S_a. In this case the above probability can be related to the

exceedance levels of the above strong motion parameters during the economic and/or social lifetime of the facility. Let the design life of the STPP be N years. For an event ($Y>a_g$) with return period T_R and annual probability of exceedance P_a , the exceedance probability over N years is

$$P(Y>a_g \text{ in N years})= 1-(1-P_a)^N \cong [1-e^{(-N/TR)}] \cong N/T_R \quad (2)$$

The approximations are valid for small Pa and large N. Hence, if the design period is 100 years and a PGA value of a_g is chosen with a1000-year return period (P_a=0.001), the exceedance probability is still 0.1 or 10 percent. As per BNBC code, MCE corresponds to 2 % prob of exceedance in 50 years, which means N= 50 years and Pa = 0.02. The corresponding return period (TR) can be estimated from Equation 2 as 2500 yrs. Hence the site specific spectra should be obtained for 2500 yr return period.

1.2 Geology and Seismic Status of the Region

Estimation of seismic hazard requires identification of geological and tectonic zones in the 500 km region around the site. A brief review on seismotectonic setting and geology is presented in this section. The geological map of Indian subcontinent is reported in GSI (2000) is shown in Figure 1. The project site is located in the Bengal basin tectonic unit. it can be observed from Figure 1 that the Bengal basin is predominantly of alluvial deposits. Further the basement contour map of the region is given in Figure 2. It can be noticed that the contours trend N-S and are parallel to the Indian shield margin and basement occurs at as depth of around 4.0km just west of Bharampur. Along Culcutta-Krishnanagar line the basement depth varies between 7-10km. Thus the basin depth is observed to increase from 4km to 7km. In Bangladesh the basement trent NE. It can be seen from the Figure 2. that the basement depth at the project site is around 15km. This high basement depth is attributed to the enormous amount of sediments flown down by the Ganga-Brahmaputra drainage system building the world's largest submarine fan-Bengal fan.

The broad and detailed geological map of Bangladesh published by Geological Survey of Bangladesh (GSB) is shown in Figure 3 and Figure 4 respectively. The three major

geological formations in Bangladesh are (i) Teritinary hill segment in the north-eastern hills, (ii) the Madhupur clay from Madhupur Barind Tract and (iii) the recent alluvium in the flood plain and esturine areas occupying the remainder country (Brammer (1996)). Physiographically Bangladesh can be divided into 7 divisions (Figure 3.). Each of these divisions has distinguished characteristic of its own.

a) Hilly regions (in the eastern and northern frontier): i) Chittagong Hill Tracts, ii) Hill Ranges of northeastern Sylhet, iii) Hills along the narrow northern strip of Sylhet and Mymensingh
b) Pleistocene uplands: i) Barind Tract in the north western part, ii) Madhupur Tract in the central part, iii) Lalmai Hill
c) Tippera Surface
d) Tista Fan (in the northern part)
e) Flood plains: i) Ganges flood plain, ii) Atrai flood plain, iii) Brahmaputra-Jamuna flood plain, iii) Old Brahmaputra flood plain, iv) Meghna flood plain
f) Deltaic plain of the Ganges-Brahmaputra-Meghna Delta Complex: i) Inactive delta, ii) Active delta, iii) Tidal delta
g) Sylhet Depression and Inland marshes (Scattered all over Bangladesh)

The Bengal delta is a combination of three deltas namely the Ganges delta, the old Brahmaputra-Meghna delta and the Ganges-Jamuna (the present Brahmaputra)-Meghna delta. In some recent literature the name, "Ganges-Brahmaputra-Meghna Delta Complex" has been used. Holocene or Holocene sediments from a few hundred to thousands of meters cover the Flood plains and the Delta.

Geologic evolution of the Bengal Basin starting from Upper Paleozoic time is directly related with the break up of eastern Gondwanaland and collision of the Indian plate with the Asian plate, it can be divided into four major stages: I. Permo-carboniferous pre-breakup stage, II. Early Cretaceous Rift stage, III. Late Cretaceous-Eocene Plate or drift stage, and IV. Oligocene-Holocene Orogenic stage. The sedimentary cover of the basin with a maximum thickness of 20 km includes three major lithostratigraphic units separated by three major unconformities. The western part of Bangladesh is the platform shelf, whereas the eastern part of the country is represented by the folded belt. The central part representing the most subsided part of the basin comprises two major

depressions at the north (Sylhet Trough) and south (Patuakhali Depression). The transition zone from the shelf to basin is represented by the hinge zone-a Eocene shelf/slope break. The western and Northern foreland shelves, which were source areas earlier, the rising chains of the Himalayas and the Indo-Burman Ranges were increasingly subjected to erosion and supplied much of the sediments since the Mid-Miocene in the basinal area (Shamsuddin and Abdullah, 1997).

Bangladesh contain thick sediment (up to 20 km in the southern part) sequences of Permian to Holocene. The sediment thickness is shallowest in northern Bangladesh (114 m). Recently, Singh *et al.* (2016) determined the sedimentary and crustal depth at the Bengal Basin at 11 stations by inversion of high quality receiver functions. The results from their study are presented in Figure 5. It is clear that the thickness of the sediments increases dramatically across the Hinge Zone of the Early Cretaceous passive margin from 3 to 17 km. The Moho depth shallows across the region. This reflects thinning of the crystalline crust from 38 km in the Indian Craton to 34 km at the Hinge Zone to <16 km in the Bengal Basin. This variation in the crust thickness is depicted in Figure 6 for NS and EW sections through the region (Alam *et al.* (2003)). The thickness of the sediments increases dramatically from 3 to 17 km south of Madhupur tract which reflects the regions of highest influx of clastic sediments from the Himalayan collision zone. Major part of the sediment is deposited by the Ganges-Brahmaputra-Meghna river systems during Miocene to Holocene time. In Bangladesh the oldest sediment is the Permian Gondwana rock that lies over the Pre-Cambrian Basement complex. Over the Gondwana rock successively lies the Cretaceous Rajmal Trap, Paleocene Tura Sandstone, Eocene Sylhet limestone and Kopili, Oligocene Barail, Miocene Bhuban, Bokabil and Tipam Sandstone, Pliocene Dihing and Dupi Tila Sandstone, Pleistocene Madhupur Clay and Holocene Alluvium sediments (Islam and Uddin (2002)). This generalized sequence is not common in all parts of the country and in some places many formations are missing due to depositional, non-depositional, and post depositional erosion. The stratigraphic sequence is also variable between the Fore Deep area and the Shelf areas. The Holocene alluvium sediments mainly constitute of sand silt and clay. In the Ganges-Brahmaputra-Meghna Delta complex, vertical and horizontal variations of the lithofacies in the Holocene are very high. It is difficult to

correlate them from one place to another even at short distances. Inter fingering of the sediments are common. We must keep in mind that the Bengal Basin is one of the fastest subsiding regions of the world. The high rate of subsidence along with similar high rate of sediment deposition makes mapping of these units quite difficult. Thus, From Figure 2, 3, 4 and 5 it is clear that in the project site lies on the tidal deltaic deposit. The basement depth at the site is around 15 km.

The fault map of Bangladesh prepared from the Bangladesh Meteorological Department (BMD) and GSI (2000) is shown in Figure 5. The collision between the Indian subcontinent and the Eurasian continent, which started in Paleogene time and continues today, produced the Himalaya and the Tibetan Plateau. The region under consderation is in close proximity to West Bengal. Tectonically Bangladesh is divided broadly into the following divisions

1. Indian Platform and Shelf (a) Dinajpur slope (Himalayan Fore Deep); b) Rangpur Saddle, c) Bogra Slope
2. Hinge Zone (Eocene slope break)
3. Bengal Fore Deep: a)Folded flank, b) Basinal area; i) Sylhet Trough, ii) Chandpur-Barisal High, v) Patuakhali Depression (Hatia Trough)

The area around BIFPCL, Maitree site, comprises part of two major tectonic domains- the outer molasse basin of Tripura Chittagong and the Bengal basin. The Bengal basin has three structural domains; the western scrap zone architectured by badin marginal fault, middle shelf zone and eastern deeper basinal part. The major structures of the area are the regional antiforms and synforms with N-S trending axes and NE and NW trending conjugate fault/ lineament system developed as a result of E-W compression. The Tripura Chittagong domain , comprises the Tripura-Mizoram Hills, the Chittagong hill tracts and Coastal Burma, represent a large Neogene basin formed west of Paleogene Arakan-Yoma Fold belt and is broadly confined within the Naga Thrust and Dauki Fault to the north and Sylhet Fault and Barisal Chandpur High to the west and northwest. The Bengal basin tectonic domain of the area comprises enormous sediments flown down by the Ganga--Brahmaputra drainage system, building the world's largest submarine fan- the Bengal fan, to the south. Incidently, the Bengal fan conceals the northern extension of the Ninety East Ridge and the bathymetric trench,

related to subduction of Indian Plate. Teritary sequence in the shelf zone dips homoclinically towards southwest with a sudden flexure along the Ecocene Hinge Zone. The Garhamoyna-Khandaghosh fault (GKF) is quite extensive along the basin margin that joins the Rajmahal Fault in the north. The NE trending Jangipu- Gaibhandha Fault (JGF) branches from GKF that separates Rangpur-malada saddle from the Bogra shelf. The seismicity near the region is mostly of shallow focus. It is mostly of moderate magnitude earthquakes.

The plate boundary fault from Myanmarto to Chittagong is the northern extension of the rupture area which has caused the 2004 Mw 9.2 Sumatra earthquake. The 1762 earthquake has occurred in this region and accompanied the tsunami in the river near Dhaka (Steckler et al., 2008). The Madhupur blind fault is inferred on the western margin of the Madhupur Tract, northwest of Dhaka. The fault is considered as an important structure for the seismic hazard assessment of Dhaka, the capital of Bangladesh, although there is no definitive evidence for its presence (ADPC (2013)). tilted to the east. The straight low scarps with NW-SE direction are recognized on the western margin of the Madhupur Tract.

2 Seismogenic Zones

The seismotectonic map (Figure 7) shows that there are some regions that are more active than the other. This activity is correlated with the number of occurrence of past earthquakes and also with the presence of faults and lineaments. There is a possibility that not all past epicentres can be uniquely identified with particular faults. This gives rise to the postulation of diffuse aerial sources in some places to be the cause of seismic activity. The distribution of faults varies spatially as seen from Figure 7. Some specific patterns can be recognized about the faults and epicentres being dense in some regions. This pattern and the known tectonic disposition can be used to demarcate source zones for further work. The first official seismic hazard-zoning map for Bangladesh wad published in 1979 for the Geological Survey of Bangladesh prepared by a Committee of experts on Earthquake Hazard Minimization. Recently NDMA (2011) document on PSHA map of India divides Indian-subcontinent into 32 homogeneous seismic source zones based on historical seismicity, tectonic features

and geology. These zones along with the faults and seismicity within each zone are shown in Figure 8 and 9. It can be observed that the ground motion at the BIFPCL, Maitree site is influenced by events occurring on faults located in the neighbouring ten zones surrounding the site.

BIFPCL, Maitree site, lies in Source 9 (Bengal Basin) which has the high b-value of 0.75. The other zones that influences the region includes the seismically active Himalayan zones 3 and 4 with N(4)>2.4, which lies in the north part of the site. These sources represent the plate boundary regions where lie the MBT, MCT, Indus-Tsangpo suture and the Tethys suture. Source zone 8 occupies the Shillong plateau and the Assam valley region. This region has active linear structures like the Dauki, Dhubri, and Kopili faults. Source zone 10 is connected with the subduction of the Indian plate below the Burmese plate. Source zone 18 consists of the Mahanadi Graben and the Eastern Craton of the Indian Shield. The Eastern passive margins are represented by source zones 17. Singhbum Craton lie in source 31. Source 32 encloses the new fault identified in Bay of Bengal by ONGC. There are also various other attempts to determine the seismic hazard of the region (ADPC(2009), Al-Hussaini *et al.* (2015))

2.1 Earthquake Catalogue

Bangladesh Meterological Department (BMD)(2016) has reported 431 events that occured in and around Bangladesh from 1918-2016. Out of these 2 are great events (>8), 10 are major events ($7<M_w<8$), 15 are strong events ($6<M_w<7$), 103 moderate events ($5<M_w<6$), 219 light events ($4<M_w<5$), 78 minor events ($3<M_w<4$) and 4 are very minor events (M_w <3). In addition, NDMA (2011) and USGS website (*http://neic.usgs.gov/*) has compiled the earthquakes of magnitude from 825 to 2016 in the vicinity of the region. From the compiled catalogue, a total of almost 2800 events of $M_w>3$ have been collected form the ten seismic zones near to the BIFPCL, Maitree site. Epicenters of these earthquakes are plotted in Figure 8. A list of earthquakes with magnitudes $M_w \geq 6$ in the historical and instrumental period are reported in Table 1.

2.2 Fault Map

Fault maps for BIFPCL, Maitree site have been prepared using the data from Geological

survey of Bangladesh, Bangladesh Meteorological Department (BMD) and Seismo-tectonic Atlas of India (GSI 2000). These drawings have also been digitized using MATLAB. These drawings are prepared such that all the important seismo-tectonic features within seven seismogenic zones are captured. The causative fault map for the site is shown in Figure 8 along with all known epicenters. This figure immeadiately provides a synoptic view of the spatial pattern of the seismicty in the controlling region. It can be observed that most of seismic activity is concentrated along the Himlalayan region. The major faults and seismogenic zones which influence seismic hazard at the BIFPCL, Maitree site, Bagerhat have been identified from Figure 8 and 9 respectively. Small faults which are at far off distances and which are not seismically active are not considered. Based on past activity and data the maximum potential magnitude of each fault has been estimated. Whenever past events occurred near a fault, the magnitude of the largest of such events has been increased by 0.5 units to fix up M_{max}.

Regional Recurrence

The seismic activity of a region is characterized in terms of Gutenberg-Richter recurrence (frequency-magnitude) relationship. This is represented as

$$\text{Log}_{10} N = a - bM \qquad (3)$$

where N is number of earthquakes greater than a particular magnitude M and (a , b) are the parameters representing the seismicity of the region. The simplest way to obtain (a,b) is through least square regression, but due to the incompleteness of the database, this approach is known to lead to erroneous results. To circumvent this difficulty, Kijko and Sellvoll (1998) proposed a new method where the data is organized into two parts called the extreme and the complete part. Extreme part refers to the time period where information on large historical events are only available and complete part represents the time period in which information on both large as well as small magnitude earthquakes are available. Their method assumes a doubly truncated Gutenberg-Richter relationship and a poisson model for earthquake occurrences. The uncertainty in the estimation of magnitudes is also incorporated in deriving the unknowns. In the

present study, 1958-2016 is considered as complete part and before 1958 is taken as extreme part to find the recurrence parameters. The a-value and b-value for the seven tectonic regions around BIFPCL, Maitree site, obtained from the procedure of Kijko and Sellvoll (1998) are shown in Table 2. The recurrence relation for these ten regions is plotted in Figure 10.

2.3 Fault Deaggregation

The recurrence relation derived above is for the entire source region and is not specific to any particular fault. Now, the recurrence relation has to be found individually for each of these faults, which is a difficult task. With no reliable information on the slip rate of the faults, further analysis has to be heuristically handled. A simple principle based on conservation of seismic activity which states that the regional seismicity value quantified as $N(m_0)$ (number of earthquakes per year with $m > m_0$) should be equal to the sum of individual fault value $N_k(m_0)$ (k=1,2,..23), is invoked for estimating the recurrence relation. Let the number of earthquakes per year with $m > m_0$ in a given source zone consisting of n number of faults be denoted as $N(m_0)$. Since all these events are associated with the faults within the zone, it follows $N(m_0)= \sum N_k(m_0)$ where $N_k(m_0)$ stands for the annual frequency of event $(m > m_0)$ on the k^{th} fault (k=1,2,3,...n). This conservation property ca be heuristically used to develop G-R relations for each fault in the source zone. Here we take (m_0 = 4) for further work. The number of events $N_s(m_0)$ that can occur on a given fault depends on a variety of factors, the most important being the potential of the fault to break depending on its length and known past activity. This argument just reiterates that a long fault is capable of breaking into more number of smaller sections. At the same time a shorter fault might be more active contributing to more small magnitude events in the catalogue. Thus two parameters namely the fault length L_k and the number of past events n_k associated with the s^{th} fault have to be used as weights for finding $N_k(m_0)$. If N_z number of events is available in the zonal catalogue we get two weights for each fault within the zone as,

$$\alpha_k = L_k / \sum L_k \text{ and } \delta_k = n_k / N_k \quad (4)$$

Taking the mean of the above two factors as indicating the seismic activity of the s^{th}

fault in the zone we get

$$N_k(m_0) = 0.5\ (\alpha_k + \delta_k)\ N(m_0) \tag{5}$$

as the *a*-value in the G-R relation of the k^{th} fault. The *b*-value for all the faults is taken to be constant equal to the zonal *b*-value already computed in Table 2. A further constraint appears in the form of the maximum possible magnitude m_u that can be foreseen on a given fault, depending on its length. This has to be less than the zonal potential but can be higher than the past magnitudes associated with the particular fault. Here it is taken to be half unit more than the past maximum magnitude. In the absence of past activity m_u is estimated depending on the length of the fault using the empirical relation proposed by Wells and Coppersmith (1994).

3. Generation of earthquake ground motion

After determining the recurrence relation for each of the faults, attenuation relation valid for the region under consideration has to be derived. Attenuation equation is a key component in PSHA. This equation describes the average or other moments of the hazard parameter in terms of the magnitude and distance. The instrumental database for Bangladesh is sparse and hence not useful to derive instrument based attenuation relationships. Thus, due to lack of ground motion data during strong earthquakes, no such relation is available for Bangladesh. Hence a global relation derived by Abrahamson et al. (2014), Boore et al. (2014), Campbell and Bozorgnia (2014) and Chiou and Youngs (2014) is used for the region (will be refered as ASK-2014, BSSA-2014, CB-2014 and CY-2014 respectively further in this report).

3.1 BSSA-2014

The functional form of GMPE is given as

$$\begin{aligned}\ln Y = {} & F_E(\mathbf{M}, mech) + F_P(R_{JB}, \mathbf{M}, region) + F_S(V_{S30}, R_{JB}, \mathbf{M}, region, z_1) \\ & + \varepsilon_n \sigma(\mathbf{M}, R_{JB}, V_{S30})\end{aligned} \tag{6}$$

where ln *Y* represents the natural logarithm of a ground motion (PGA, PGV, or PSA); F_E, F_P, and F_S represent functions for source ("E" for "event"), path ("P"), and site ("S")

effects, respectively; ε_n is the fractional number of standard deviations of a single predicted value of ln $\underline{Y}$ away from the mean (e.g., ε_n = -1.5 is 1.5 standard deviations smaller than the mean); and σ is the total standard deviation of the model. The predictor variables are M, *mech*, R_{JB} (in km), *region*; V_{S30} (in m/s), and z_1 (in km). Parameter mech = 0, 1, 2, and 3 for unspecified, SS, NS, and RS, respectively. Parameter region is 0 if no regional correction is to be made (default value); 1 for California, New Zealand, and Taiwan (this also provides no correction); 2 for China and Turkey; and 3 for Italy and Japan. The units of PGA and PSA are g; the units of PGV are cm/s.

The source (event) function is given by:

$$F_E(\mathbf{M}, mech) = \begin{cases} e_0 U + e_1 SS + e_2 NS + e_3 RS + e_4(\mathbf{M} - \mathbf{M}_h) + e_5(\mathbf{M} - \mathbf{M}_h)^2 & \mathbf{M} \le \mathbf{M}_h \\ e_0 U + e_1 SS + e_2 NS + e_3 RS + e_6(\mathbf{M} - \mathbf{M}_h) & \mathbf{M} > \mathbf{M}_h \end{cases} \quad (7)$$

where *U*, *SS*, *NS*, and *RS* are dummy variables, with a value of 1 to specify strikeslip, normal-slip, and reverse-slip fault types, respectively, and 0 if the fault type is unspecified; the hinge magnitude M_h is period-dependent, and e_0 to e_6 are model coefficients.

The path function is given by:

$$F_P(R_{JB}, \mathbf{M}, region) = [c_1 + c_2(\mathbf{M} - \mathbf{M}_{ref})] \ln(R/R_{ref}) + (c_3 + \Delta c_3)(R - R_{ref}) \quad (8)$$

where, $R = \sqrt{R_{JB}^2 + h^2}$, c_1, c_2, c_3, Δc_3, M_{ref} , R_{ref} and h are model coefficients. Parameter Δc_3 depends on the geographic region,

The site function is given by:

$$F_S(V_{S30}, R_{JB}, \mathbf{M}, region, z_1) = \ln(F_{lin}) + \ln(F_{nl}) + F_{\delta z_1}(\delta z_1) \quad (9)$$

where F_{lin} represents the linear component of site amplification, F_{nl} represents the nonlinear component of site amplification, and $F_{\delta z1}$ represents the effects of basin depth. Terms F_{nl} and $F_{\delta z1}$ are region-dependent. The corresponding expression for each is explained in detail in Boore et al (2014) and the coefficients of the same in Table 3(d)

The Aleatoric uncertainity is represented through the total standard deviation σ, partitioned into components that represent between-event variability (τ) and within-

event variability (ϕ) as follows:

$$\sigma(\mathbf{M}, R_{JB}, V_{S30}) = \sqrt{\phi^2(\mathbf{M}, R_{JB}, V_{S30}) + \tau^2(\mathbf{M})} \tag{10}$$

The **M**-dependent between-event standard deviation τ is given by

$$\tau(\mathbf{M}) = \begin{cases} \tau_1 & \mathbf{M} \leq 4.5 \\ \tau_1 + (\tau_2 - \tau_1)(\mathbf{M} - 4.5) & 4.5 < \mathbf{M} < 5.5 \\ \tau_2 & \mathbf{M} \geq 5.5 \end{cases} \tag{11}$$

and the **M**-, R_{JB}-, and V_{S30}-dependent within-event standard deviation ϕ is given by

$$\phi(\mathbf{M}, R_{JB}, V_{S30}) = \begin{cases} \phi(\mathbf{M}, R_{JB}) & V_{S30} \geq V_2 \\ \phi(\mathbf{M}, R_{JB}) - \Delta\phi_V \left(\frac{\ln(V_2/V_{S30})}{\ln(V_2/V_1)}\right) & V_1 \leq V_{S30} \leq V_2 \\ \phi(\mathbf{M}, R_{JB}) - \Delta\phi_V & V_{S30} \leq V_1 \end{cases} \tag{12}$$

where

$$\phi(\mathbf{M}, R_{JB}) = \begin{cases} \phi(\mathbf{M}) & R_{JB} \leq R_1 \\ \phi(\mathbf{M}) + \Delta\phi_R \left(\frac{\ln(R_{JB}/R_1)}{\ln(R_2/R_1)}\right) & R_1 < R_{JB} \leq R_2 \\ \phi(\mathbf{M}) + \Delta\phi_R & R_{JB} > R_2 \end{cases} \tag{13}$$

and where the M-dependent ϕ is given by:

$$\phi(\mathbf{M}) = \begin{cases} \phi_1 & \mathbf{M} \leq 4.5 \\ \phi_1 + (\phi_2 - \phi_1)(\mathbf{M} - 4.5) & 4.5 < \mathbf{M} < 5.5 \\ \phi_2 & \mathbf{M} \geq 5.5 \end{cases} \tag{14}$$

The coefficients of the GMPE is provided in Table 3. For the present study for developing the attenuation relation the Magnitude is taken from 4-9, distance till 500km, reverse mechanism, applied global parameters and V_{s30}=170m/s (average value obtained at site). The attenuation relation for V_{s30}=170m/s is given in Figure 11 a.

3.2 CB-2014

The median ground motion relation developed by Cambell and Bozorgnia(2014) can be expressed as

$$\ln(Y) = \begin{cases} \ln PGA; & PSA < PGA \quad and \quad T < 0.25s \\ f_{mag} + f_{dis} + f_{flt} + f_{hng} + f_{site} + f_{sed} + f_{hyp} + f_{dip} + f_{atn} & otherwise \end{cases} \tag{15}$$

where Y is the intensity measure of interest and f-term represents the scaling of ground motion with respect to earthquake magnitude, geometric attenuation, style of faulting, hanging wall geometry, shallow site response, basin response, hypocentral depth, fault dip, and anelastic attenuation, respectively. The terms in the above equation are described further:

Magnitude Term

$$f_{mag} = \begin{cases} c_0 + c_1\mathbf{M}; & \mathbf{M} \le 4.5 \\ c_0 + c_1\mathbf{M} + c_2(\mathbf{M} - 4.5); & 4.5 < \mathbf{M} \le 5.5 \\ c_0 + c_1\mathbf{M} + c_2(\mathbf{M} - 4.5) + c_3(\mathbf{M} - 5.5); & 5.5 < \mathbf{M} \le 6.5 \\ c_0 + c_1\mathbf{M} + c_2(\mathbf{M} - 4.5) + c_3(\mathbf{M} - 5.5) + c_4(\mathbf{M} - 6.5); & \mathbf{M} > 6.5 \end{cases} \tag{16}$$

Geometric Attenuation Term

$$f_{dis} = (c_5 + c_6\mathrm{M})\ln(\sqrt{R_{rup}^2 + c_7^2}) \tag{17}$$

Style of Faulting Term

$$f_{flt} = f_{flt,F} f_{flt,M}$$
$$f_{flt,F} = c_9 F_{NM} \tag{18}$$
$$f_{flt,M} = \begin{cases} 0; & \mathrm{M} \le 4.5 \\ \mathrm{M} - 4.5 & 4.5 \le \mathrm{M} \le 5.5 \\ 1; & M > 5.5 \end{cases}$$

Hanging Wall Term

$$f_{hng} = c_{10} f_{hng,R_x} f_{hng,R_{RUP}} f_{hng,M} f_{hng,Z} f_{hng,\delta} \tag{19}$$

$$f_{hng,R_x} = \begin{cases} 0; & R_x < 0 \\ f_1(R_x); & 0 \le R_x < R_1 \\ \max[f_2(R_x), 0]; & R_x \ge R_1 \end{cases} \tag{20}$$

$$f_1(R_x) = h_1 + h_2(R_x / R_1) + h_3(R_x / R_1)^2$$

$$f_2(R_x) = h_4 + h_5\left(\frac{R_x - R_1}{R_2 - R_1}\right) + h_6\left(\frac{R_x - R_1}{R_2 - R_1}\right)^2$$

$$R_1 = W\cos(\delta) \qquad and \qquad R_2 = 62\mathrm{M} - 350$$

$$f_{hng,R_{RUP}} = \begin{cases} 1; & R_{Rup} = 0 \\ (R_{Rup} - R_{JB}) / R_{Rup} & R_{Rup} > 0 \end{cases} \tag{21}$$

$$f_{hng,M} = \begin{cases} 0; & \mathrm{M} \le 5.5 \\ (\mathrm{M} - 5.5)\left[1 + a_2(\mathrm{M} - 6.5)\right] & 5.5 \le \mathrm{M} \le 6.5 \\ 1 + a_2(\mathrm{M} - 6.5); & M > 6.5 \end{cases} \tag{22}$$

$$f_{hng,Z} = \begin{cases} 1 - 0.06Z_{TOR}; & Z_{TOR} \le 16.66 \\ 0; & Z_{TOR} > 16.66 \end{cases} \tag{23}$$

$$f_{hng,\delta} = (90 - \delta) / 45 \tag{24}$$

Shallow Site Response Term

$$f_{site} = f_{site,G} + S_J f_{site,J} \tag{25}$$

$$f_{site,G} = \begin{cases} c_{11}\ln\left(\frac{V_{s30}}{k_1}\right) + k_2\left\{\ln\left[A_{1100} + c\left(\frac{V_{s30}}{k_1}\right)^n\right] - \ln\left(\frac{200}{k_1}\right)\right\}; & V_{s30} \le k_1 \\ (c_{11} + k_2 n)\ln\left(\frac{V_{s30}}{k_1}\right); & V_{s30} > k_1 \end{cases} \tag{26}$$

$$f_{site,J} = \begin{cases} (c_{12} + k_2 n)\left[\ln\left(\frac{V_{s30}}{k_1}\right) - \ln\left(\frac{200}{k_1}\right)\right]; & V_{s30} \le 200 \\ (c_{13} + k_2 n)\ln\left(\frac{V_{s30}}{k_1}\right); & All\ V_{s30} \end{cases} \tag{27}$$

Basin Response Term

$$f_{sed} = \begin{cases} (c_{14} + c_{15} S_J)(Z_{2.5} - 1); & Z_{2.5} \le 1 \\ 0; & 1 \le Z_{2.5} \le 3 \\ c_{16} k_3 e^{-0.75} \left[1 - \exp(-0.25(Z_{2.5} - 3))\right]; & Z_{2.5} > 3 \end{cases} \quad (28)$$

Hypocentral Depth Term

$$f_{hyp} = f_{hyp,H} f_{hyp,M} \quad (29)$$

$$f_{hyp,H} = \begin{cases} 0; & Z_{HYP} \le 1 \\ Z_{HYP} - 7; & 7 \le Z_{HYP} \le 20 \\ 13; & Z_{HYP} > 20 \end{cases} \quad (30)$$

$$f_{hyp,M} = \begin{cases} c_{17}; & \mathrm{M} \le 5.5 \\ \left[c_{17} + (c_{18} - c_{17})(\mathrm{M} - 6.5)\right] & 5.5 \le \mathrm{M} \le 6.5 \\ c_{18}; & M > 6.5 \end{cases} \quad (31)$$

Fault Dip Term

$$f_{dip} = \begin{cases} c_{19}\delta; & \mathrm{M} \le 4.5 \\ c_{19}(5.5 - \mathrm{M})\delta & 4.5 \le \mathrm{M} \le 5.5 \\ 0; & M > 5.5 \end{cases} \quad (32)$$

Anelastic Attenuation Term

$$f_{atn} = \begin{cases} (c_{20} + \Delta c_{20})(R_{Rup} - 80); & R_{Rup} > 80 \\ 0 & R_{Rup} \le 80 \end{cases} \quad (33)$$

The corresponding coefficients obtained after regression is summarized in Table 4

Definitions of Predictor Variables

The definitions of the predictor variables appearing in the equations given in the previous sections are defined as follows:

• **M** is moment magnitude. (4-9)

• R_{RUP} (km) is closest distance to the coseismic fault rupture plane (a.k.a. rupture distance).(0-500km)

• R_{JB} (km) is closest distance to the surface projection of the coseismic fault

ruptureplane (a.k.a. Joyner-Boore distance). (0-500km)

• R_X (km) is closest distance to the surface projection of the top edge of the coseismic fault rupture plane measured perpendicular to its average strike (0-500km)

• W (km) is the down-dip width of the fault rupture plane. (calculated using Wills and coppersmith equation)

• λ (°) is rake angle defined as the average angle of slip measured in the plane of rupture between the strike direction and the slip vector (90^0).

• F_{RV} is an indicator variable representing reverse and reverse-oblique faulting, where F_{RV} = 1 for 30° < λ < 150° and F_{RV} = 0 otherwise.

• F_{NM} is an indicator variable representing normal and normal-oblique faulting, where F_{NM} = 1 for -150° < λ < -30° and F_{NM} = 0 otherwise.

• Z_{TOR} (km) is the depth to the top of the fault rupture plane.

• δ (°) is the average dip angle (45^0) of the fault rupture plane measured from horizontal.

• V_{S30} (m⁄s) is the time-averaged shear wave velocity in the top 30 m of the site (a.k.a. 30 m shear wave velocity). (170km/s)

• A_{1100} (g) is the median estimated value of PGA on rock with V_{S30} = 1100m⁄s (a.k.a. rock PGA).

• S_J is an indicator variable representing regional site effects, where S_J = 1 for sites located in Japan and S_J = 0 otherwise.

• $Z_{2.5}$ (km) is the depth to the 2.5 km⁄s shear wave velocity horizon beneath the site (a.k.a. sediment depth).

• Z_{HYP} (km) is the hypocentral depth of the earthquake measured from sea level.

The attenuation relation for V_{s30}=170m/s is given in Figure 11 b.

3.3 ASK-2014

The function for of the GMPE of Abrahamson *et al.* (2014) is expressed as:

$$
\begin{aligned}
ln\ Sa(g) = & f_1(\mathbf{M}, R_{RUP}) + F_{RV} f_7(\mathbf{M}) + F_N f_8(\mathbf{M}) + F_{As} f_{11}(CR_{JB}) \\
& + f_5(\widehat{Sa}_{1180}, V_{S30}) + F_{HW} f_4(R_{JB}, R_{RUP}, R_x, R_{y0}, W, dip, Z_{TOR}, \mathbf{M}) \\
& + f_6(Z_{TOR}) + f_{10}(Z_1, V_{S30}) + Regional(V_{S30}, R_{RUP})
\end{aligned} \tag{34}
$$

where, M is the moment magnitude, CR_{jb} centroid R_{jB}, Z_{TOR} Depth to the top of rupture, F_{RV} and F_N flag for reverse and normal faulting respectively, F_{AS} flag for aftershocks, R_{RUP} Rupture distance, R_{JB} Joyner-Boore distance, R_x Horizontal distance from top edge of rupture, R_{y0} Horizontal distance off the end of the rupture measured parallel to strike, V_{s30} shear wave velocity over top 3m (m/s), dip- Fault dip, W Width of fault.

the functional forms for f_1, f_4, f_5, f_6, f_7, f_8, f_{10}, f_{11}, and the regional term are given below: (Detailed description of these functional forms can be checked in Abrahamson *et al.* (2014))

$$
f_1 = \begin{cases}
a_1 + a_5(\mathbf{M} - M_1) + a_8(8.5 - \mathbf{M})^2 + [a_2 + a_3(\mathbf{M} - M_1)]\ln(R) + a_{17} R_{RUP} & for\ \mathbf{M} > M_1 \\
a_1 + a_4(\mathbf{M} - M_1) + a_8(8.5 - \mathbf{M})^2 + [a_2 + a_3(\mathbf{M} - M_1)]\ln(R) + a_{17} R_{RUP} & for\ M_2 \le \mathbf{M} < M_1 \\
a_1 + a_4(M_2 - M_1) + a_8(8.5 - M_2)^2 + a_6(\mathbf{M} - M_2) & \\
\quad + a_7(\mathbf{M} - M_2)^2 + [a_2 + a_3(M_2 - M_1)]\ln(R) + a_{17} R_{RUP} & for\ \mathbf{M} < M_2
\end{cases} \tag{35}
$$

where

$$
R = \sqrt{R_{RUP}^2 + c_{4M}^2} \qquad \text{where} \qquad c_{4M}(\mathbf{M}) = \begin{cases} c_4 & for\ \mathbf{M} > 5 \\ c_4 - (c_4 - 1)(5 - \mathbf{M}) & for\ 4 < \mathbf{M} \le 5 \\ 1 & for\ \mathbf{M} \le 4 \end{cases}
$$

Style of Faulting (SOF) Model

$$
f_7(\mathbf{M}) = \begin{cases} a_{11} & for\ \mathbf{M} > 5.0 \\ a_{11}(\mathbf{M} - 4) & for\ 4 \le \mathbf{M} \le 5 \\ 0 & for\ \mathbf{M} < 4.0 \end{cases}
$$

$$
f_8(\mathbf{M}) = \begin{cases} a_{12} & for\ \mathbf{M} > 5.0 \\ a_{12}(\mathbf{M} - 4) & for\ 4 \le \mathbf{M} \le 5 \\ 0 & for\ \mathbf{M} < 4.0 \end{cases} \tag{36}
$$

Note that although their functional form allows for scaling of reverse faults, the final regression results are such that there is no scaling between strike-slip and reverse events (a11= 0)

Site Response Model

$$f_5(\widetilde{Sa}_{1180}, V_{S30}) = \begin{cases} (a_{10} + bn)\ln\left(\frac{V_{S30}^*}{V_{Lin}}\right) & for\ V_{S30} \geq V_{Lin} \\ (a_{10})ln\left(\frac{V_{S30}^*}{V_{Lin}}\right) - b\ ln(\widetilde{Sa}_{1180} + c) + b\ ln\left(\widetilde{Sa}_{1180} + c\left(\frac{V_{S30}^*}{V_{Lin}}\right)^n\right) & for\ V_{S30} < V_{Lin} \end{cases} \quad (37)$$

where

$$V_{S30}^* = \begin{cases} V_{S30} & for\ V_{S30} < V_1 \\ V_1 & for\ V_{S30} \geq V_1 \end{cases}$$

$$V_1 = \begin{cases} 1500 & for\ T \leq 0.5\ \text{s} \\ \exp(-0.35\ \ln(\frac{T}{0.5}) + \ln(1500)) & for\ 0.5\ \text{s} < T < 3\ \text{s} \\ 800 & for\ T \geq 3\ \text{s} \end{cases}$$

Hanging wall model

$$f_4(R_{JB}, R_{RUP}, R_x, R_{x0}, W, dip, Z_{TOR}, \mathbf{M}) = a_{13}T_1(dip)T_2(\mathbf{M})T_3(R_x, W, dip)T_4(Z_{TOR})T_5(R_x, R_{x0}\ \text{OR}\ R_{JB}) \quad (38)$$

Depth-to-Top of Rupture Model

$$f_6(Z_{TOR}) = \begin{cases} a_{15}\frac{Z_{TOR}}{20} & for\ Z_{TOR} < 20\ \text{km} \\ a_{15} & for\ Z_{TOR} \geq 20\ \text{km} \end{cases} \quad (39)$$

Soil Depth Model

$$f_{10}(Z_1, V_{S30}) = \begin{cases} a_{43}\ ln\left(\frac{Z_1+0.01}{Z_{1,ref}+0.01}\right) & for\ V_{S30} \leq 200 \\ a_{44}\ ln\left(\frac{Z_1+0.01}{Z_{1,ref}+0.01}\right) & for\ 200 < V_{S30} \leq 300 \\ a_{45}\ ln\left(\frac{Z_1+0.01}{Z_{1,ref}+0.01}\right) & for\ 300 < V_{S30} \leq 500 \\ a_{46}\ ln\left(\frac{Z_1+0.01}{Z_{1,ref}+0.01}\right) & for\ 500 < V_{S30} \end{cases} \quad (40)$$

Aftershock Scaling

$$f_{11}(CR_{JB}) = \begin{cases} a_{14} & for\ CR_{JB} \leq 5 \\ a_{14}\left[1 - \frac{CR_{JB}-5}{10}\right] & for\ 5 < CR_{JB} < 15 \\ 0 & for\ CR_{JB} \geq 15 \end{cases} \quad (41)$$

Regionalization

$$Regional(V_{S30}, R_{RUP}) = F_{TW}(f_{12}(V_{S30}) + a_{25}R_{RUP}) + F_{CN}(a_{28}R_{RUP}) + F_{JP}(f_{13}(V_{S30}) + a_{29}R_{RUP}) \quad (42)$$

The coefficients F_{TW}, F_{CN} and F_{JP} is taken as 0 except for Taiwan, China and Japan. The coefficients in the expression above is given in Table 5. For the present study for developing the attenuation relation the Magnitude is taken from 4-9, distance till 500km, reverse mechanism, applied global parameters and V_{s30}=170m/s (average value obtained at site). The attenuation relation for V_{s30}=170m/s is given in Figure 11 c.

3.4 CY-2014

The revised GMPE given by CY-2014 is explianed as further

$$\begin{aligned}
\ln(y_{refij}) = {} & c_1 + \left\{c_{1a} + \frac{c_{1c}}{\cosh(2 \cdot \max(\mathbf{M}_i - 4.5, 0))}\right\} F_{RVi} \\
& + \left\{c_{1b} + \frac{c_{1d}}{\cosh(2 \cdot \max(\mathbf{M}_i - 4.5, 0))}\right\} F_{NMi} \\
& + \left\{c_7 + \frac{c_{7b}}{\cosh(2 \cdot \max(\mathbf{M}_i - 4.5, 0))}\right\} \Delta Z_{TORi} \\
& + \left\{c_{11} + \frac{c_{11b}}{\cosh(2 \cdot \max(\mathbf{M}_i - 4.5, 0))}\right\} (\cos \delta_i)^2 \\
& + c_2(\mathbf{M}_i - 6) + \frac{c_2 - c_3}{c_n} \ln(1 + e^{c_n(c_M - \mathbf{M}_i)}) \\
& + c_4 \ln(R_{RUPij} + c_5 \cosh(c_6 \cdot \max(\mathbf{M}_i - c_{HM}, 0))) \\
& + (c_{4a} - c_4) \ln\left(\sqrt{R_{RUPij}^2 + c_{RB}^2}\right) \\
& + \left\{c_{\gamma 1} + \frac{c_{\gamma 2}}{\cosh(\max(\mathbf{M}_i - c_{\gamma 3}, 0))}\right\} R_{RUPij} \\
& + c_8 \max\left(1 - \frac{\max(R_{RUPij} - 40, 0)}{30}, 0\right) \\
& \times \min\left(\frac{\max(\mathbf{M}_i - 5.5, 0)}{0.8}, 1\right) e^{-c_{8a}(\mathbf{M}_i - c_{8b})^2} \Delta DPP_{ij} \\
& + c_9 F_{HWij} \cos \delta_i \left\{c_{9a} + (1 - c_{9a}) \tanh\left(\frac{R_{Xij}}{c_{9b}}\right)\right\} \left\{1 - \frac{\sqrt{R_{JBij}^2 + Z_{TORi}^2}}{R_{RUPij} + 1}\right\}
\end{aligned} \quad (43)$$

$$\ln(y_{ij}) = \ln(y_{ref_{ij}}) + \eta_i + \phi_1 \cdot \min\left(\ln\left(\frac{V_{S30j}}{1130}\right), 0\right) + \phi_2\left(e^{\phi_3(\min(V_{S30j},1130)-360)} - e^{\phi_3(1130-360)}\right)\ln\left(\frac{y_{ref_{ij}}e^{\eta_i} + \phi_4}{\phi_4}\right) + \phi_5\left(1 - e^{-\Delta Z_{1.0j}/\phi_6}\right) + \varepsilon_{ij} \quad (44)$$

Dependent variable y_{ij} is the ground motion amplitude for earthquake i at station j. Variable y_{refij} is the population median for the reference condition V_{s30} = 1130 m/s. Random variables η_i and ε_i represent the two modeling errors that contribute to the aleatory variability of predicted motion. The predictor variables in equations above are

M = Moment magnitude.

R_{RUP} = Closest distance (km) to the ruptured plane

R_{JB} = Closest distance (km) to the surface projection of ruptured plane.

R_X = Site coordinate (km) measured perpendicular to the fault strike from the fault line, with the down-dip direction being positive.

F_{HW} = Hanging-wall flag: 1 for $R_X \geq 0$ and 0 for $R_X < 0$.

δ = Fault dip angle

Z_{TOR} = Depth (km) to the top of ruptured plane.

ΔZ_{TOR} = Z_{TOR} centered on the M-dependent average Z_{TOR} (km).

F_{RV} = Reverse-faulting flag: 1 for $30° \leq \lambda \leq 150°$ (combined reverse and reverse-oblique), 0 otherwise; λ is the rake angle.

F_{NM} = Normal faulting flag: 1 for $-120° \leq \lambda \leq -60°$ (excludes normal-oblique), 0 otherwise.

V_{S30} = Travel-time averaged shear-wave velocity (m/s) of the top 30 m of soil.

$Z_{1.0}$ = Depth (m) to shear-wave velocity of 1.0 km/s.

$\Delta Z_{1.0}$ = $Z_{1.0}$ centered on the V_{S30}-dependent average $Z_{1.0}$ (m).

DPP = Direct point parameter for directivity effect.

ΔDPP = DPP centered on the site- and earthquake-specific average DPP.

For the present study for developing the attenuation relation the Magnitude is taken from 4-9, distance till 500km, reverse mechanism, applied global parameters and

V_{s30}=170m/s (average value obtained at site). The coefficients of the equations are given in Table 6 and 7. The attenuation relation V_{s30}=170m/s for is given in Figure 11 d.

4. Site Classification

To identify the soil condition at the BIFPCL, Maitree site of interest, the cross hole surveys at site by BHEL is used. This test is usually performed by generating horizontally traveling P and S waves at a particular level in one borehole (Source Hole) and recording their arrivals at same level in two nearby boreholes (Receiver Holes). Using this data the site can be classified based on the average shear wave velocity of the top 30 meters of the subsoil. This technique is popular among engineers as a quick way of understanding how ground motion during an earthquake differs on rock sites and soil sites. Standard documents such as Bangladesh National Building Code (BNBC-2012) can be referred for classifying sites based on borehole data or velocity profiling of the region. This standard site classification definition is shown in Table 8. For the present region soil properties is determined using values reported form the 5 cross hole test. The shear wave velocities, which, is obtained at an interval of every 2 m depth from each of these crossholes are summarized in Figure 12. The average shear wave velocity ($\overline{V}_s$) at a given borehole can be obtained using the following expression as suggested by BNBC-2012.

$$\overline{V}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{V_{s\,i}}} \tag{45}$$

where, d_i is the thickness of a given soil layer and n is the total number of layers. Here, the $\overline{V}_s$ values are obatined for soil upto a depth of 30m from the surface for the five cross hole tests as 169.52m/s, 167.24m/s, 168.08m/s, 171.94m/s and 173.25m/s respectively at each cross holes. It is clear from Table 4 that the all the sites belong to SD- Type soil condition ($\overline{V}_s$ *<180m/s*). In addition, if the $\overline{V}_s$ values are estimated from 5.00m below the ground, then the corresponding values for the five cross holes will be 179.62 m/s, 177.07 m/s, 178.03 m/s, 182.72 m/s, 184.26 m/s. It is clear that the site still

belongs to SD- Type soil condition ($\overline{V}_s$ <*180m/s*).

Further, to accertain the dynamic characteristic of this soil strata, analysis is performed using Equivalent linear Earthquake site Response Analyses (EERA) of layered soil deposits. The simulation is performed with a typical acceleration time history for SC-type soil condition from NGA database as input earthquake ground motion. The tansfer function or the frequency reponse function, which is ratio of the displacement, velocity or accelertion at two different layers, with respect to frequency is obtained and is shown in Figure 13. It is clear from the figure that the predominant period of the soil strata is 0.44sec. Further, the responce spectra following the DSHA, PSHA and according to Bangladesh National Building Code (BNBC (2012)) are generated for SD type (170m/s) soil condition.

5. Response spectra based on National Building Code, Bangladesh

Traditionally design of a building is done based on the response spectra, which is the maximum response of a single degree of freedom system at different frequencies for a given input ground motion. According to BNBC the spectral acceleration for a design earthquake is given by:

$$S_a = \frac{2}{3}\frac{ZI}{R}C_s \tag{46}$$

where S_a is design spectral acceleration, Z is seismic Zone coefficient, I is the importance factor, R is the response reduction factor based on the type of structural system, and C_s is the normalized acceleration response spectrum, which is a function of structure period and soil type as defined by the following equations:

$$
\begin{aligned}
C_s &= S\left(1+\frac{T}{T_B}(2.5\eta-1)\right) && for \quad 0 \le T \le T_B \\
C_s &= 2.5S\eta && for \quad T_B \le T \le T_C \\
C_s &= 2.5S\eta\left(\frac{T_C}{T}\right) && for \quad T_C \le T \le T_D \\
C_s &= 2.5S\eta\left(\frac{T_C T_D}{T^2}\right) && for \quad T_D \le T \le 4\,\text{sec}
\end{aligned}
\tag{47}
$$

where, S is the soil factor depending on site class and T is the structural period, T_B is the lower limit of the period of the constant spectral acceleration branch, T_C is the upper limit of the period of the constant spectral acceleration branch, T_D is the lower limit of the period of the constant spectral displacement branch. The values of S, T_B, T_C and T_D for different site classes is summarised in Table 5. η is the damping correction factor as a function of damping with a reference value of η=1 for 5% viscous damping. The expression η is

$$
\eta = \sqrt{10/(5+\xi)} \ge 0.55 \tag{48}
$$

where, ξ is the viscous damping ratio of the structure. In the present study, design acceleration response spectra are obtained for the site by taking R and I as unity. As per BNBC (2012), the Z value for Bagerhat is given as 0.12. From the average shear wave velocities obtained from the cross-hole tests (170m/s), the site belongs to 'SD, type soil condition. It is known that the percentage damping to be used depends on the type of structure. Hence response spectra are obtained for 0.8%, 1.0%, 1.6%, 2%, 3%, 5%, 7% and 10% damping according to BNBC (2012) and are summarized in Figure 14 and Table 10. For the particular response spectra I and R are taken as unity. These response spectra will be compared with that obtained from DSHA and PSHA as explained further.

6. Deterministic Seismic Hazard Analysis (DSHA)

The DSHA approach uses the known seismic sources sufficiently near the site and available historical seismic and geological data to generate discrete, single-valued

events or models of ground motion at the site. Typically one or more earthquakes are specified by magnitude and location with respect to the site. Usually the earthquakes are assumed to occur on the portion of the site closest to the site. The site ground motions are estimated deterministically, given the magnitude, source-to-site distance, and site condition. The steps involved in DSHA (Kramer 1996) as expressed through Figure 15 is described in brief as follows

Step 1: Identification of all sources capable of producing significant ground motion at the site such as Large sources at long distances and Small sources at short distances. Characterization includes Definition of source geometry and Establishment of earthquake potential.

Step 2: Selection of source-site distance parameter must be consistent with predictive relationship and should include finite fault effect

Step 3: Selection of Controlling Earthquakes is based on ground motion parameter(s). Consider all sources, assume M_{max} occurs at R_{min} for each source. Compute ground motion parameter(s) based on M_{max} and R_{min}. Then, determine critical value(s) of ground motion parameter(s).

Step 4: Definition of hazard using controlling earthquake involves the use of M and R to determine parameters such as Peak acceleration, spectral acceleration and Duration

The determinstic analysis performed for the region using source characteristics, and the different attenuation relations available in the global database. Here, DSHA is performed by considering the earthquake corresponding to 2% probability of exceedance in 50 years (2500 yrs return period). It is noted that the critical fault according to this analysis is the eocene hinge zone with a magnitude 7.5 at a distance of 106km from site. The corresponding attenuation at the site is illustrated along with response spectra according to BNBC (2012) for 5% damping in Figure 16 and Table 11. It can be seen that the spectral values obtained corresponding to the magnitude with 2% probability of exceedance in 50 years (2500yrs return period, (as per BNBC)) is comparable with BNBC(5% damping). The PGA is obtained as 0.069, 0.074, 0.058 and 0.089 g correspondingly for ASK, BSSA, CB and CY. Similarly for S_a at 0.2 sec is estimated as 0.211, 0.158, 0.114 and 0.199 and for 1 sec the values for corresponding

GMPEs are 0.167, 0.111, 0.115 and 0.160.

The percentage damping considered for the construction of response spectra should depend on the type of the structure. Thus, the flexible structure will have lesser damping percentace, while for rigid structures the damping percentage would be higher. It should be noted that the GMPE's used here is developed based on spectral values correspoinding to 5% damping. Hence, it is nessary to apply suitable damping correction factors to estimate the spectras corresponding to other damping. The commonly used damping correction factors are those given in Newmarks and Halls (1982). There are several other literatures proposing the damping correction factors (Boomer et al. (2000), Priestley (2003), Atkinson and Pierre (2004) etc.). In this report, the more recent damping correction factor (DCF) for deep soil reported by Cameron and Green (2007) is considered. The DCF values is linearly interpolated, for all the required time periods and damping percentages, and is summarized in Table 13. Further, It should be noted that the uncertainities in the source should be accounted in the study and thereby taking just the a single magnitude and distance value will lead to an overconservative estimate of spectral values.

7. Probabilistic Seismic Hazard Analysis (PSHA)

Probabilistic seismic hazard analysis estimates the probability of exceedance of various ground motion levels at a site given all possible earthquakes. The basic formulation for PSHA has been derived by Cornell (1968) assuming point source model for earthquakes. Later PSHA has been improved to include finite source and its uncertainty by Kiureghian and Ang (1977). Now a days, PSHA has become a standard tool for estimating ground motion. The procedure required for PSHA has been discussed in great detail in the literature (Kramer 1996). The same methodology has been followed in the present study also. The basic steps are briefly mentioned here. The uncertainty in the magnitude of a future event is represented as a an exponential random variable

$$p_M(m) = \frac{\beta e^{-\beta(m-m_0)}}{1-\beta e^{-\beta(m_u-m_0)}}; \quad (m_0 \le m \le m_u),\ \beta = 2.303b \tag{49}$$

The other unknown factor is the distance R of the site to the future hypocenter. The conditional probability distribution function of R, given that magnitude M = m for a rupture segment uniformly distributed along a fault can be numerically computed following the method of Der Kiureghian and Ang (1977) . Referring to Figure 17. we have

$$\begin{aligned} &P(R<r \mid M=m) = 0 \quad for\ R < \left(D^2 + L_o^2\right)^{1/2} \\ &P(R<r \mid M=m) = \frac{\left(r^2 - D^2\right)^{1/2} - L_o}{L - X(m)} \\ &\qquad for \left(D^2 + L_o^2\right)^{1/2} \le R < \left\{D^2 + \left[L + L_o - X(m)\right]^2\right\}^{1/2} \\ &P(R<r \mid M=m) = 1 \quad for\ R > \left\{D^2 + \left[L + L_o - X(m)\right]^2\right\}^{1/2} \end{aligned} \tag{50}$$

The rupture length, $X(m)$, for an event of magnitude m, is given by

$$X(m) = MIN\left[10^{(-2.44+0.59m)}, fault\ length\right] \tag{51}$$

Probabilistic seismic hazard analysis estimates the probability of exceedance of spectral acceleration S_a at a site due to all possible future earthquakes as visualized by the previous hazard scenario. Assuming that the number of earthquakes occurring on a fault follows a stationary Poisson process, the probability that the control variable Y exceeds level y^*, in a time window of T years is given by

$$P(Y > y^* \text{ in T years}) = 1\text{-}\exp(-\mu_{y^*} T) \tag{52}$$

The rate of exceedance, μ_{y^*} is computed from the expression

$$\mu_{y^*} = \sum_{i=1}^{K} N_i(m_0) \int_m \int_r P(Y > y^* \mid m, r)\, p_{R|M}(r \mid m)\, p_M(m)\ \ dr\,dm \tag{53}$$

Here, K is the total number of faults in the zone, $p_M(m)$ and $p_{R|M}$ $(r \mid m)$ are the probability density functions of magnitude and hypocentral distance respectively. $P(Y > y^* \mid m, r)$ is the conditional probability of exceedance of the ground motion parameter Y. This is found as a lognormal random variable with mean value given by the attenuation equation conditioned on particular m and r values. The reciprocal of the annual probability of exceedance gives the return period for the corresponding ground motion value. The mean annual rate of exceedance of y^* is obtained by summing over the individual probabilities due to all faults. This is repeated for various ground motion values y^* to obtain the seismic hazard curves. These curves are first obtained individually for all the faults located in the ten tectonic zones and combined to estimate the aggregate hazard at the site.

7.1. Uniform Hazard Response Spectra

The uniform hazard response spectra (UHRS), the spectrum having the same mean recurrence interval at all frequencies, will be developed for BIFPCL, Maitree site, at Bagerhat. These results will be obtained using the appropriate global attenuation ground motion. The site specific UHRS will be obtained for return periods of 2500yrs, which corresponds to 2% probability in 50years or Maximum Considered Earthquake (MCE). According to BNBC (2012), the design basis earthquake is taken as 2/3 of the MCE. Hence, the UHRS for 2/3 of the corresponding value obtained for 2500 return period is given in Table 12 and Figure 18. The PGA is obtained as 0.067, 0.08, 0.056, 0.073 for correspondingly for ASK (2014), BSSA (2014), CB (2014) and CY (2014) for 2/3 of 2500yrs return period. As explained in the previous sections, the GMPE used here is valid for only 5% damping. Hence to generate the UHRS corresponding to other damping, the corresponding values have to be applied with suitable damping correction factor (DCF). In this report the DCF reported by Cameron and Green (2007), given in Table 13, is used to obtain the UHRS for different percentage of damping.

8. Recommended Spectra

The maximum values obtained from the DSHA and the 2/3 of UHRS with 2500yrs return

period is compared with that of BNBC response spectra at 5% damping and is shown in Table 14 and Figure 19. It is clear that the BNBC is higher than the other two spectras up to the time period of 2 seconds. After 2 sec DSHA values are observed to be the highest among the three spectras. Hence it is recommended to consider an envelope encompassing the maximum values of the response spectra for the design of structures at the site (shown as black line in Figure 19). The PGA, S_a (T=0.2s) and S_a (T=1 s) of the envelop are 0.108g 0.272g and 0.216g respectively.

To achieve the recommended response spectra for other damping it is necessary to compare the corresponding value of BNBC (2012) with the DSHA and UHRS values corrected for damping. Thus, the DSHA and UHRS are multiplied with the respective damping correction factors reported in Table 13. Figure 20 (a) and (b) shows the comparison of all the three spectra for 1% and 10% damping respectively. It is clear that for the lower percentage of damping BNBC is lower than that obtained from DSHA and UHRS. Thus it is necessary to increase the BNBC values in the intermediate time period range to obtain the recommended response spectra for the site. The corresponding multiplying factors imposed on BNBC spectra for 0.8%, 1%, 1.6%, 2% and 3% are respectively 1.2823, 1.2589, 1.1776, 1.1147 and 1.1143. The final recommended spectra obtained for different percentage of damping is shown in Table 15 and Figure 21. The PGA value is observed as 0.108g for all the damping ratios. The maximum values of the spectra range between 0.2s to 0.8s and the corresponding values for 0.8%, 1%, 1.6%, 2%, 3%, 5%, 7% and 10% are 0.455g, 0.439g, 0.391g, 0.360g, 0.336g, 0.272g, 0.246g and 0.220g respectively.

9. Spectrum Compatible Acceleration Time History

Acceleration time histories are essential for the non-linear and dynamic analysis of the structure. These acceleration time histories will be desirable if it represent the spectral characteristics of the site under consideration. There are various methods available to generate this synthetic acceleration which is compatible with the site specific response spectra. One such method is that developed by Alexander *et al.* (2014). According to this method, first, the seed time series (any desired time series from the global

database) is re-expressed as a discrete Volterra series. The first-order Volterra kernel is estimated by a multilevel wavelet decomposition using the stationary wavelet transform. Second, the higher-order Volterra kernels are estimated using a complete multinomial mixing of the first-order kernel functions. Finally, the weighting of every term in this Volterra series is optimally adapted using a Levenberg–Marquardt algorithm such that the modified time series matches any target response spectrum.

For the present site this method is applied to generate 5 samples of acceleration time history which are compatible with the response spectra corresponding to the recommended envelope for 5% damping given in Figure 21. The comparison of the response spectras of the sample acceleration time histories with that of the envelope is shown in Figure 22. Further, the generated acceleration time histories are represented in Figure 23 and also provided as '.txt' document along with this report. These samples can be used for the analysis of the structure at site.

10. Summary and Recommendation

The objective of this report is to derive the site specific response spectra for BIFPCL, Maitree STPP project site located in Bagerhat, Bangladesh. The site response spectras are obtained according to deterministic seismic hazard analysis, probabilistic seismic hazard analysis and as per the Bangladesh national building code procedure. Since there are no regional ground motion prediction equations available for Bangladesh, the GMPEs available in the global database which account for various active regions in the world are considered for the study.

A brief review on the geological and tectonic zones surrounding the site is presented in the report. The site is located in tidal delta geological zone. It is observed that the thickness of holocene sediments at the site is around 15 km. In the present study, first, all the faults located within 500km of the site are identified. The faults surrounding the site are grouped into ten homogeneous seismogenic zones to estimate the recurrence parameters. A comprehensive earthquake catalogue consisting of around 2800 events is compiled for the bridge site. To determine the site specific response spectra it is necessary to determine the site condition through field tests. The 5 cross-hole test data

supplied by BHEL for the site is used for this purpose. It is observed that the site belongs to SD type soil (V_{s30}<180m/s) condition, even after removal of top 5m soil, according to BNBC-2012. Further, design response spectra are constructed for the site following BNBC (2012), DSHA and PSHA and are summarized in Figures 14, 16 and 18 and Table 10, 11 and 12. The maximum value obtained from DSHA and 2/3UHRS-2500yrs RP (PSHA) at each time period is compared with BNBC-5% damping as shown Figure 19. It is observed from the figures that the response spectra according to DSHA (M7.5 corresponding to 2500yrs return period) as well as from UHRS (2500yrs return period) is lower than that obtained according to BNBC for 5% damping till 2 seconds. After 2 seconds the DSHA response spectra is observed to be dominant among the three spectras considered. Hence it is recommended to use an envelope of the maximum value shown in Figure 19 for the design of structure at site.

Further it is known that the damping ratio to be considered in design should depend on the type of structure. Typically the damping ratio ranges for different type of structure are 0.1% -1% for aluminum structures, 1%-2% for steel structures, 5%-7% for concrete structures and 10% to 20% for soil structures. Hence in this report response spectras are obtained for 0.8%, 1%, 1.6%, 2%, 3%, 5%, 7% and 10% damping. Since the GMPE's used in the present work corresponded to 5% damping only the DSHA and UHRS values obtained from this case is multiplied with suitable damping correction factors as proposed by Cameron and Green (2007).

The spectral acceleration for design earthquake (refer Clause 2.5.6.3 of BNBC 2012) based upon the site specific seismic study shall be considered as follows (instead of using equation 2.5.4 of BNBC 2012):-

$$S_a = C_{ss} * I/R \tag{54}$$

where,

Sa = Design spectral acceleration (in units of g)

C_{ss} = Site specific acceleration response spectrum. Recommended values are given in Table 15 and Figure 21 for various viscous damping ratios.

I = Structure Importance factor. Shall be considered as per BNBC 2012.
R = Reponse reduction factor. Shall be considered as per BNBC 2012.

Thus final recommended site specific spectra obtained by considering the maximum values from all the cases individually for different percentage of damping, shown in Table 15 and Figure 21, are obtained by considering *I* and *R* as unity.

The features of the final recommended spectra (C_s) are as follows

- The Zero period design acceleration value is observed as 0.108g for all the damping ratios.
- The maximum values of the spectra range between 0.2s to 0.8s time period.
- The maximum value of the spectra for 0.8%, 1%, 1.6%, 2%, 3%, 5%, 7% and 10% are 0.455g, 0.439g, 0.391g, 0.360g, 0.336g, 0.272g, 0.246g and 0.220g respectively.
- It is observed that the soil class at site belongs to 'SD' type according to BNBC-2012 even after removal of top 5m of soil. Hence the spectras reported in Table 15 and Figure 21 is valid for a depth of 5m as well.
- The values given in Table 15 and Figure 21 are for *I/R*=1. In order to obtain the spectral acceleration for the design earthquake to be applied for the design of structure at site, these recommended values should be multiplied by suitable *I/R* (BNBC (2012)); where *I* is the Structural Importance Factor and *R* is the response reduction factor, considered as per BNBC 2012.

. Further, acceleration time histories compatible with recommended envelope corresponding to 5% damping is provided, which can be used for the analysis of the structure at site.

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Table 1. Earthquakes of magnitude Mw ≥ 6 around BIFPCL, Maitree site, Bagerhat, Bangladesh.

Long. (^{0}N)	Lat. (^{0}E)	Year	Month	Date	Magnitude (M_w)	Depth (km)
91.80	26.10	825	1	1	8	0
88.40	22.60	1737	10	11	7.2	0
92.00	22.00	1762	4	2	7.5	0
88.00	24.00	1764	6	4	6	0
89.75	24.50	1787	6	1	7.8	0
91.00	23.50	1822	4	3	6	0
89.40	25.80	1834	7	8	6.3	0
90.00	25.00	1842	11	11	6.5	0
90.40	24.80	1846	10	17	6.3	0
92.70	26.30	1847	1	1	6.3	0
92.50	22.20	1865	12	19	6	0
92.50	24.50	1869	1	10	7.5	0
90.00	24.00	1885	7	14	7	0
91.00	25.90	1897	6	12	8.1	0
91.00	24.50	1918	7	8	7.6	0
93.20	22.20	1920	8	15	6	0
93.40	22.60	1923	8	10	6	0
91.00	25.30	1923	9	9	7.1	0
93.00	25.00	1924	1	30	6	0
90.20	25.80	1930	7	2	7.1	0
93.80	25.30	1930	9	22	6	0
90.00	25.00	1932	3	24	7.4	0
92.00	24.50	1932	3	27	7.4	0
92.00	26.50	1932	11	09	7.4	0
91.00	26.00	1933	3	6	7.6	0
86.80	26.60	1934	1	15	8.3	0
89.50	24.40	1935	3	21	6.2	0
92.00	27.00	1941	1	21	6.8	0
90.90	25.10	1945	5	19	6.1	0
89.00	26.00	1949	12	10	6	0
93.00	25.00	1950	8	15	6	0
92.70	21.60	1955	12	14	6.7	0
91.30	28.30	1954	2	23	6.5	0
90.90	24.80	1956	6	12	6	0
93.95	22.60	1956	7	12	6.3	0

93.76	24.38	1957	7	1	7.2	41
90.30	26.90	1960	7	29	6.5	11
90.50	24.90	1963	6	19	6.2	0
93.58	22.33	1964	1	22	6	60
86.63	26.72	1988	8	20	6.4	65
91.36	27.40	2009	9	21	6.4	
99.49	20.70	2011	3	24	6.8	0
88.17	27.48	2011	9	18	6.8	0
95.55	23.47	2012	11	11	6.6	0
18.80	87.50	2014	5	21	6.1	
84.52	28.5	2015	4	25	7.5	0
86.10	27.60	2015	5	12	7.1	0
86.11	27.48	2015	4	26	6.6	0
94.26	23.21	2016	4	13	7.2	0
93.15	24.50	2016	4	1	6.6	

Table 2. Seismicity parameters for seven seismogenic zones considered in this study

Source No.	Zones	*b*-value	*N(4)*	Max. Potential Magnitude (M_{max})	No. of earthquakes
3	Central Himalaya II	0.8±0.03	2.39±0.31	8.8±0.4	403
4	Eastern Himalaya	0.74±0.03	2.87±0.54	8±0.3	243
8	Shillong Plateau & Assam Valley	0.76±0.03	2±0.34	8.4±0.3	200
9	Bengal Basin	0.75±0.03	2±0.22	8.1±0.5	330
10	Indo Burmese Arc	0.82±0.02	12.04±1.74	7.8±0.3	1126
11	Shan-Sagaing fault	0.68±0.03	5.64±1.11	8.1±0.3	319
17	Eastern Passive Margin	0.8±0.07	0.36±0.07	6.3±0.3	42
18	Mahanandi Garben & Eastern Carton	0.79±0.09	0.3±0.1	5.8±0.5	27
31	Gangetic region	0.89±0.08	0.33±0.08	6.3±0.5	31
32	Bay of Bengal	0.63±0.06	1.07±0.26	6.8±0.3	75

Table 3. (a) Coefficients in the attenuation relation of BSSA-2014 for Magnitude scaling term

Period(sec)	e0	e1	e2	e3	e4	e5	e6	Mh
0	4.47E-01	4.86E-01	2.46E-01	4.54E-01	1.43E+00	5.05E-02	-1.66E-01	5.5
0.01	4.53E-01	4.92E-01	2.52E-01	4.60E-01	1.42E+00	4.93E-02	-1.66E-01	5.5
0.02	4.86E-01	5.24E-01	2.97E-01	4.89E-01	1.43E+00	5.34E-02	-1.66E-01	5.5
0.03	5.69E-01	6.09E-01	4.04E-01	5.58E-01	1.43E+00	6.14E-02	-1.67E-01	5.5
0.05	7.54E-01	7.99E-01	6.07E-01	7.27E-01	1.40E+00	6.74E-02	-1.81E-01	5.5
0.075	9.64E-01	1.01E+00	7.77E-01	9.56E-01	1.42E+00	7.35E-02	-1.97E-01	5.5
0.1	1.13E+00	1.17E+00	8.87E-01	1.15E+00	1.43E+00	5.52E-02	-1.98E-01	5.54
0.15	1.31E+00	1.35E+00	1.06E+00	1.33E+00	1.28E+00	-4.21E-02	-1.82E-01	5.74
0.2	1.33E+00	1.36E+00	1.12E+00	1.34E+00	1.13E+00	-1.11E-01	-1.59E-01	5.92
0.3	1.22E+00	1.24E+00	1.02E+00	1.27E+00	9.57E-01	-1.96E-01	-9.29E-02	6.14
0.4	1.10E+00	1.12E+00	8.98E-01	1.16E+00	9.68E-01	-2.26E-01	-2.32E-02	6.2
0.5	9.70E-01	9.91E-01	7.62E-01	1.01E+00	1.04E+00	-2.35E-01	2.91E-02	6.2
0.75	6.69E-01	6.97E-01	4.75E-01	6.92E-01	1.29E+00	-2.16E-01	1.08E-01	6.2
1	3.93E-01	4.22E-01	2.07E-01	4.12E-01	1.50E+00	-1.90E-01	1.79E-01	6.2
1.5	-1.50E-01	-1.19E-01	-3.14E-01	-1.44E-01	1.76E+00	-1.47E-01	3.39E-01	6.2
2	-5.87E-01	-5.50E-01	-7.15E-01	-6.07E-01	1.92E+00	-1.12E-01	4.48E-01	6.2
3	-1.19E+00	-1.14E+00	-1.23E+00	-1.27E+00	2.13E+00	-4.33E-02	6.27E-01	6.2
4	-1.64E+00	-1.57E+00	-1.67E+00	-1.75E+00	2.20E+00	-1.46E-02	7.63E-01	6.2
5	-1.97E+00	-1.89E+00	-2.02E+00	-2.09E+00	2.23E+00	-1.49E-02	8.73E-01	6.2
7.5	-2.59E+00	-2.49E+00	-2.82E+00	-2.69E+00	2.12E+00	-8.16E-02	1.01E+00	6.2
10	-3.07E+00	-2.95E+00	-3.38E+00	-3.17E+00	1.88E+00	-1.51E-01	1.07E+00	6.2

Table 3(b) Coefficients in the attenuation relation of BSSA-2014 for Distance scaling term

Period(sec)	c1	c2	c3	Mref	Rref (km)	h (km)
0	-1.13	1.92E-01	-8.09E-03	4.5	1	4.5
0.01	-1.13	1.92E-01	-8.09E-03	4.5	1	4.5
0.02	-1.14	1.90E-01	-8.07E-03	4.5	1	4.5
0.03	-1.14	1.88E-01	-8.34E-03	4.5	1	4.49
0.05	-1.12	1.87E-01	-9.82E-03	4.5	1	4.2
0.075	-1.08	1.82E-01	-1.06E-02	4.5	1	4.04
0.1	-1.07	1.72E-01	-1.02E-02	4.5	1	4.13
0.15	-1.05	1.54E-01	-8.98E-03	4.5	1	4.39
0.2	-1.06	1.45E-01	-7.72E-03	4.5	1	4.61
0.3	-1.09	1.34E-01	-5.48E-03	4.5	1	4.93
0.4	-1.12	1.25E-01	-4.05E-03	4.5	1	5.16
0.5	-1.15	1.20E-01	-3.22E-03	4.5	1	5.34
0.75	-1.18	1.11E-01	-1.93E-03	4.5	1	5.6
1	-1.19	1.02E-01	-1.21E-03	4.5	1	5.74
1.5	-1.21	9.64E-02	-3.65E-04	4.5	1	6.18
2	-1.22	9.64E-02	0.00E+00	4.5	1	6.54
3	-1.22	9.76E-02	0.00E+00	4.5	1	6.93
4	-1.22	1.02E-01	-5.20E-05	4.5	1	7.32
5	-1.22	1.04E-01	0.00E+00	4.5	1	7.78
7.5	-1.25	1.25E-01	0.00E+00	4.5	1	9.48
10	-1.33	1.52E-01	0.00E+00	4.5	1	9.66

Table 3 (c) Coefficients in the attenuation relation of BSSA-2014 for Site term

Period (sec)	Linear Site term			Linear Site term			Basin Depth	
	c	Vc (m/s)	Vref (m/s)	f3	f4	f5	f6 (1/km)	f7
0	-6.00E-01	1500	760	0.1	-1.50E-01	-7.01E-03	-9.90E+00	-9.90E+00
0.01	-6.04E-01	1500.2	760	0.1	-1.48E-01	-7.01E-03	-9.90E+00	-9.90E+00
0.02	-5.74E-01	1500.36	760	0.1	-1.47E-01	-7.28E-03	-9.90E+00	-9.90E+00
0.03	-5.34E-01	1502.95	760	0.1	-1.55E-01	-7.35E-03	-9.90E+00	-9.90E+00
0.05	-4.58E-01	1501.42	760	0.1	-1.92E-01	-6.47E-03	-9.90E+00	-9.90E+00
0.075	-4.44E-01	1494	760	0.1	-2.35E-01	-5.73E-03	-9.90E+00	-9.90E+00
0.1	-4.87E-01	1479.12	760	0.1	-2.49E-01	-5.60E-03	-9.90E+00	-9.90E+00
0.15	-5.80E-01	1442.85	760	0.1	-2.57E-01	-5.85E-03	-9.90E+00	-9.90E+00
0.2	-6.88E-01	1392.61	760	0.1	-2.47E-01	-6.14E-03	-9.90E+00	-9.90E+00
0.3	-8.42E-01	1308.47	760	0.1	-2.19E-01	-6.70E-03	-9.90E+00	-9.90E+00
0.4	-9.11E-01	1252.66	760	0.1	-1.96E-01	-7.13E-03	-9.90E+00	-9.90E+00
0.5	-9.69E-01	1203.91	760	0.1	-1.75E-01	-7.44E-03	-9.90E+00	-9.90E+00
0.75	-1.02E+00	1147.59	760	0.1	-1.39E-01	-8.12E-03	9.23E-02	5.90E-02
1	-1.05E+00	1109.95	760	0.1	-1.05E-01	-8.44E-03	3.67E-01	2.08E-01
1.5	-1.05E+00	1072.39	760	0.1	-6.20E-02	-7.71E-03	6.38E-01	3.09E-01
2	-1.04E+00	1009.49	760	0.1	-3.61E-02	-4.79E-03	8.71E-01	3.82E-01
3	-1.01E+00	922.43	760	0.1	-1.36E-02	-1.83E-03	1.13E+00	5.16E-01
4	-9.69E-01	844.48	760	0.1	-3.21E-03	-1.52E-03	1.27E+00	6.29E-01
5	-9.20E-01	793.13	760	0.1	-2.55E-04	-1.44E-03	1.33E+00	7.38E-01
7.5	-7.77E-01	771.01	760	0.1	-5.46E-05	-1.37E-03	1.33E+00	8.09E-01
10	-6.56E-01	775	760	0.1	0.00E+00	-1.36E-03	1.18E+00	7.03E-01

Table 3 (d) Coefficients in the attenuation relation of BSSA-2014 for Aleatory Uncertainity

Period (s)	$R`_1$ (km)	R_2 (km)	DfR	DfV	V_1 (m/s)	V_2 (m/s)	ϕ_1	ϕ_2	τ_1	τ_2
0	110	270	0.1	0.07	225	300	0.695	0.495	0.398	0.348
0.01	111.67	270	0.096	0.07	225	300	0.698	0.499	0.402	0.345
0.02	113.1	270	0.092	0.03	225	300	0.702	0.502	0.409	0.346
0.03	112.13	270	0.081	0.029	225	300	0.721	0.514	0.445	0.364
0.05	97.93	270	0.063	0.03	225	300	0.753	0.532	0.503	0.426
0.075	85.99	270.04	0.064	0.022	225	300	0.745	0.542	0.474	0.466
0.1	79.59	270.09	0.087	0.014	225	300	0.728	0.541	0.415	0.458
0.15	81.33	270.16	0.12	0.015	225	300	0.72	0.537	0.354	0.388
0.2	90.91	270	0.136	0.045	225	300	0.711	0.539	0.344	0.309
0.3	103.15	268.59	0.138	0.05	225	300	0.675	0.561	0.363	0.229
0.4	106.02	266.54	0.122	0.049	225	300	0.643	0.58	0.381	0.21
0.5	105.54	265	0.109	0.06	225	300	0.615	0.599	0.41	0.224
0.75	108.39	266.51	0.1	0.07	225	300	0.581	0.622	0.457	0.266
1	116.39	270	0.098	0.02	225	300	0.553	0.625	0.498	0.298
1.5	125.38	262.41	0.104	0.01	225	300	0.532	0.619	0.525	0.315
2	130.37	240.14	0.105	0.008	225	300	0.526	0.618	0.532	0.329
3	130.36	195	0.088	0	225	300	0.534	0.619	0.537	0.344
4	129.49	199.45	0.07	0	225	300	0.536	0.616	0.543	0.349
5	130.22	230	0.061	0	225	300	0.528	0.622	0.532	0.335
7.5	130.72	250.39	0.058	0	225	300	0.512	0.634	0.511	0.27
10	130	210	0.06	0	225	300	0.51	0.604	0.487	0.239

Table 4. Coefficients of the median horizontal ground motion model (CB-2014)

T (s)	c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_9
0.01	-4.365	0.97	0.533	-1.485	-0.499	-2.773	0.248	6.753	-0.214
0.02	-4.348	0.97	0.549	-1.488	-0.501	-2.772	0.247	6.502	-0.208
0.03	-4.024	0.93	0.628	-1.494	-0.517	-2.782	0.246	6.291	-0.213
0.05	-3.479	0.88	0.674	-1.388	-0.615	-2.791	0.24	6.317	-0.244
0.075	-3.293	0.90	0.726	-1.469	-0.596	-2.745	0.227	6.861	-0.266
0.1	-3.666	0.99	0.698	-1.572	-0.536	-2.633	0.21	7.294	-0.229
0.15	-4.866	1.26	0.51	-1.669	-0.49	-2.458	0.183	8.031	-0.211
0.2	-5.411	1.36	0.447	-1.75	-0.451	-2.421	0.182	8.385	-0.163
0.25	-5.962	1.45	0.274	-1.711	-0.404	-2.392	0.189	7.534	-0.15
0.3	-6.403	1.52	0.193	-1.77	-0.321	-2.376	0.195	6.99	-0.131
0.4	-7.566	1.73	-0.02	-1.594	-0.426	-2.303	0.185	7.012	-0.159
0.5	-8.379	1.87	-0.121	-1.577	-0.44	-2.296	0.186	6.902	-0.153
0.75	-9.841	2.02	-0.042	-1.757	-0.443	-2.232	0.186	5.522	-0.09
1	-11.011	2.18	-0.069	-1.707	-0.527	-2.158	0.169	5.65	-0.105
1.5	-12.469	2.27	0.047	-1.621	-0.63	-2.063	0.158	5.795	-0.058
2	-12.969	2.27	0.149	-1.512	-0.768	-2.104	0.158	6.632	-0.028
3	-13.306	2.15	0.368	-1.315	-0.89	-2.051	0.148	6.759	0
4	-14.02	2.13	0.726	-1.506	-0.885	-1.986	0.135	7.978	0
5	-14.558	2.11	1.027	-1.721	-0.878	-2.021	0.14	8.538	0
7.5	-15.509	2.22	0.169	-0.756	-1.077	-2.179	0.178	8.468	0
10	-15.975	2.13	0.367	-0.8	-1.282	-2.244	0.194	6.564	0
PGA	-4.416	0.98	0.537	-1.499	-0.496	-2.773	0.248	6.768	-0.212
PGV	-2.895	1.51	0.27	-1.299	-0.453	-2.466	0.204	5.837	-0.168

Table 4. Coefficients of the median horizontal ground motion model (CB-2014) (contd..)

T (s)	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}	c_{17}
0.01	-0.214	0.72	1.094	2.191	1.416	-0.007	-0.207	0.39	0.0981
0.02	-0.208	0.73	1.149	2.189	1.453	-0.0167	-0.199	0.387	0.1009
0.03	-0.213	0.759	1.29	2.164	1.476	-0.0422	-0.202	0.378	0.1095
0.05	-0.244	0.826	1.449	2.138	1.549	-0.0663	-0.339	0.295	0.1226
0.075	-0.266	0.815	1.535	2.446	1.772	-0.0794	-0.404	0.322	0.1165
0.1	-0.229	0.831	1.615	2.969	1.916	-0.0294	-0.416	0.384	0.0998
0.15	-0.211	0.749	1.877	3.544	2.161	0.0642	-0.407	0.417	0.076
0.2	-0.163	0.764	2.069	3.707	2.465	0.0968	-0.311	0.404	0.0571
0.25	-0.15	0.716	2.205	3.343	2.766	0.1441	-0.172	0.466	0.0437
0.3	-0.131	0.737	2.306	3.334	3.011	0.1597	-0.084	0.528	0.0323
0.4	-0.159	0.738	2.398	3.544	3.203	0.141	0.085	0.54	0.0209
0.5	-0.153	0.718	2.355	3.016	3.333	0.1474	0.233	0.638	0.0092
0.75	-0.09	0.795	1.995	2.616	3.054	0.1764	0.411	0.776	-0.0082
1	-0.105	0.556	1.447	2.47	2.562	0.2593	0.479	0.771	-0.0131
1.5	-0.058	0.48	0.33	2.108	1.453	0.2881	0.566	0.748	-0.0187
2	-0.028	0.401	-0.514	1.327	0.657	0.3112	0.562	0.763	-0.0258
3	0	0.206	-0.848	0.601	0.367	0.3478	0.534	0.686	-0.0311
4	0	0.105	-0.793	0.568	0.306	0.3747	0.522	0.691	-0.0413
5	0	0	-0.748	0.356	0.268	0.3382	0.477	0.67	-0.0281
7.5	0	0	-0.664	0.075	0.374	0.3754	0.321	0.757	-0.0205
10	0	0	-0.576	-0.027	0.297	0.3506	0.174	0.621	0.0009
PGA	-0.212	0.72	1.09	2.186	1.42	-0.0064	-0.202	0.393	0.0977
PGV	-0.168	0.305	1.713	2.602	2.457	0.106	0.332	0.585	0.0517

Table 4. Coefficients of the median horizontal ground motion model (CB-2014) (contd..)

T (s)	c_{18}	c_{19}	c_{20}	$\Delta c_{20,JI}$	$\Delta c_{20,CH}$
0.01	0.0334	0.00755	-0.0055	-0.0035	0.0036
0.02	0.0327	0.00759	-0.0055	-0.0035	0.0036
0.03	0.0331	0.0079	-0.0057	-0.0034	0.0037
0.05	0.027	0.00803	-0.0063	-0.0037	0.004
0.075	0.0288	0.00811	-0.007	-0.0037	0.0039
0.1	0.0325	0.00744	-0.0073	-0.0034	0.0042
0.15	0.0388	0.00716	-0.0069	-0.003	0.0042
0.2	0.0437	0.00688	-0.006	-0.0031	0.0041
0.25	0.0463	0.00556	-0.0055	-0.0033	0.0036
0.3	0.0508	0.00458	-0.0049	-0.0035	0.0031
0.4	0.0432	0.00401	-0.0037	-0.0034	0.0028
0.5	0.0405	0.00388	-0.0027	-0.0034	0.0025
0.75	0.042	0.0042	-0.0016	-0.0032	0.0016
1	0.0426	0.00409	-0.0006	-0.003	0.0006
1.5	0.038	0.00424	0	-0.0019	0
2	0.0252	0.00448	0	-0.0005	0
3	c_{18}	0.00345	0	0	0
4	0.0334	0.00603	0	0	0
5	0.0327	0.00805	0	0	0
7.5	0.0331	0.0028	0	0	0
10	0.027	0.00458	0	0	0
PGA	0.0288	0.00757	-0.0055	-0.0035	0.0036
PGV	0.0325	0.00613	-0.0017	-0.0006	0.0017

Table 4. Coefficients of the median horizontal ground motion model (CB-2014) (contd..)

T (s)	k_1	k_2	k_3	a_1	h_1	h_2	h_3	h_5	h_6
0.01	865	-1.186	1.839	0.168	0.242	1.471	-0.714	-0.336	-0.27
0.02	865	-1.219	1.84	0.166	0.244	1.467	-0.711	-0.339	-0.263
0.03	908	-1.273	1.841	0.167	0.246	1.467	-0.713	-0.338	-0.259
0.05	1054	-1.346	1.843	0.173	0.251	1.449	-0.701	-0.338	-0.263
0.075	1086	-1.471	1.845	0.198	0.26	1.435	-0.695	-0.347	-0.219
0.1	1032	-1.624	1.847	0.174	0.259	1.449	-0.708	-0.391	-0.201
0.15	878	-1.931	1.852	0.198	0.254	1.461	-0.715	-0.449	-0.099
0.2	748	-2.188	1.856	0.204	0.237	1.484	-0.721	-0.393	-0.198
0.25	654	-2.381	1.861	0.185	0.206	1.581	-0.787	-0.339	-0.21
0.3	587	-2.518	1.865	0.164	0.21	1.586	-0.795	-0.447	-0.121
0.4	503	-2.657	1.874	0.16	0.226	1.544	-0.77	-0.525	-0.086
0.5	457	-2.669	1.883	0.184	0.217	1.554	-0.77	-0.407	-0.281
0.75	410	-2.401	1.906	0.216	0.154	1.626	-0.78	-0.371	-0.285
1	400	-1.955	1.929	0.596	0.117	1.616	-0.733	-0.128	-0.756
1.5	400	-1.025	1.974	0.596	0.117	1.616	-0.733	-0.128	-0.756
2	400	-0.299	2.019	0.596	0.117	1.616	-0.733	-0.128	-0.756
3	400	0	2.11	0.596	0.117	1.616	-0.733	-0.128	-0.756
4	400	0	2.2	0.596	0.117	1.616	-0.733	-0.128	-0.756
5	400	0	2.291	0.596	0.117	1.616	-0.733	-0.128	-0.756
7.5	400	0	2.517	0.596	0.117	1.616	-0.733	-0.128	-0.756
10	400	0	2.744	0.596	0.117	1.616	-0.733	-0.128	-0.756
PGA	865	-1.186	1.839	0.167	0.241	1.474	-0.715	-0.337	-0.27
PGV	400	-1.955	1.929	0.596	0.117	1.616	-0.733	-0.128	-0.756

Table 5. (a) Coefficient of median ground motion derived by ASK-2014

T	c_4	M_1	M_2	a_1	a_2	a_3	a_4	a_5	a_6	a_8
0.010	4.500	6.750	5.000	0.587	-0.790	0.275	-0.100	-0.410	2.154	-0.015
0.020	4.500	6.750	5.000	0.598	-0.790	0.275	-0.100	-0.410	2.146	-0.015
0.030	4.500	6.750	5.000	0.602	-0.790	0.275	-0.100	-0.410	2.157	-0.015
0.050	4.500	6.750	5.000	0.707	-0.790	0.275	-0.100	-0.410	2.085	-0.015
0.075	4.500	6.750	5.000	0.973	-0.790	0.275	-0.100	-0.410	2.029	-0.015
0.100	4.500	6.750	5.000	1.169	-0.790	0.275	-0.100	-0.410	2.041	-0.015
0.150	4.500	6.750	5.000	1.442	-0.790	0.275	-0.100	-0.410	2.121	-0.022
0.200	4.500	6.750	5.000	1.637	-0.790	0.275	-0.100	-0.410	2.224	-0.030
0.250	4.500	6.750	5.000	1.701	-0.790	0.275	-0.100	-0.410	2.312	-0.038
0.300	4.500	6.750	5.000	1.712	-0.790	0.275	-0.100	-0.410	2.338	-0.045
0.400	4.500	6.750	5.000	1.662	-0.790	0.275	-0.100	-0.410	2.469	-0.055
0.500	4.500	6.750	5.000	1.571	-0.790	0.275	-0.100	-0.410	2.559	-0.065
0.750	4.500	6.750	5.000	1.299	-0.790	0.275	-0.100	-0.410	2.682	-0.095
1.000	4.500	6.750	5.000	1.043	-0.790	0.275	-0.100	-0.410	2.763	-0.110
1.500	4.500	6.750	5.000	0.665	-0.790	0.275	-0.100	-0.410	2.836	-0.124
2.000	4.500	6.750	5.000	0.329	-0.790	0.275	-0.100	-0.410	2.897	-0.138
3.000	4.500	6.820	5.000	-0.060	-0.790	0.275	-0.100	-0.410	2.906	-0.172
4.000	4.500	6.920	5.000	-0.299	-0.790	0.275	-0.100	-0.410	2.889	-0.197
5.000	4.500	7.000	5.000	-0.562	-0.765	0.275	-0.100	-0.410	2.898	-0.218
6.000	4.500	7.060	5.000	-0.875	-0.711	0.275	-0.100	-0.410	2.896	-0.235
7.500	4.500	7.145	5.000	-1.303	-0.634	0.275	-0.100	-0.410	2.870	-0.255
10.000	4.500	7.250	5.000	-1.928	-0.529	0.275	-0.100	-0.410	2.843	-0.285
PGA	4.500	6.750	5.000	0.587	-0.790	0.275	-0.100	-0.410	2.154	-0.015
PGV	4.500	6.750	5.000	5.975	-0.919	0.275	-0.100	-0.410	2.366	-0.094

Table 5 (b) Coefficient of median ground motion derived by ASK-2014

T	a_{12}	a_{13}	a_{14}	a_{15}	a_{17}
0.01	-0.1	0.6	-0.3	1.1	-0.0072
0.02	-0.1	0.6	-0.3	1.1	-0.0073
0.03	-0.1	0.6	-0.3	1.1	-0.0075
0.05	-0.1	0.6	-0.3	1.1	-0.008
0.075	-0.1	0.6	-0.3	1.1	-0.0089
0.1	-0.1	0.6	-0.3	1.1	-0.0095
0.15	-0.1	0.6	-0.3	1.1	-0.0095
0.2	-0.1	0.6	-0.3	1.1	-0.0086
0.25	-0.1	0.6	-0.24	1.1	-0.0074
0.3	-0.1	0.6	-0.19	1.03	-0.0064
0.4	-0.1	0.58	-0.11	0.92	-0.0043
0.5	-0.1	0.56	-0.04	0.84	-0.0032
0.75	-0.1	0.53	0.07	0.68	-0.0025
1	-0.1	0.5	0.15	0.57	-0.0025
1.5	-0.1	0.42	0.27	0.42	-0.0022
2	-0.1	0.35	0.35	0.31	-0.0019
3	-0.1	0.2	0.46	0.16	-0.0015
4	-0.1	0	0.54	0.05	-0.001
5	-0.1	0	0.61	-0.04	-0.001
6	-0.2	0	0.65	-0.11	-0.001
7.5	-0.2	0	0.72	-0.19	-0.001
10	-0.2	0	0.8	-0.3	-0.001
PGA	-0.1	0.6	-0.3	1.1	-0.0072
PGV	-0.1	0.25	0.22	0.3	-0.0005

Table 5 (c). Coefficient of linear and non-linear soil response - ASK2014

T	a_{10}	V_{Lin}	b	n	c
0.01	1.735	660	-1.47	1.5	2.4
0.02	1.718	680	-1.459	1.5	2.4
0.03	1.615	770	-1.39	1.5	2.4
0.05	1.358	915	-1.219	1.5	2.4
0.075	1.258	960	-1.152	1.5	2.4
0.1	1.31	910	-1.23	1.5	2.4
0.15	1.66	740	-1.587	1.5	2.4
0.2	2.22	590	-2.012	1.5	2.4
0.25	2.77	495	-2.411	1.5	2.4
0.3	3.25	430	-2.757	1.5	2.4
0.4	3.99	360	-3.278	1.5	2.4
0.5	4.45	340	-3.599	1.5	2.4
0.75	4.75	330	-3.8	1.5	2.4
1	4.3	330	-3.5	1.5	2.4
1.5	2.6	330	-2.4	1.5	2.4
2	0.55	330	-1	1.5	2.4
3	-0.95	330	0	1.5	2.4
4	-0.95	330	0	1.5	2.4
5	-0.93	330	0	1.5	2.4
6	-0.91	330	0	1.5	2.4
7.5	-0.87	330	0	1.5	2.4
10	-0.8	330	0	1.5	2.4
0	1.735	660	-1.47	1.5	2.4
PGV	2.36	330	-2.02	1.5	2400

Table 5 (d). Coefficient for Z_1 scaling of the median ground motion- ASK2014

T	a_{43}	a_{44}	a_{45}	a_{46}
0.01	0.1	0.05	0	-0.05
0.02	0.1	0.05	0	-0.05
0.03	0.1	0.05	0	-0.05
0.05	0.1	0.05	0	-0.05
0.075	0.1	0.05	0	-0.05
0.1	0.1	0.05	0	-0.05
0.15	0.1	0.05	0	-0.05
0.2	0.1	0.05	0	-0.03
0.25	0.1	0.05	0	0
0.3	0.1	0.05	0.03	0.03
0.4	0.1	0.07	0.06	0.06
0.5	0.1	0.1	0.1	0.09
0.75	0.14	0.14	0.14	0.13
1	0.17	0.17	0.17	0.14
1.5	0.22	0.21	0.2	0.16
2	0.26	0.25	0.22	0.16
3	0.34	0.3	0.23	0.16
4	0.41	0.32	0.23	0.14
5	0.51	0.32	0.22	0.13
6	0.55	0.32	0.2	0.1
7.5	0.49	0.275	0.17	0.09
10	0.42	0.22	0.14	0.08
0	0.1	0.05	0	-0.05
PGV	0.28	0.15	0.09	0.07

Table 5(e) Coefficient for the median ground motion of other regions- ASK2014

T	a_{25}	a_{28}	a_{29}	a_{31}
0.01	-0.0015	0.0025	-0.0034	-0.1503
0.02	-0.0015	0.0024	-0.0033	-0.1479
0.03	-0.0016	0.0023	-0.0034	-0.1447
0.05	-0.002	0.0027	-0.0033	-0.1326
0.075	-0.0027	0.0032	-0.0029	-0.1353
0.1	-0.0033	0.0036	-0.0025	-0.1128
0.15	-0.0035	0.0033	-0.0025	0.0383
0.2	-0.0033	0.0027	-0.0031	0.0775
0.25	-0.0029	0.0024	-0.0036	0.0741
0.3	-0.0027	0.002	-0.0039	0.2548
0.4	-0.0023	0.001	-0.0048	0.2136
0.5	-0.002	0.0008	-0.005	0.1542
0.75	-0.001	0.0007	-0.0041	0.0787
1	-0.0005	0.0007	-0.0032	0.0476
1.5	-0.0004	0.0006	-0.002	-0.0163
2	-0.0002	0.0003	-0.0017	-0.1203
3	0	0	-0.002	-0.2719
4	0	0	-0.002	-0.2958
5	0	0	-0.002	-0.2718
6	0	0	-0.002	-0.2517
7.5	0	0	-0.002	-0.14
10	0	0	-0.002	-0.0216
0	-0.0015	0.0025	-0.0034	-0.1503
-1	-0.0001	0.0005	-0.0037	-0.1462

Table 6. Period-dependent coefficients of model ln(y_{ref}) (CY-2014)

Period (s)	c_1	c_{1a}	c_{1b}	c_{1c}	c_{1d}	c_n	c_M	c_3
PGA	-1.5065	0.1650	-0.2550	-0.1650	0.255	16.0875	4.9993	1.9636
PGV	2.3549	0.1650	-0.0626	-0.1650	0.0626	3.30240	5.4230	2.3152
0.01	-1.5065	0.1650	-0.2550	-0.1650	0.2550	16.0875	4.9993	1.9636
0.02	-1.4798	0.1650	-0.2550	-0.1650	0.2550	15.7118	4.9993	1.9636
0.03	-1.2972	0.1650	-0.2550	-0.1650	0.2550	15.8819	4.9993	1.9636
0.04	-1.1007	0.1650	-0.2550	-0.1650	0.2550	16.4556	4.9993	1.9636
0.05	-0.9292	0.1650	-0.2550	-0.1650	0.2550	17.6453	4.9993	1.9636
0.075	-0.6580	0.1650	-0.2540	-0.1650	0.2540	20.1772	5.0031	1.9636
0.1	-0.5613	0.1650	-0.2530	-0.1650	0.2530	19.9992	5.0172	1.9636
0.12	-0.5342	0.1650	-0.2520	-0.1650	0.2520	18.7106	5.0315	1.9795
0.15	-0.5462	0.1650	-0.2500	-0.1650	0.2500	16.6246	5.0547	2.0362
0.17	-0.5858	0.1650	-0.2480	-0.1650	0.2480	15.3709	5.0704	2.0823
0.2	-0.6798	0.1650	-0.2449	-0.1650	0.2449	13.7012	5.0939	2.1521
0.25	-0.8663	0.1650	-0.2382	-0.1650	0.2382	11.2667	5.1315	2.2574
0.3	-1.0514	0.1650	-0.2313	-0.1650	0.2313	9.19080	5.1670	2.3440
0.4	-1.3794	0.1650	-0.2146	-0.1650	0.2146	6.54590	5.2317	2.4709
0.5	-1.6508	0.1650	-0.1972	-0.1650	0.1972	5.23050	5.2893	2.5567
0.75	-2.1511	0.1650	-0.1620	-0.1650	0.1620	3.78960	5.4109	2.6812
1	-2.5365	0.1650	-0.1400	-0.1650	0.1400	3.30240	5.5106	2.7474
1.5	-3.0686	0.1650	-0.1184	-0.1650	0.1184	2.84980	5.6705	2.8161
2	-3.4148	0.1645	-0.1100	-0.1645	0.1100	2.54170	5.7981	2.8514
3	-3.9013	0.1168	-0.1040	-0.1168	0.1040	2.14880	5.9983	2.8875
4	-4.2466	0.0732	-0.1020	-0.0732	0.1020	1.89570	6.1552	2.9058
5	-4.5143	0.0484	-0.1010	-0.0484	0.1010	1.72280	6.2856	2.9169
7.5	-5.0009	0.0220	-0.1010	-0.0220	0.1010	1.57370	6.5428	2.9320
10	-5.3461	0.0124	-0.1000	-0.0124	0.1000	1.52650	6.7415	2.9396

Table 6. Period-dependent coefficients of model ln(*yref*) (CY-2014) (contd..)

Period (s)	c_5	c_{HM}	c_6	c_7	c_{7b}	c_8	c_{8b}
PGA	6.4551	3.0956	0.4908	0.0352	0.0462	0.0000	0.4833
PGV	5.8096	3.0514	0.4407	0.0324	0.0097	0.2154	5.0000
0.01	6.4551	3.0956	0.4908	0.0352	0.0462	0.0000	0.4833
0.02	6.4551	3.0963	0.4925	0.0352	0.0472	0.0000	1.2144
0.03	6.4551	3.0974	0.4992	0.0352	0.0533	0.0000	1.6421
0.04	6.4551	3.0988	0.5037	0.0352	0.0596	0.0000	1.9456
0.05	6.4551	3.1011	0.5048	0.0352	0.0639	0.0000	2.1810
0.075	6.4551	3.1094	0.5048	0.0352	0.063	0.0000	2.6087
0.1	6.8305	3.2381	0.5048	0.0352	0.0532	0.0000	2.9122
0.12	7.1333	3.3407	0.5048	0.0352	0.0452	0.0000	3.1045
0.15	7.3621	3.4300	0.5045	0.0352	0.0345	0.0000	3.3399
0.17	7.4365	3.4688	0.5036	0.0352	0.0283	0.0000	3.4719
0.2	7.4972	3.5146	0.5016	0.0352	0.0202	0.0000	3.6434
0.25	7.5416	3.5746	0.4971	0.0352	0.009	0.0000	3.8787
0.3	7.5600	3.6232	0.4919	0.0352	-0.0004	0.0000	4.0711
0.4	7.5735	3.6945	0.4807	0.0352	-0.0155	0.0000	4.3745
0.5	7.5778	3.7401	0.4707	0.0352	-0.0278	0.0991	4.6099
0.75	7.5808	3.7941	0.4575	0.0352	-0.0477	0.1982	5.0376
1	7.5814	3.8144	0.4522	0.0352	-0.0559	0.2154	5.3411
1.5	7.5817	3.8284	0.4501	0.0352	-0.063	0.2154	5.7688
2	7.5818	3.8330	0.4500	0.0352	-0.0665	0.2154	6.0723
3	7.5818	3.8361	0.4500	0.0160	-0.0516	0.2154	6.5000
4	7.5818	3.8369	0.4500	0.0062	-0.0448	0.2154	6.8035
5	7.5818	3.8376	0.4500	0.0029	-0.0424	0.2154	7.0389
7.5	7.5818	3.8380	0.4500	0.0007	-0.0348	0.2154	7.4666
10	7.5818	3.8380	0.4500	0.0003	-0.0253	0.2154	7.7700

Table 6. Period-dependent coefficients of model ln(*yref*) (CY-2014) (contd..)

Period(s)	c_9	c_{9a}	c_{9b}	c_{11b}	c_{g1}	c_{g2}	c_{g3}
PGA	0.9228	0.1202	6.8607	-0.4536	-0.00715	-0.00676	4.2542
PGV	0.3079	0.1000	6.5000	-0.3834	-0.00185	-0.00740	4.3439
0.01	0.9228	0.1202	6.8607	-0.4536	-0.00715	-0.00676	4.2542
0.02	0.9296	0.1217	6.8697	-0.4536	-0.00725	-0.00676	4.2386
0.03	0.9396	0.1194	6.9113	-0.4536	-0.00787	-0.00676	4.2519
0.04	0.9661	0.1166	7.0271	-0.4536	-0.00832	-0.00676	4.2960
0.05	0.9794	0.1176	7.0959	-0.4536	-0.00874	-0.00676	4.3578
0.075	1.0260	0.1171	7.3298	-0.4536	-0.00954	-0.00619	4.5455
0.1	1.0177	0.1146	7.2588	-0.4536	-0.00983	-0.00533	4.7603
0.12	1.0008	0.1128	7.2372	-0.4536	-0.00991	-0.00473	4.8963
0.15	0.9801	0.1106	7.2109	-0.4536	-0.00990	-0.00381	5.0644
0.17	0.9652	0.1150	7.2491	-0.4536	-0.00979	-0.00328	5.1371
0.2	0.9459	0.1208	7.2988	-0.4440	-0.00951	-0.00269	5.1880
0.25	0.9196	0.1208	7.3691	-0.3539	-0.00892	-0.00213	5.2164
0.3	0.8829	0.1175	6.8789	-0.2688	-0.00825	-0.00181	5.1954
0.4	0.8302	0.1060	6.5334	-0.1793	-0.00727	-0.00127	5.0899
0.5	0.7884	0.1061	6.5260	-0.1428	-0.00649	-0.00107	4.7854
0.75	0.6754	0.1000	6.5000	-0.1138	-0.00515	-0.00112	4.3304
1	0.6196	0.1000	6.5000	-0.1062	-0.00428	-0.00120	4.1667
1.5	0.5101	0.1000	6.5000	-0.102	-0.00298	-0.00168	4.0029
2	0.3917	0.1000	6.5000	-0.1009	-0.00230	-0.00235	3.8949
3	0.1244	0.1000	6.5000	-0.1003	-0.00134	-0.00331	3.7928
4	0.0086	0.1000	6.5000	-0.1001	-0.00108	-0.00357	3.7443
5	0.0000	0.1000	6.5000	-0.1001	-0.00101	-0.00364	3.7090
7.5	0.0000	0.1000	6.5000	-0.1000	-0.00096	-0.00369	3.6632
10	0.0000	0.1000	6.5000	-0.1000	-0.00095	-0.00370	3.6230

Table 7. Coefficients of site response model for ln(y) CY-2014

Period(s)	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	ϕ_6
PGA	-0.5210	-0.1417	-0.00701	0.102151	0	300
PGV	-0.7936	-0.0699	-0.00844	5.410000	0.0202	300
0.01	-0.5210	-0.1417	-0.00701	0.102151	0.0000	300
0.02	-0.5055	-0.1364	-0.00728	0.108360	0.0000	300
0.03	-0.4368	-0.1403	-0.00735	0.119888	0.0000	300
0.04	-0.3752	-0.1591	-0.00698	0.133641	0.0000	300
0.05	-0.3469	-0.1862	-0.00647	0.148927	0.0000	300
0.075	-0.3747	-0.2538	-0.00573	0.190596	0.0000	300
0.1	-0.4440	-0.2943	-0.00560	0.230662	0.0000	300
0.12	-0.4895	-0.3077	-0.00570	0.253169	0.0000	300
0.15	-0.5477	-0.3113	-0.00585	0.266468	0.0000	300
0.17	-0.5922	-0.3062	-0.00596	0.265060	0.0000	300
0.2	-0.6693	-0.2927	-0.00614	0.255253	0.0000	300
0.25	-0.7766	-0.2662	-0.00644	0.231541	0.0000	300
0.3	-0.8501	-0.2405	-0.00670	0.207277	0.0010	300
0.4	-0.9431	-0.1975	-0.00713	0.165464	0.0040	300
0.5	-1.0044	-0.1633	-0.00744	0.133828	0.0100	300
0.75	-1.0602	-0.1028	-0.00812	0.085153	0.0340	300
1	-1.0941	-0.0699	-0.00844	0.058595	0.0670	300
1.5	-1.1142	-0.0425	-0.00771	0.031787	0.1430	300
2	-1.1154	-0.0302	-0.00479	0.019716	0.2030	300
3	-1.1081	-0.0129	-0.00183	0.009643	0.2770	300
4	-1.0603	-0.0016	-0.00152	0.005379	0.3090	300
5	-0.9872	0.0000	-0.00144	0.003223	0.3210	300
7.5	-0.8274	0.0000	-0.00137	0.001134	0.3290	300
10	-0.7053	0.0000	-0.00136	0.000515	0.3300	300

Table 8. Site classification based on soil properties, BNBC-2012

Site Class	Description of soil profile upto 30 meters depth	Average Soil Properties in top 30 meters		
		Shear wave velocity, $\bar{V}s$ (m/s)	SPT Value, $\bar{N}$ (blows/30cm)	Undrained shear strength, $\bar{S}_u$ (kPa)
SA	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface	>800	--	--
SB	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterised by a gradual increase of mechanical properties with depth	360-800	>50	>250
SC	Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters	180-360	15-50	70-250
SD	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to firm cohesive soil.	<180	<15	<70
SE	A soil profile consisting of a surface alluvium layer with V_s values of type SC or SD and thickness varying between about 5m and 20m, underlain by stiffer material with V_s>800m/s	--	--	--
S_1	Deposits consisting, or containing a layer at laeast 10 m thick, of soft clays/silts with a high plasticity index (PI>40) aand high water content	<100 (indicative)	--	10-20
S_2	Deposits of liquifiable soils of sensitive clays, or any other soil profile not included in types SA to SE or S_1	--	--	--

Table 9. Site dependent soil factor and other parameters defining eleastic response spectrum, BNBC-2012

Soil Type	S	T_B	T_C	T_D
SA	1.00	0.15	0.40	2.00
SB	1.20	0.15	0.50	2.00
SC	1.15	0.20	0.60	2.00
SD	1.35	0.20	0.80	2.00
SE	1.40	0.15	0.50	2.00

Table 10. Response spectra according to Bangladesh National Building code (BNBC) for different percentage damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, at BIFPCL, Maitree site, Bagerhat

Natural period (sec)	BNBC different percentage of damping							
	0.8%	1%	1.6%	2%	3%	5%	7%	10%
0.000	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
0.010	0.120	0.120	0.119	0.119	0.118	0.116	0.115	0.114
0.015	0.126	0.126	0.125	0.124	0.123	0.120	0.118	0.116
0.020	0.133	0.132	0.130	0.129	0.127	0.124	0.122	0.119
0.030	0.145	0.144	0.142	0.140	0.137	0.132	0.129	0.125
0.040	0.157	0.156	0.153	0.151	0.147	0.140	0.136	0.130
0.050	0.170	0.168	0.164	0.162	0.156	0.149	0.143	0.136
0.060	0.182	0.180	0.175	0.172	0.166	0.157	0.150	0.142
0.075	0.200	0.198	0.192	0.189	0.181	0.169	0.160	0.150
0.090	0.219	0.216	0.209	0.205	0.195	0.181	0.170	0.159
0.100	0.231	0.228	0.220	0.215	0.205	0.189	0.177	0.164
0.150	0.293	0.288	0.276	0.269	0.253	0.230	0.212	0.192
0.200	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.300	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.400	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.500	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.600	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.700	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.750	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.800	0.355	0.349	0.332	0.323	0.302	0.270	0.246	0.220
0.900	0.315	0.310	0.295	0.287	0.268	0.240	0.219	0.196
1.000	0.284	0.279	0.266	0.258	0.241	0.216	0.197	0.176
1.200	0.236	0.232	0.222	0.215	0.201	0.180	0.164	0.147
1.500	0.189	0.186	0.177	0.172	0.161	0.144	0.131	0.118
2.000	0.142	0.139	0.133	0.129	0.121	0.108	0.099	0.088
2.500	0.091	0.089	0.085	0.083	0.077	0.069	0.063	0.056
3.000	0.063	0.062	0.059	0.057	0.054	0.048	0.044	0.039
4.000	0.035	0.035	0.033	0.032	0.030	0.027	0.025	0.022

Table 11. Response spectra according to Bangladesh National Building code (BNBC) for 5% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, and according to Deterministic Seismic Hazard Analysis at BIFPCL, Maitree site, Bagerhat

Natural period (sec)	BNBC (g) 5% damping	DSHA (Mw 7.5, R= 106 km)			
		ASK (2014)	BSSA (2014)	CB (2014)	CY (2014)
0.000	0.108	0.069	0.074	0.058	0.089
0.010	0.116	0.069	0.075	0.059	0.089
0.015	0.120	0.069	0.072	0.058	0.089
0.020	0.124	0.069	0.069	0.058	0.089
0.030	0.132	0.070	0.065	0.058	0.089
0.040	0.140	0.074	0.064	0.058	0.089
0.050	0.149	0.077	0.063	0.059	0.090
0.060	0.157	0.082	0.068	0.063	0.099
0.075	0.169	0.089	0.075	0.069	0.111
0.090	0.181	0.101	0.087	0.077	0.125
0.100	0.189	0.109	0.095	0.082	0.135
0.150	0.229	0.167	0.129	0.096	0.167
0.200	0.270	0.211	0.158	0.114	0.199
0.300	0.270	0.253	0.193	0.165	0.236
0.400	0.270	0.272	0.191	0.172	0.239
0.500	0.270	0.269	0.181	0.172	0.232
0.600	0.270	0.242	0.159	0.161	0.214
0.700	0.270	0.222	0.143	0.152	0.199
0.750	0.270	0.214	0.136	0.148	0.193
0.800	0.270	0.202	0.130	0.140	0.185
0.900	0.240	0.183	0.120	0.126	0.171
1.000	0.216	0.167	0.111	0.115	0.160
1.200	0.180	0.146	0.095	0.103	0.139
1.500	0.144	0.124	0.079	0.089	0.117
2.000	0.108	0.089	0.060	0.066	0.092
2.500	0.069	0.070	0.047	0.052	0.072
3.000	0.048	0.058	0.039	0.043	0.059
4.000	0.027	0.043	0.029	0.029	0.036

Table 12. Response spectra according to Bangladesh National Building code (BNBC) for 5% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, and (2/3) of UHRS (from PSHA analysis) corresponding to 2500yrs RP at BIFPCL, Maitree site, Bagerhat

Natural period (sec)	BNBC (g) 5% damping	UHRS			
		ASK (2014) (2/3)×2500yrs RP (g)	BSSA (2014) (2/3)×2500yrs RP (g)	CB (2014) (2/3)×2500yrs RP (g)	CY (2014) (2/3)×2500yrs RP (g)
0.000	0.108	0.067	0.080	0.056	0.073
0.010	0.116	0.067	0.080	0.056	0.073
0.015	0.120	0.068	0.080	0.056	0.073
0.020	0.124	0.068	0.080	0.056	0.073
0.030	0.132	0.069	0.078	0.057	0.074
0.040	0.140	0.074	0.079	0.059	0.076
0.050	0.149	0.078	0.081	0.062	0.078
0.060	0.157	0.084	0.092	0.069	0.086
0.075	0.169	0.092	0.109	0.080	0.098
0.090	0.181	0.106	0.133	0.093	0.110
0.100	0.189	0.115	0.150	0.102	0.119
0.150	0.229	0.176	0.206	0.126	0.151
0.200	0.270	0.218	0.230	0.145	0.184
0.300	0.270	0.250	0.262	0.195	0.225
0.400	0.270	0.259	0.248	0.197	0.230
0.500	0.270	0.249	0.229	0.196	0.226
0.600	0.270	0.225	0.207	0.188	0.210
0.700	0.270	0.201	0.184	0.180	0.194
0.750	0.270	0.189	0.173	0.176	0.186
0.800	0.270	0.180	0.168	0.168	0.179
0.900	0.240	0.164	0.158	0.152	0.166
1.000	0.216	0.147	0.148	0.137	0.152
1.200	0.180	0.131	0.128	0.120	0.135
1.500	0.144	0.108	0.097	0.096	0.109
2.000	0.108	0.078	0.068	0.066	0.084
2.500	0.069	0.063	0.053	0.053	0.068
3.000	0.048	0.048	0.039	0.040	0.051
4.000	0.027	0.034	0.026	0.025	0.030

Table 13. The Damping correction factor applied on the 2/3 UHRS(2500yrs RP) and DSHA values(Cameron and Green (2007))

Damping / Time period	0.8%	1%	1.6%	2%	3%	5%	7%	10%
0	1	1	1	1	1	1	1	1
0.01	1.006	1.006	1.007	1.008	1.006	1	0.998	0.995
0.015	1.008	1.009	1.011	1.012	1.009	1	0.997	0.993
0.02	1.011	1.012	1.014	1.016	1.012	1	0.996	0.991
0.03	1.017	1.018	1.022	1.024	1.018	1	0.993	0.986
0.04	1.022	1.024	1.029	1.032	1.024	1	0.991	0.982
0.05	1.028	1.030	1.036	1.040	1.030	1	0.989	0.977
0.06	1.082	1.080	1.071	1.065	1.049	1	0.982	0.964
0.075	1.164	1.154	1.124	1.104	1.077	1	0.973	0.946
0.09	1.246	1.228	1.176	1.142	1.106	1	0.963	0.927
0.1	1.300	1.278	1.211	1.167	1.125	1	0.956	0.914
0.15	1.457	1.420	1.308	1.233	1.173	1	0.932	0.867
0.2	1.615	1.562	1.404	1.299	1.221	1	0.908	0.819
0.3	1.674	1.615	1.439	1.322	1.237	1	0.897	0.800
0.4	1.673	1.615	1.440	1.324	1.238	1	0.894	0.791
0.5	1.673	1.615	1.442	1.326	1.239	1	0.891	0.782
0.6	1.705	1.643	1.456	1.331	1.243	1	0.889	0.778
0.7	1.738	1.671	1.470	1.337	1.247	1	0.886	0.773
0.75	1.754	1.685	1.478	1.339	1.249	1	0.885	0.771
0.8	1.770	1.699	1.485	1.342	1.250	1	0.884	0.769
0.9	1.725	1.659	1.459	1.327	1.238	1	0.886	0.769
1	1.679	1.618	1.434	1.311	1.226	1	0.888	0.769
1.2	1.619	1.565	1.402	1.294	1.213	1	0.887	0.770
1.5	1.598	1.547	1.395	1.294	1.214	1	0.893	0.782
2	1.531	1.487	1.354	1.266	1.192	1	0.897	0.791
2.5	1.515	1.474	1.350	1.268	1.194	1	0.900	0.797
3	1.498	1.460	1.346	1.270	1.197	1	0.903	0.803
4	1.430	1.394	1.287	1.216	1.155	1	0.910	0.811

Table 14 Comparison of response spectra according to Bangladesh National Building code (BNBC) for 5% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, with maximum values obtained from DSHA and (2/3) of UHRS (PSHA analysis) corresponding to 2500yrs RP at BIFPCL, Maitree site, Bagerhat

Natural period (sec)	BNBC (g) 5% damping	DSHA (g)	(2/3)UHRS×2500yrs RP (g)
0.000	0.108	0.089	0.080
0.010	0.116	0.089	0.080
0.015	0.120	0.089	0.080
0.020	0.124	0.089	0.080
0.030	0.132	0.089	0.078
0.040	0.140	0.089	0.079
0.050	0.149	0.090	0.081
0.060	0.157	0.099	0.092
0.075	0.169	0.111	0.109
0.090	0.181	0.125	0.133
0.100	0.189	0.135	0.150
0.150	0.229	0.167	0.206
0.200	0.270	0.211	0.230
0.300	0.270	0.253	0.262
0.400	0.270	0.272	0.259
0.500	0.270	0.269	0.249
0.600	0.270	0.242	0.225
0.700	0.270	0.222	0.201
0.750	0.270	0.214	0.189
0.800	0.270	0.202	0.180
0.900	0.240	0.183	0.166
1.000	0.216	0.167	0.152
1.200	0.180	0.146	0.135
1.500	0.144	0.124	0.109
2.000	0.108	0.092	0.084
2.500	0.069	0.072	0.068
3.000	0.048	0.059	0.051
4.000	0.027	0.043	0.034

Table 15. Recommended values of response spectra for different damping percentage, at BIFPCL, Maitree site, Bagerhat

Natural period (sec)	viscous damping ratios							
	0.8%	1%	1.6%	2%	3%	5%	7%	10%
0.000	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
0.010	0.125	0.125	0.122	0.121	0.119	0.116	0.115	0.114
0.015	0.134	0.133	0.129	0.127	0.125	0.120	0.118	0.116
0.020	0.143	0.141	0.136	0.133	0.131	0.124	0.122	0.119
0.030	0.160	0.158	0.151	0.146	0.142	0.133	0.129	0.125
0.040	0.177	0.174	0.165	0.158	0.154	0.141	0.136	0.130
0.050	0.195	0.191	0.179	0.171	0.165	0.149	0.143	0.136
0.060	0.212	0.207	0.193	0.184	0.177	0.157	0.150	0.142
0.075	0.238	0.232	0.214	0.202	0.194	0.169	0.160	0.150
0.090	0.264	0.257	0.236	0.221	0.211	0.182	0.170	0.159
0.100	0.281	0.273	0.250	0.234	0.222	0.190	0.177	0.164
0.150	0.368	0.356	0.321	0.297	0.279	0.231	0.212	0.192
0.200	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.300	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.400	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.500	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.600	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.700	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.750	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.800	0.455	0.439	0.391	0.360	0.336	0.272	0.246	0.220
0.900	0.378	0.372	0.355	0.316	0.295	0.240	0.219	0.196
1.000	0.340	0.335	0.319	0.284	0.266	0.216	0.197	0.176
1.200	0.284	0.279	0.266	0.237	0.221	0.180	0.164	0.147
1.500	0.227	0.223	0.213	0.189	0.177	0.144	0.131	0.118
2.000	0.142	0.139	0.133	0.129	0.121	0.108	0.099	0.088
2.500	0.108	0.105	0.097	0.091	0.085	0.072	0.064	0.057
3.000	0.088	0.085	0.079	0.074	0.070	0.059	0.053	0.047
4.000	0.061	0.060	0.055	0.052	0.050	0.043	0.039	0.035

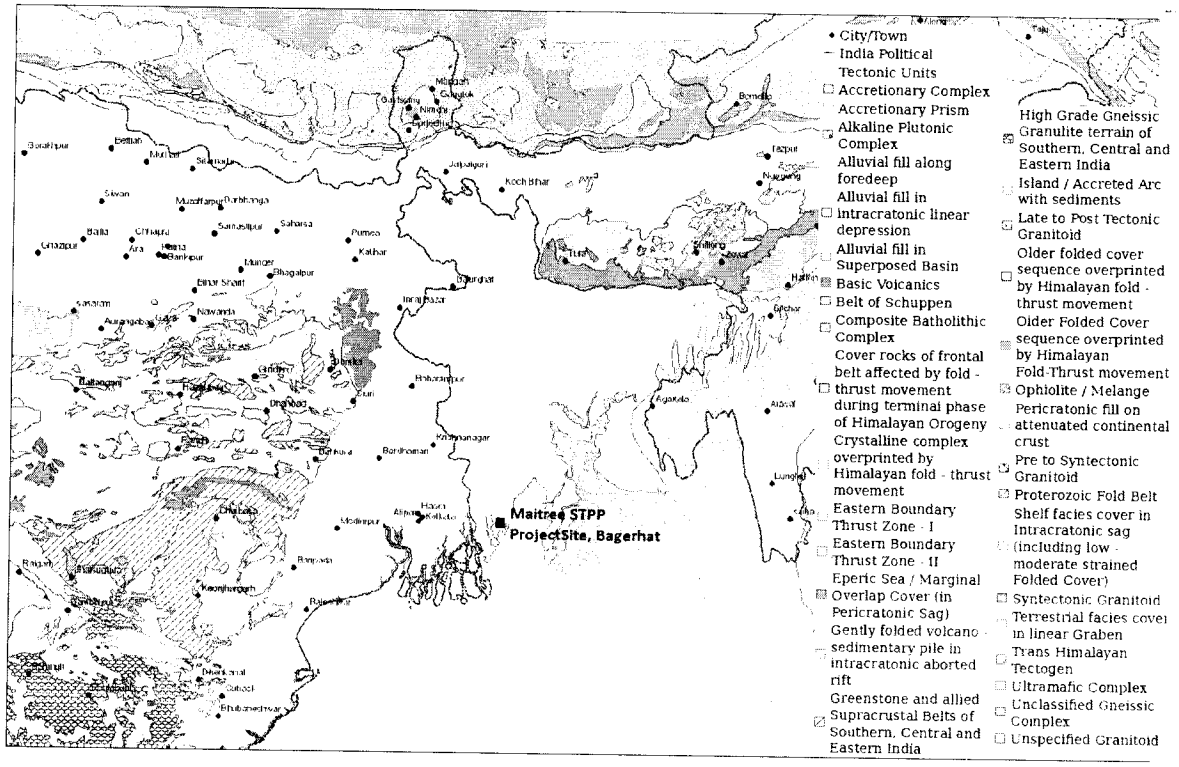


Figure 1. Geological Map of the region (GSI-2000)

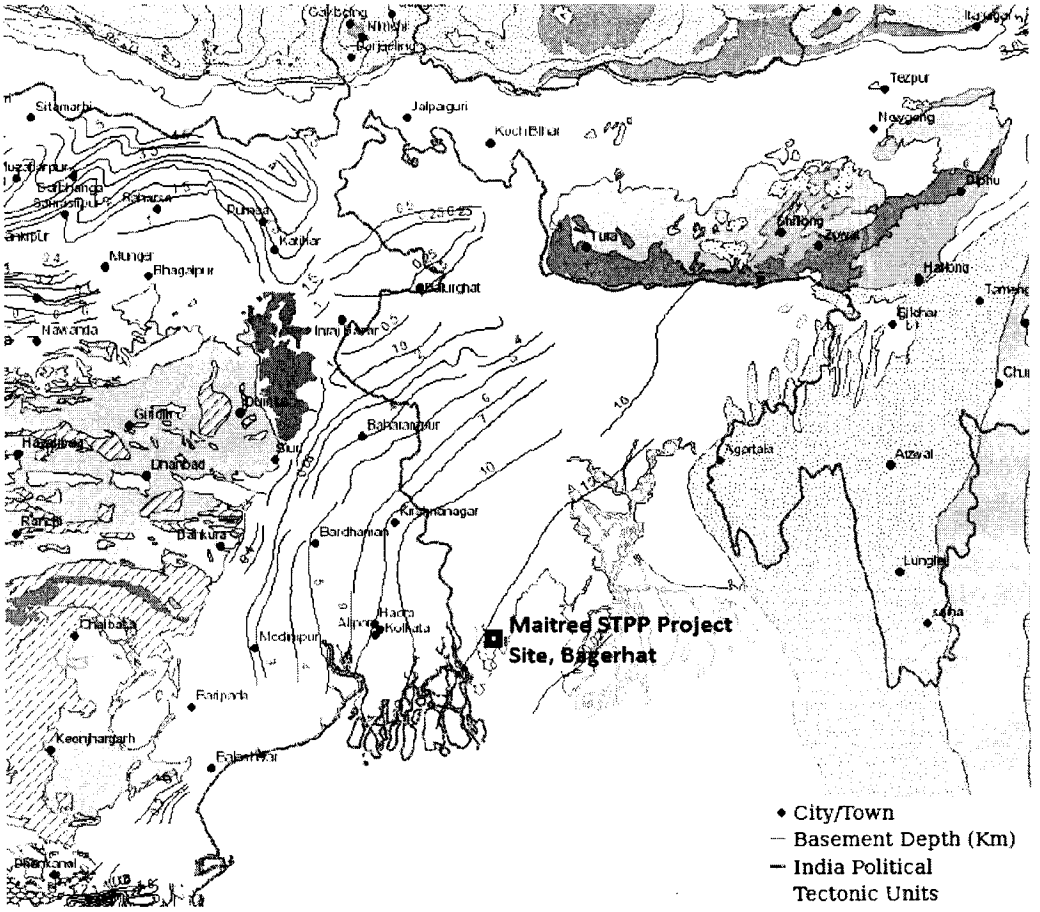


Figure 2. The Geological map of the region along with Basement depth. (GSI 2000)

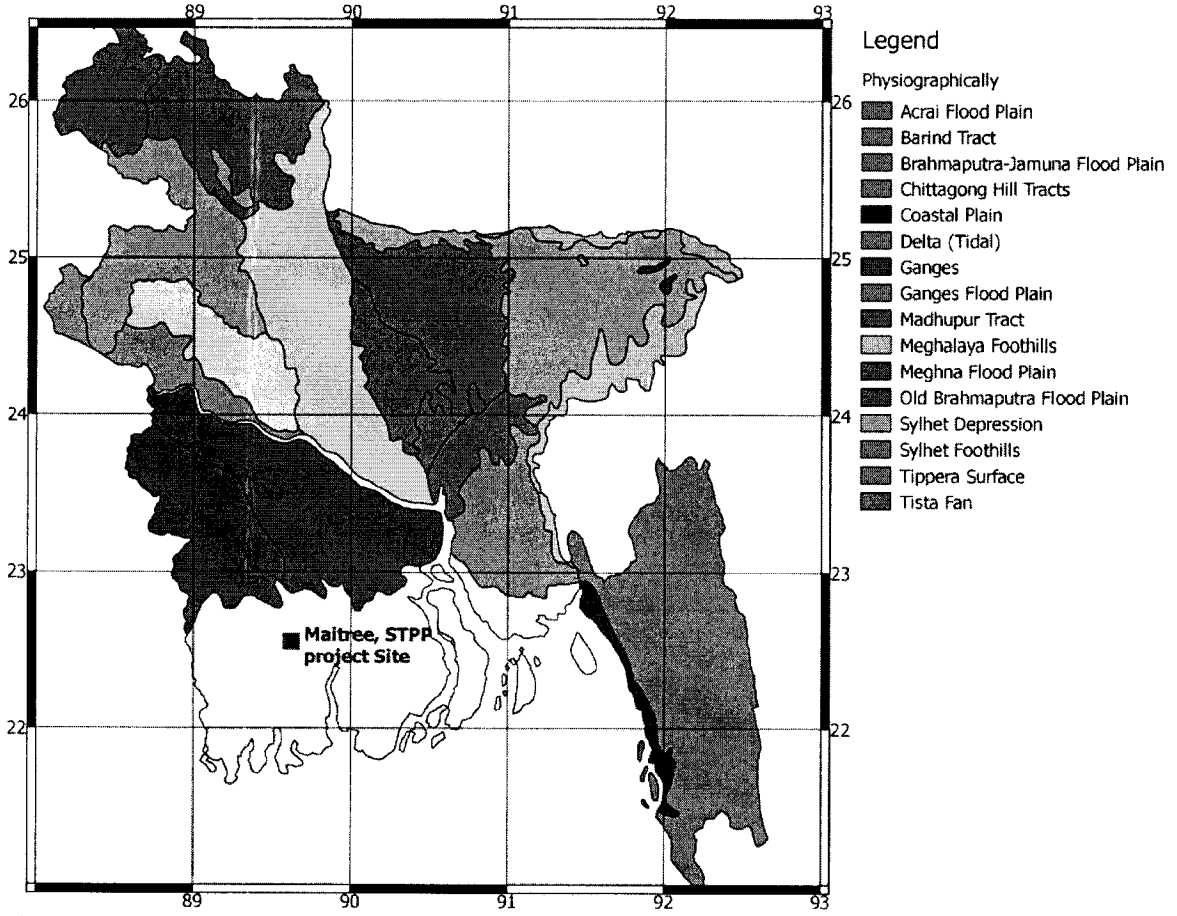


Figure 3. Physiogeographycal description of Bangladesh (Persits *et al.* 1997, updated on 2001(https://pubs.usgs.gov/of/1997/ofr-97-470/OF97-470H/))

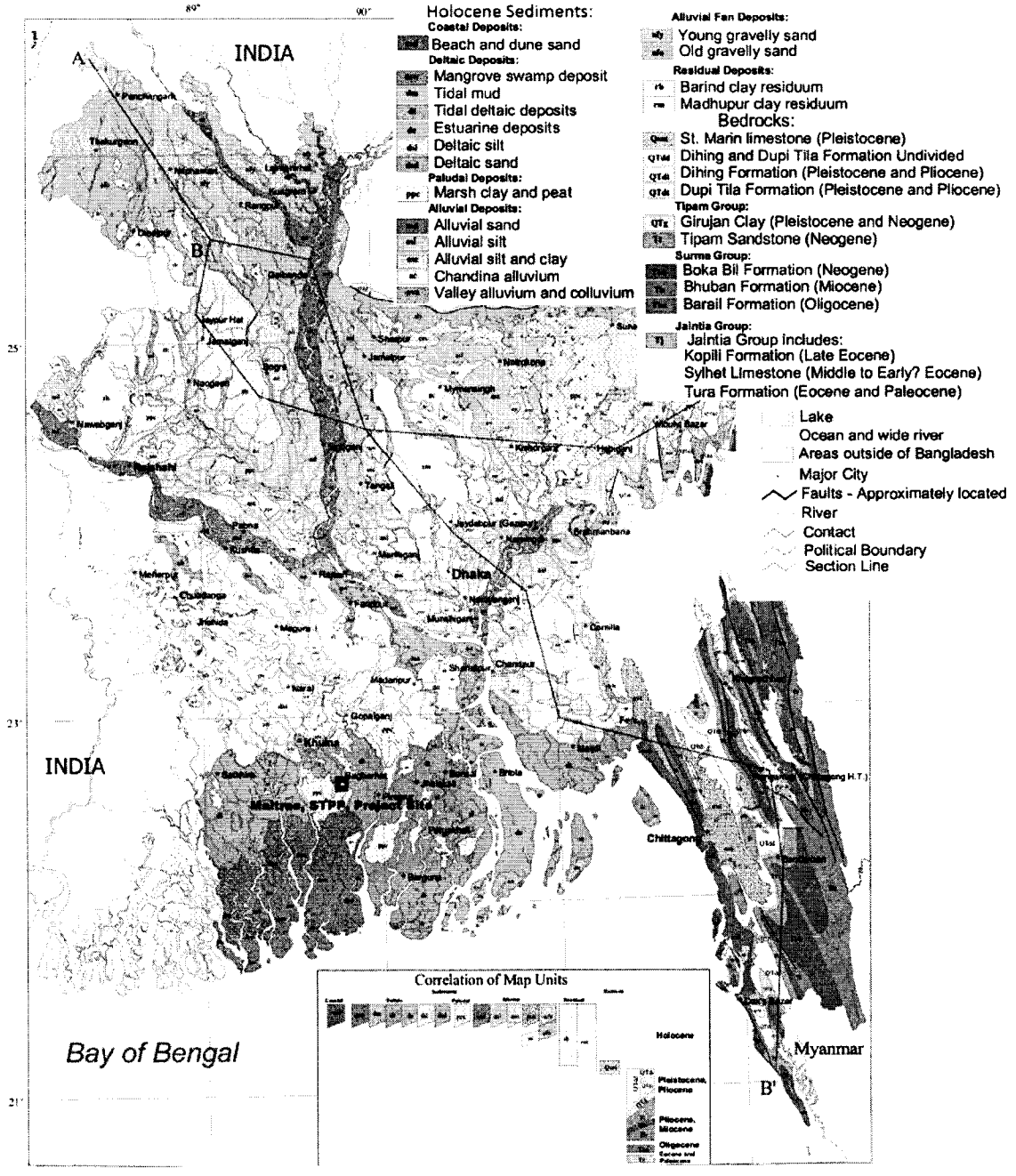


Figure 4. Detailed geological map of Bangladesh (Geological survey of Bangladesh - GSB)

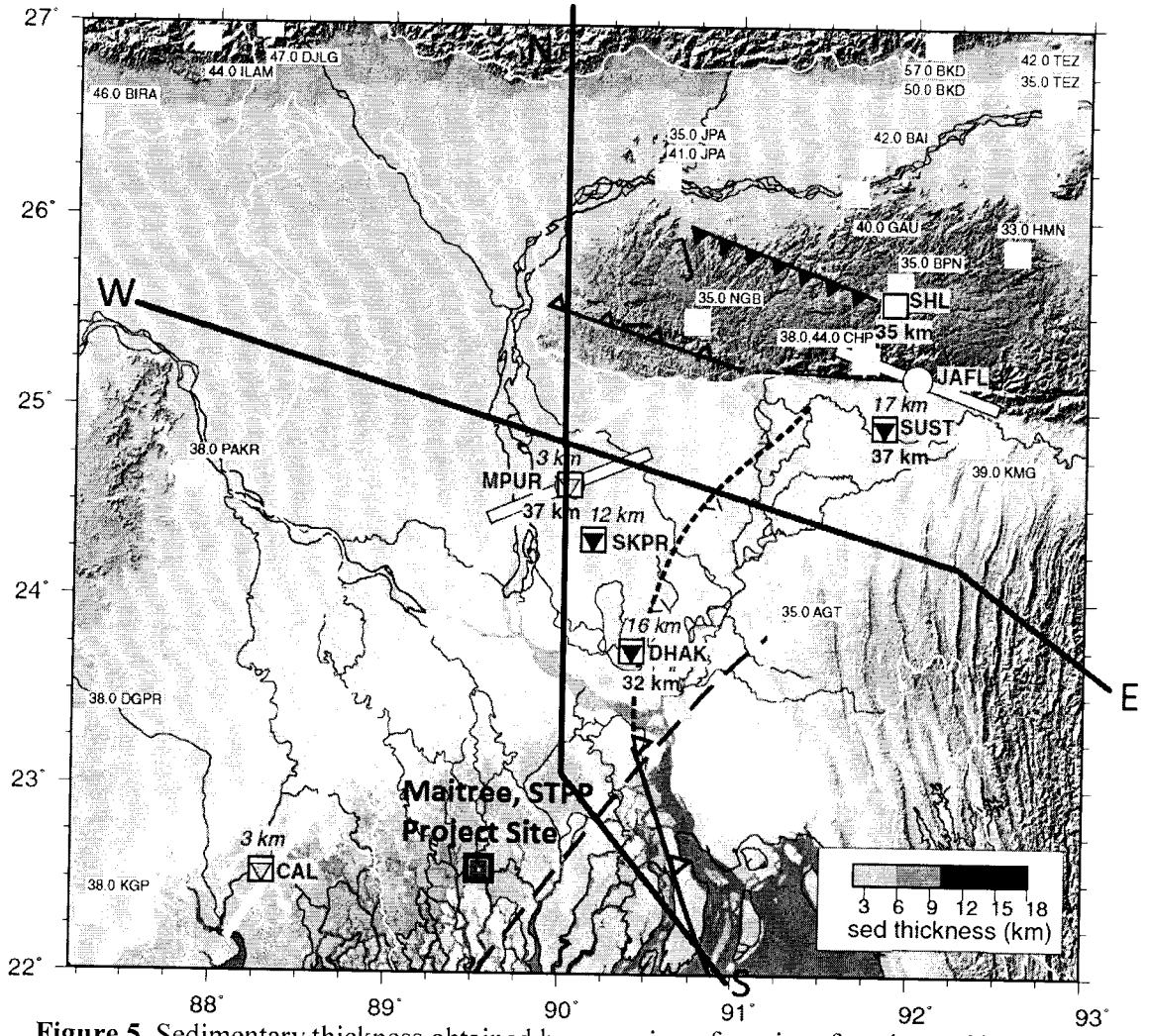


Figure 5. Sedimentary thickness obtained by reversion of receiver functions. (Singh *et al.* (2016)). The inverted triangle are the stations consdered with sediment depth obtained written on top in italics. The crustal thickness obtained are marked on grey squares.

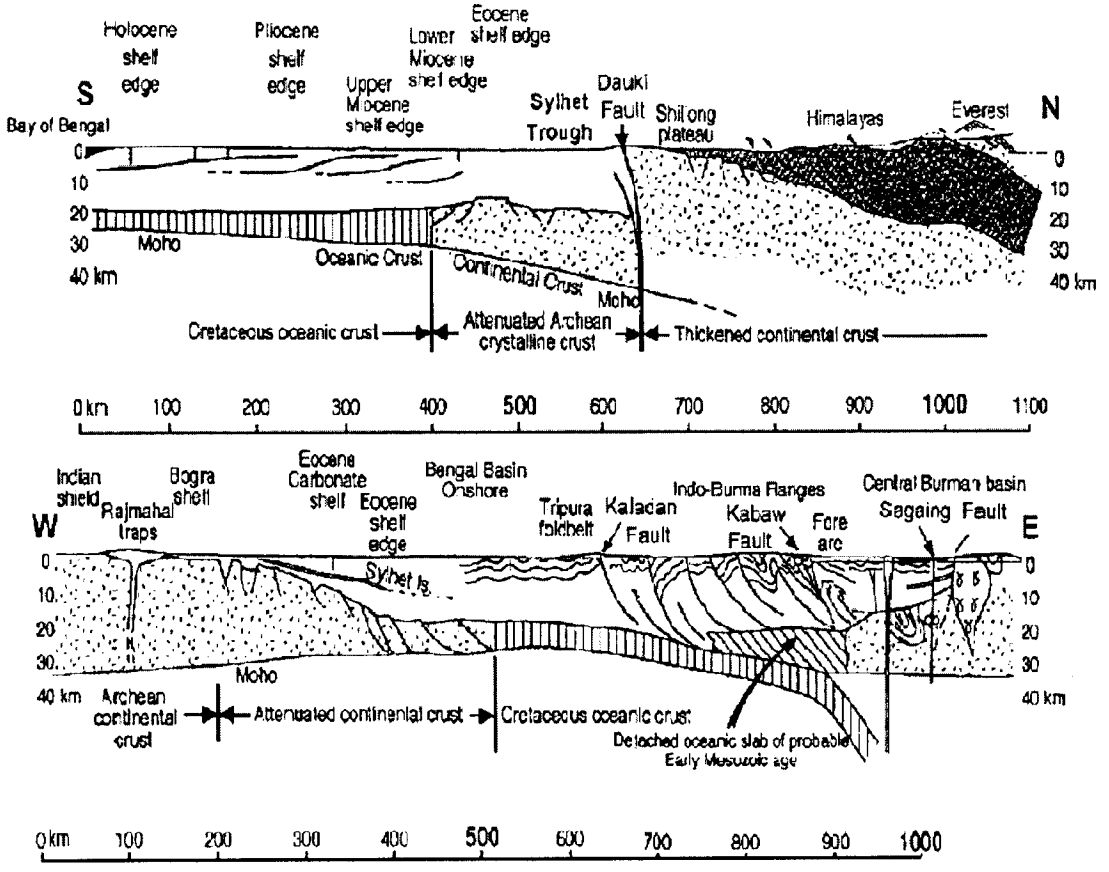


Figure 6. NS and EW sections through the region, indicating the variation of crustal thickness and the soil deposits (Alam et al. (2003))

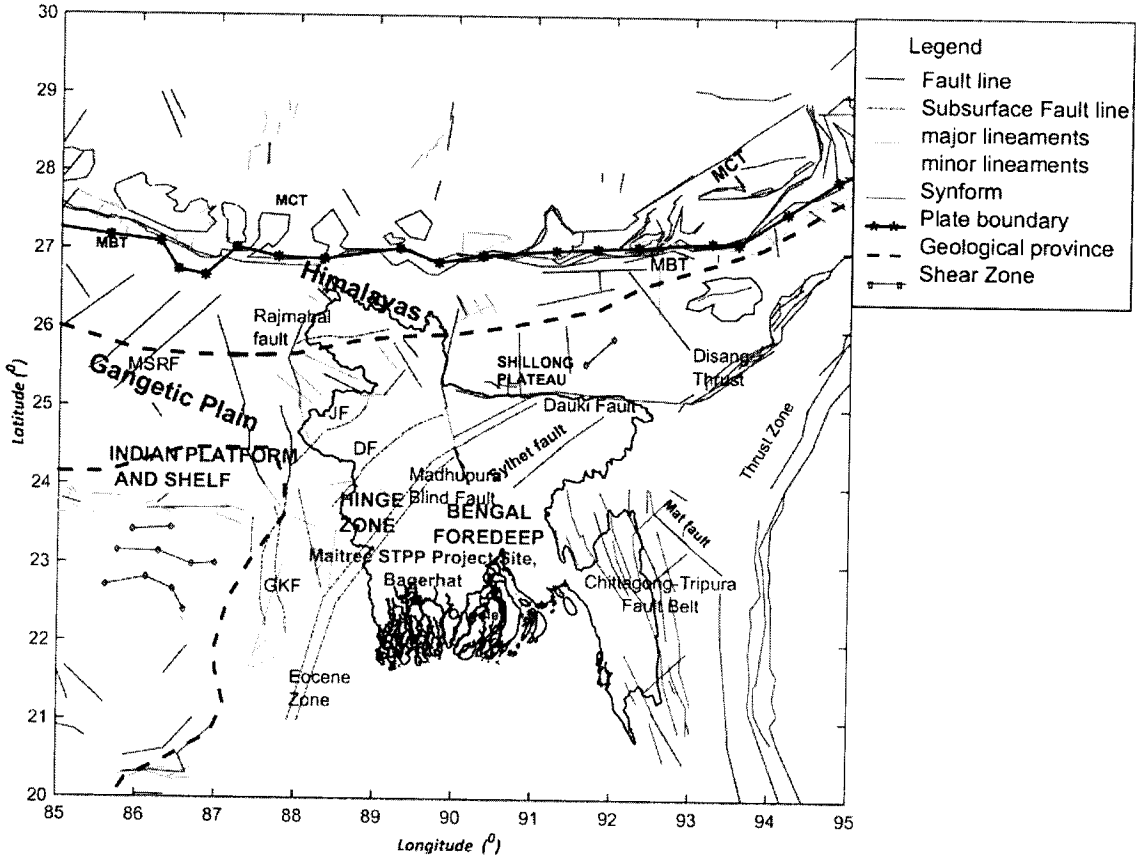


Figure 7. Seismotectonic map Bangladesh (Bangladesh Meteorological Department, Geological survey of Bangladesh, NDMA 2011)

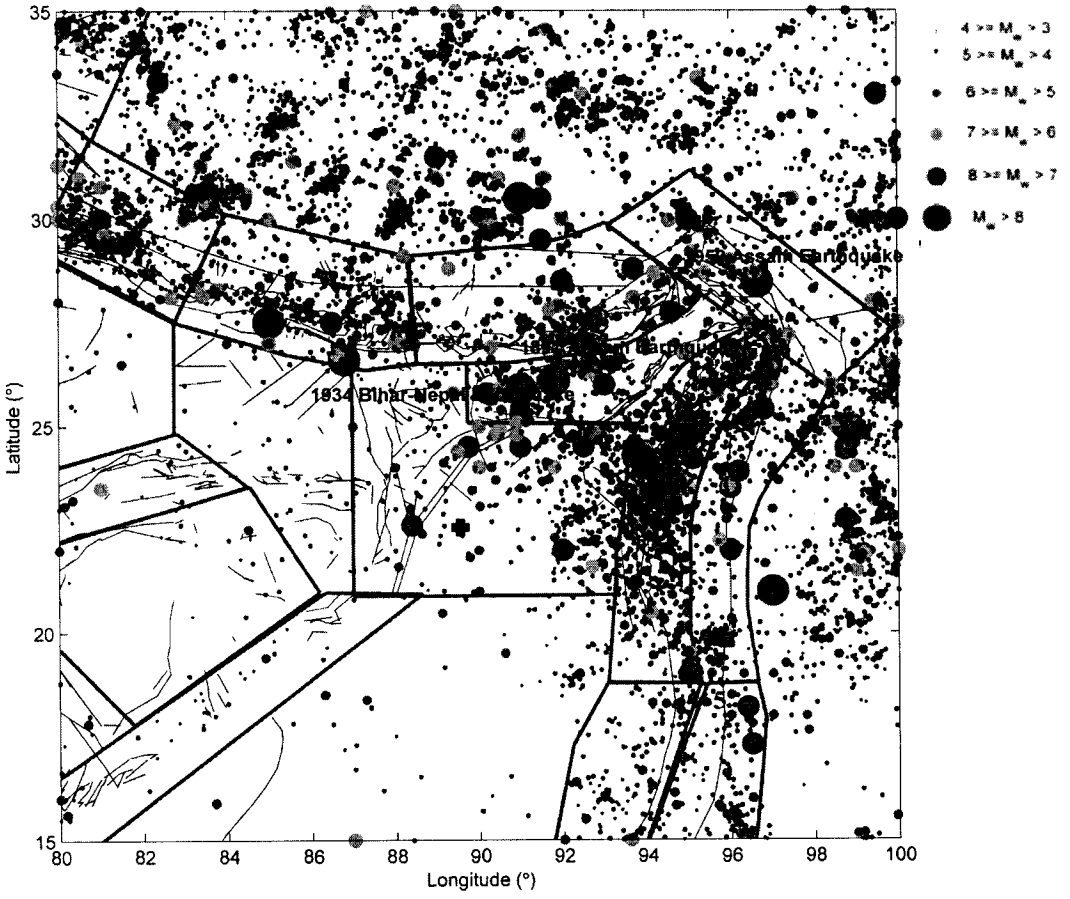


Figure 8. Seismogenic zones of Indian sub continent superimposed with faults (NDMA 2011) Blue lines - Faults, Red lines - Source Zones

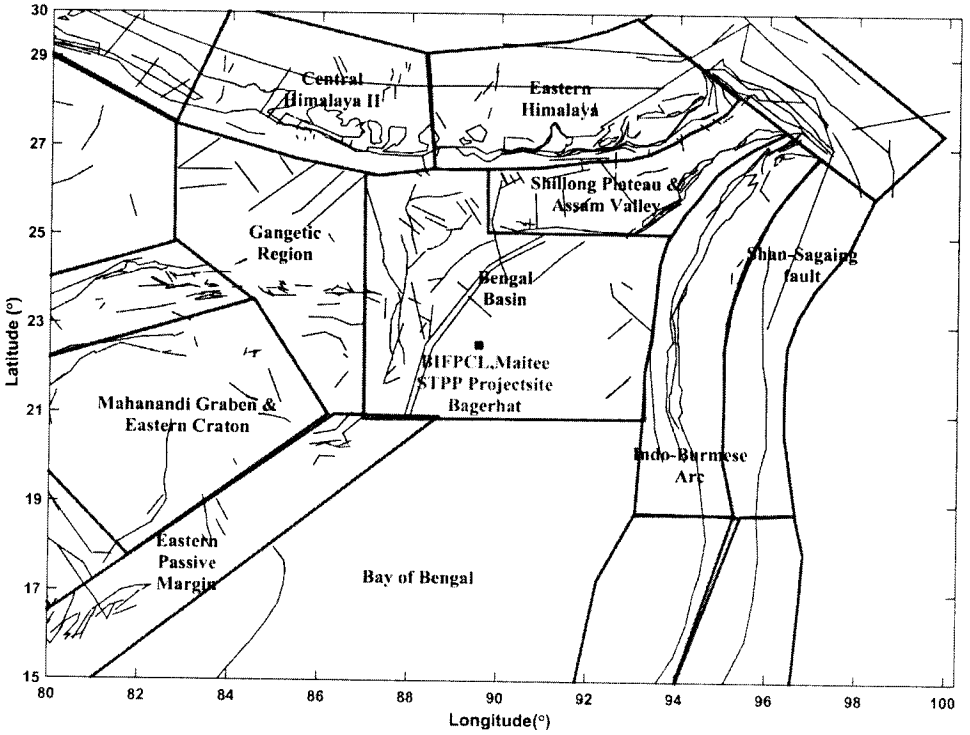


Figure 9 Seismogenic zones according to the 32 Zones identified for the Indian Sub continent as per NDMA (2011) around the BIFPCL, Maitree site, Bagerhat

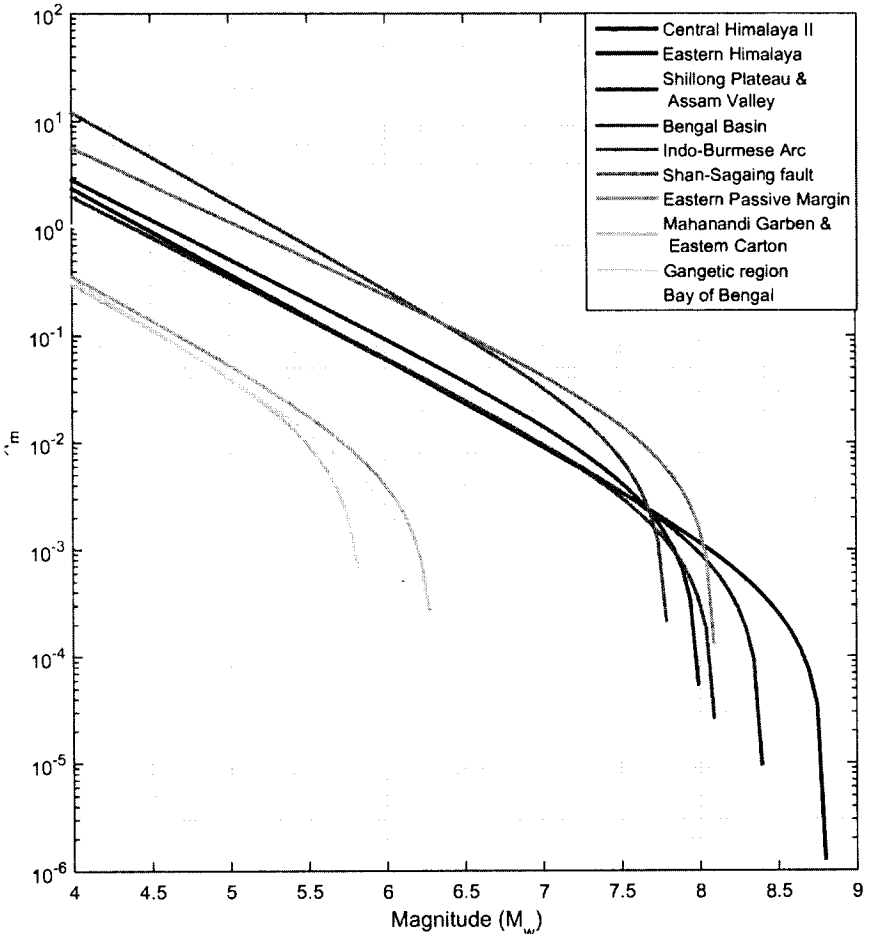
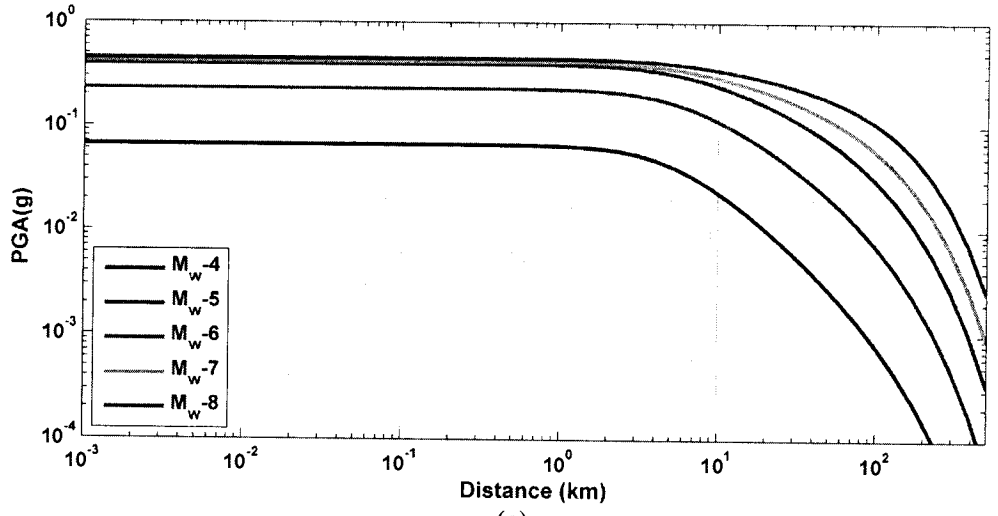
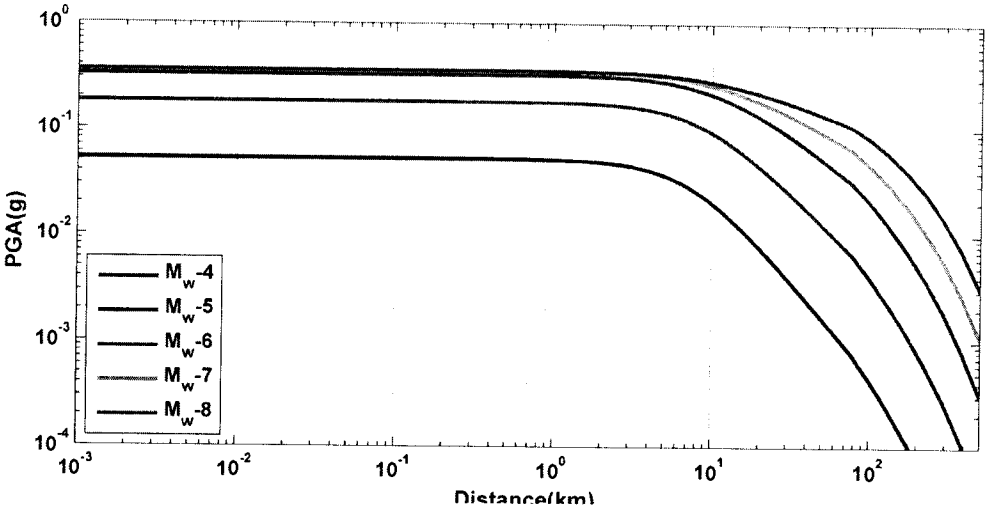


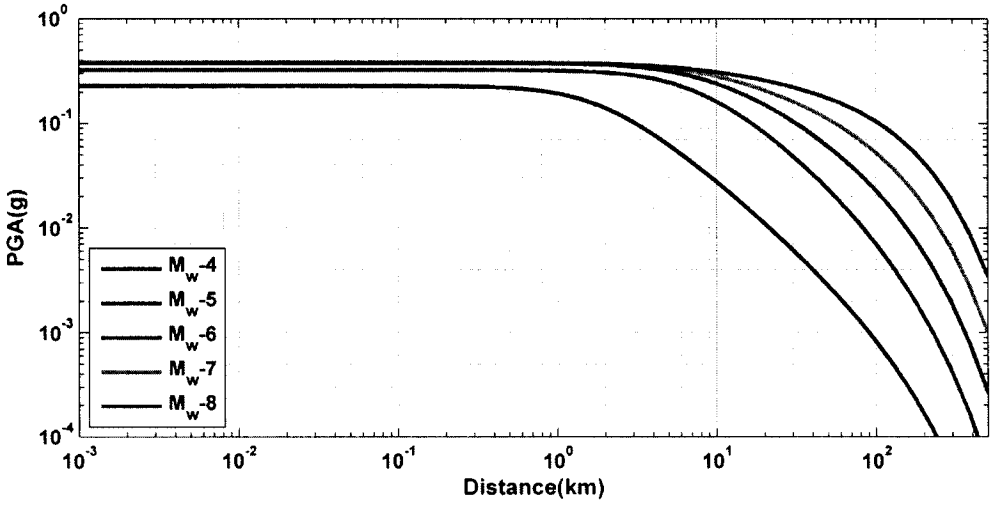
Figure 10. Regional magnitude-frequency relationship



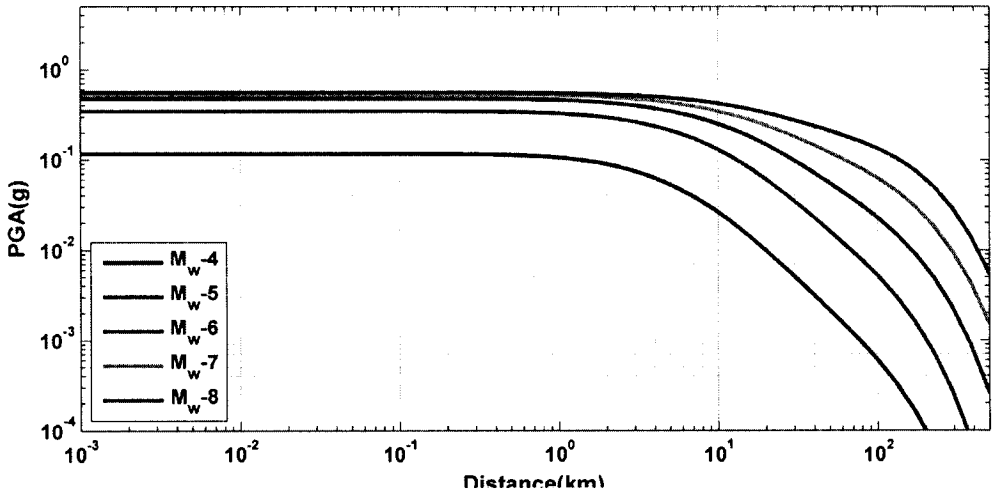
(a)



(b)



(c)



(d)

Figure 11. Attenuation of PGA (in acceleration due to gravity (g)) with hypocentral distance (in km) for SD-Type Soil Condition; (a) Boore et al. (2014), (b) Campbell and Bozorgnia (2014) (c) Atkinson *et al.* (2014) (d) Chiou and Youngs (2014)

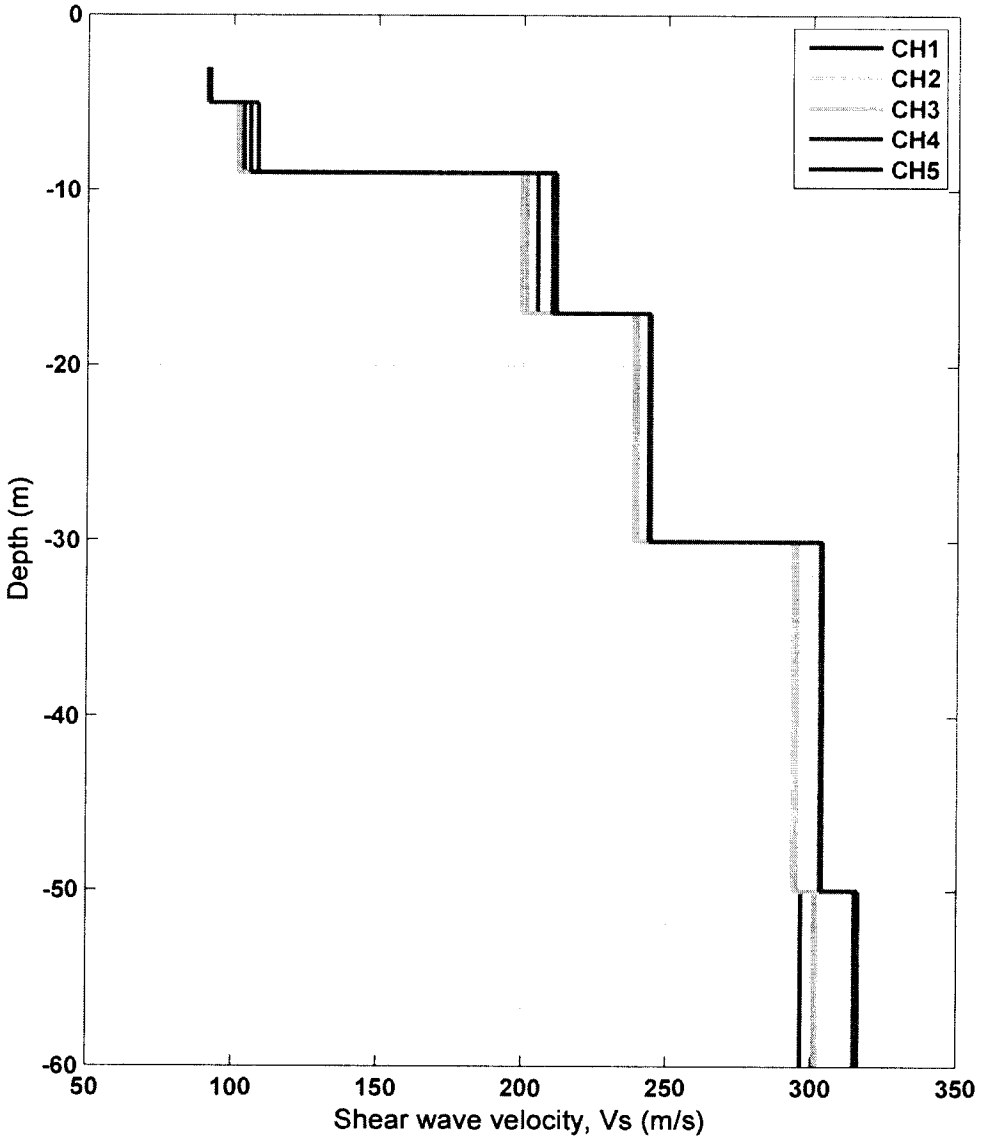


Figure 12. The shear wave velocity profile obtained from Cross Hole test at Rampal, Bagerhat, Bangladesh

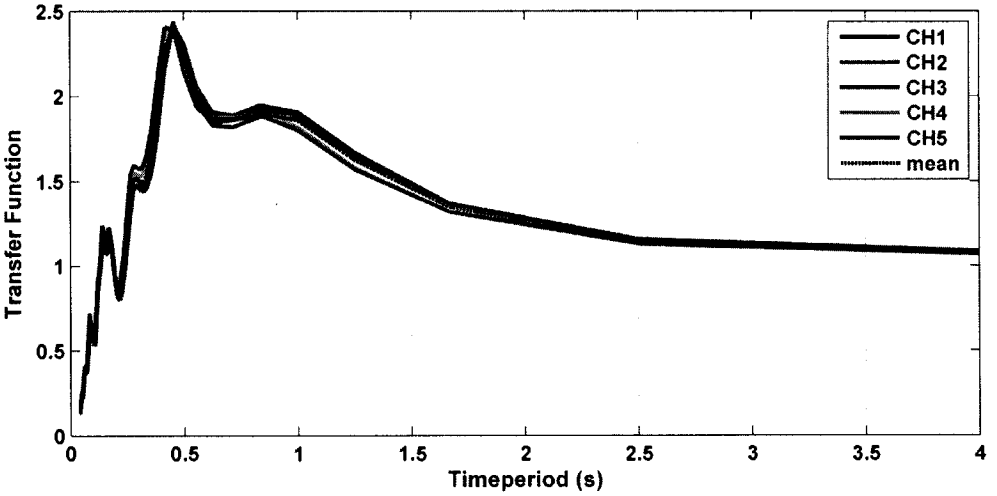


Figure 13. Transfer function with respect to timeperiod

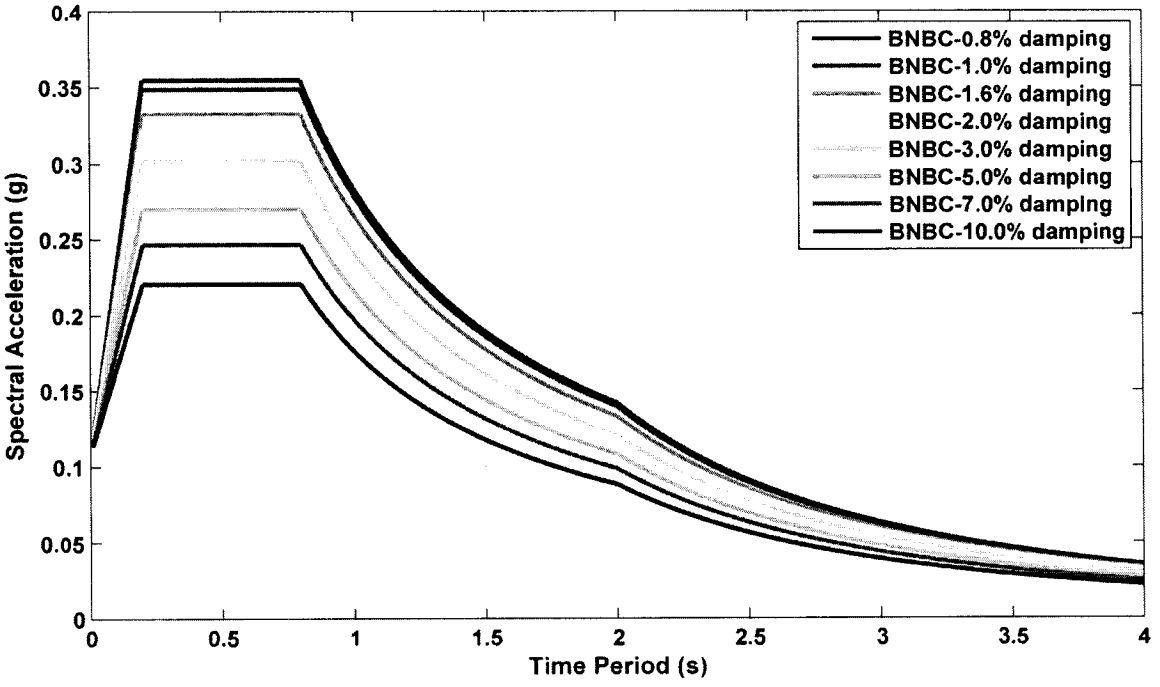
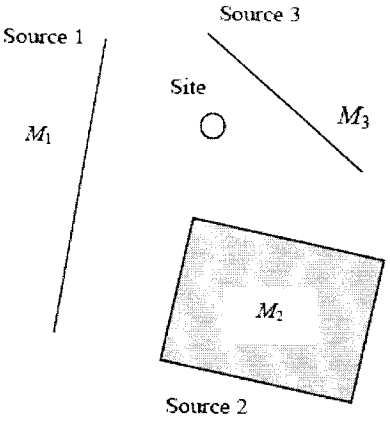
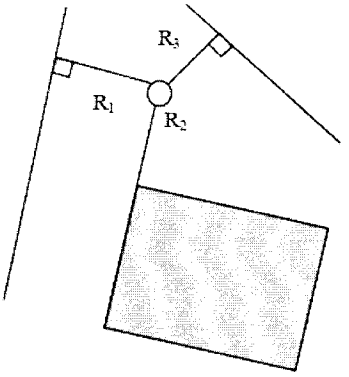


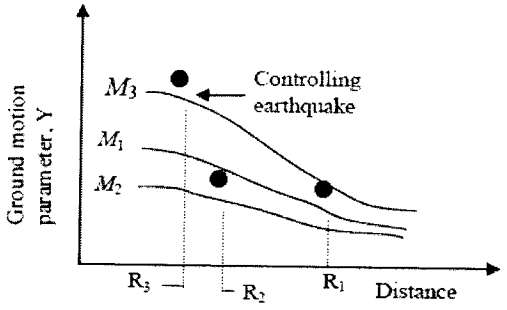
Figure 14. Response spectra according to Bangladesh National Building code (BNBC) for different damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, at BIFPCL, Maitree site, Bagerhat, Bangladesh



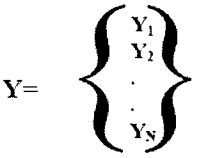
STEP 1
Identification of seismic sources



STEP 2
Shortest distance from the sourc

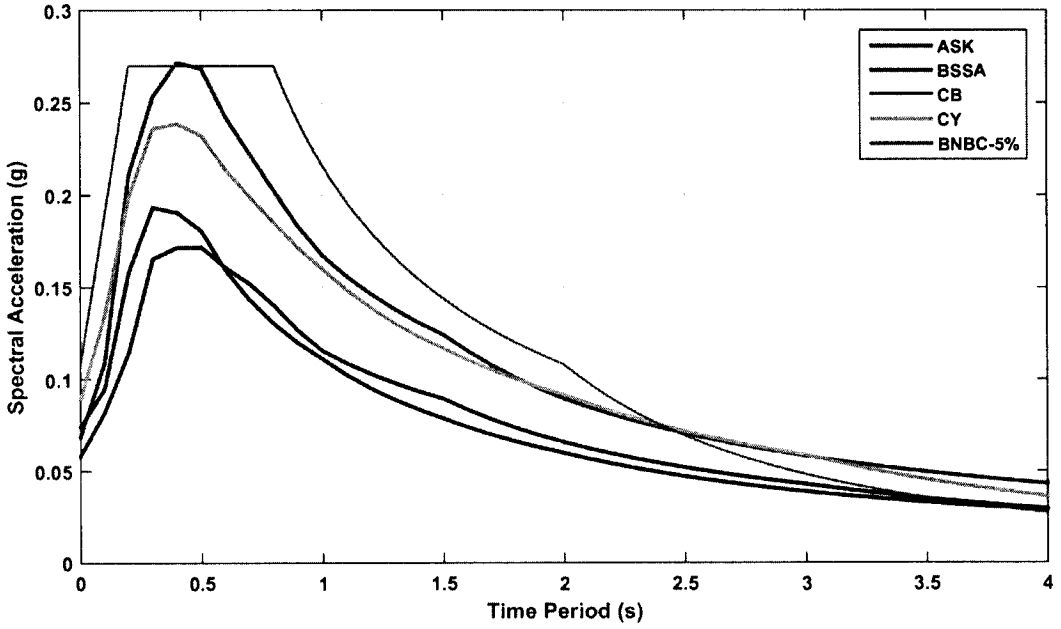


STEP 3
PGA from Attenuation relation for each source



STEP 4
PGA for controlling EQ

Figure 15. The steps to determine the Deterministic Seismic Hazard.



(b)

Figure 16. The response spectra according to deterministic seismic hazard analysis for different attenuation relationships with M_w (7.5) (corresponding to 2500yrs RP) along with that according to Bangladesh National Building code (BNBC) for 5% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, at BIFPCL, Maitree site, Bagerhat, Bangladesh

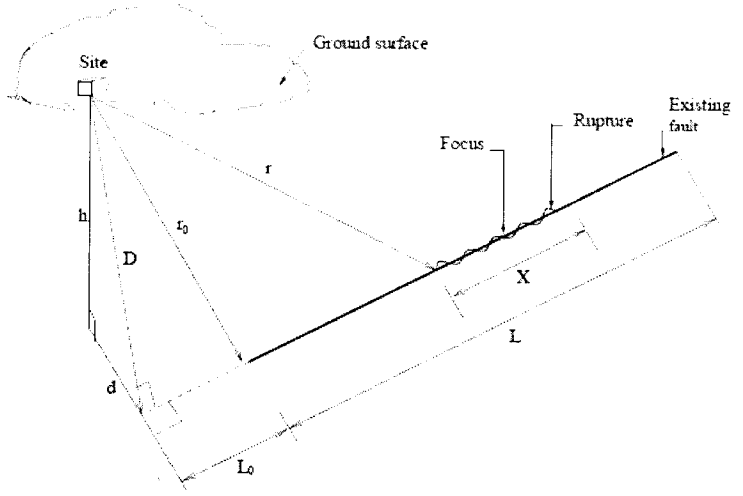


Figure 17. Source, Site and Path for PSHA , Where L is the length of fault, X is the rupture length for a particular magnitude of earthquake, h is the focal depth, r is the minimum distance from site to the region of rupture, r_0 is the minimum distance of the site from the fault, D is the perpendicular distance from site to the projection of fault line, L_0 is the projected length of the fault line from the end of the fault till the perpendicular from the site(Source: Der Kiureghian and Ang (1977))

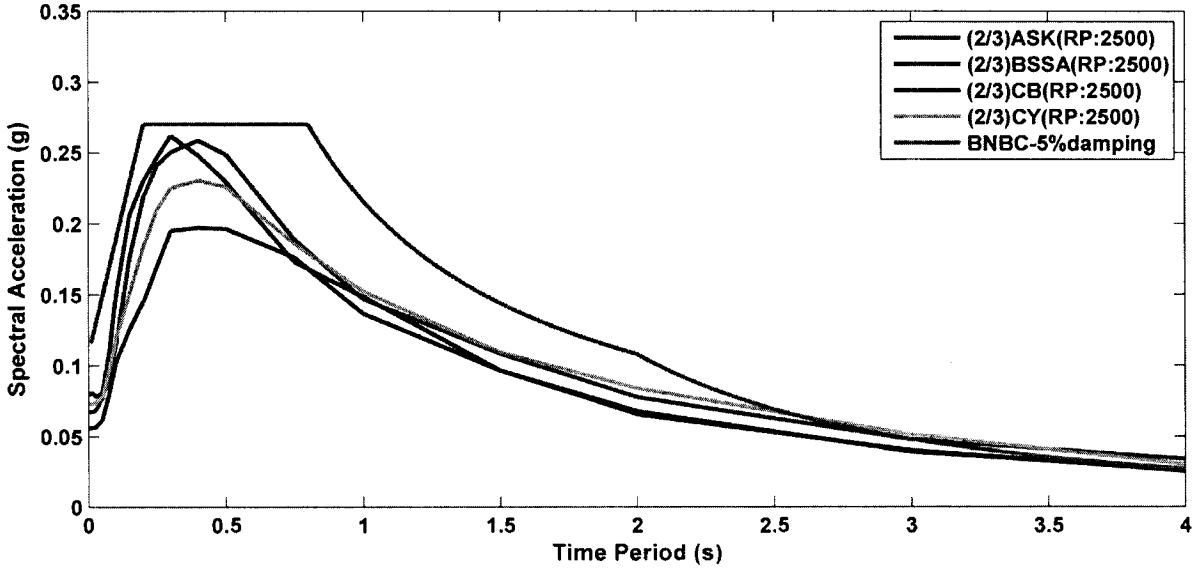


Figure 18. UHRS using different atteneuation relations along with Response spectra according to Bangladesh National Building code (BNBC (2012)) for 5% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, at BIFPCL, Maitree site, Bagerhat, Bangladesh

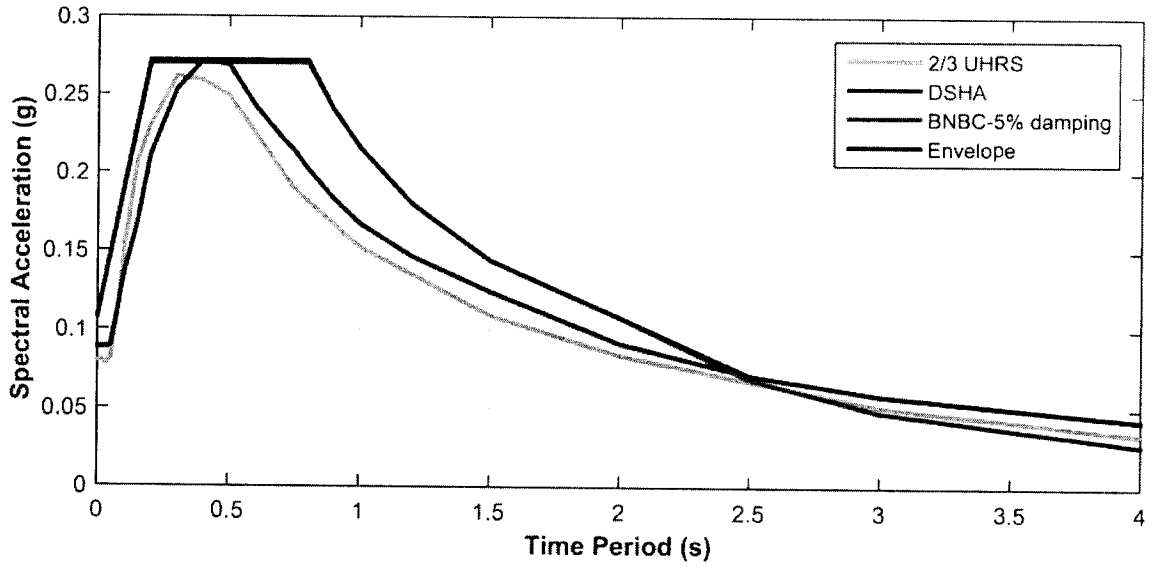
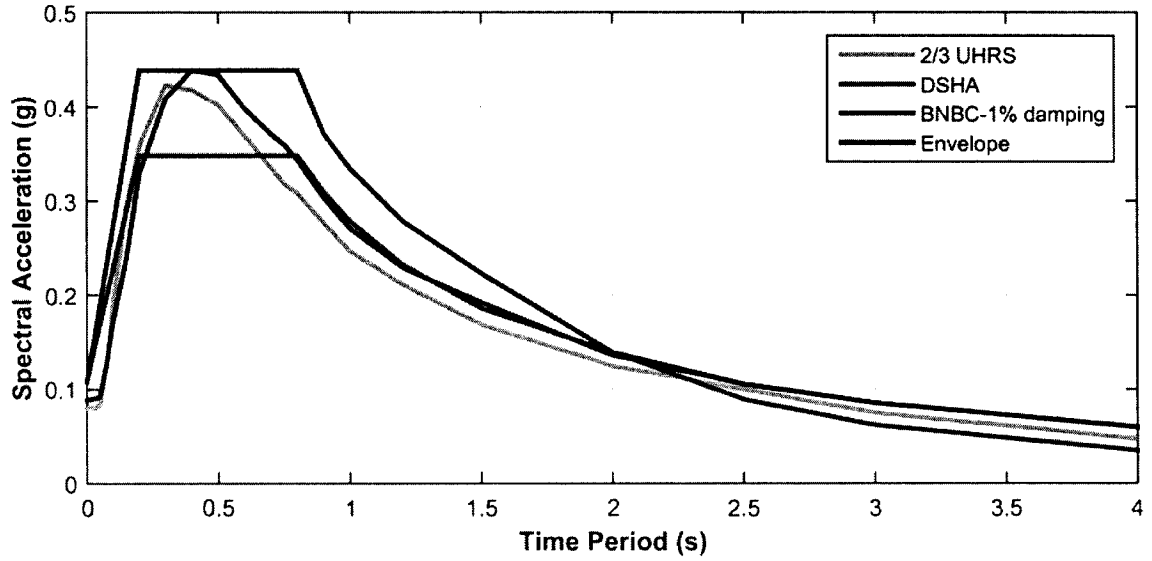
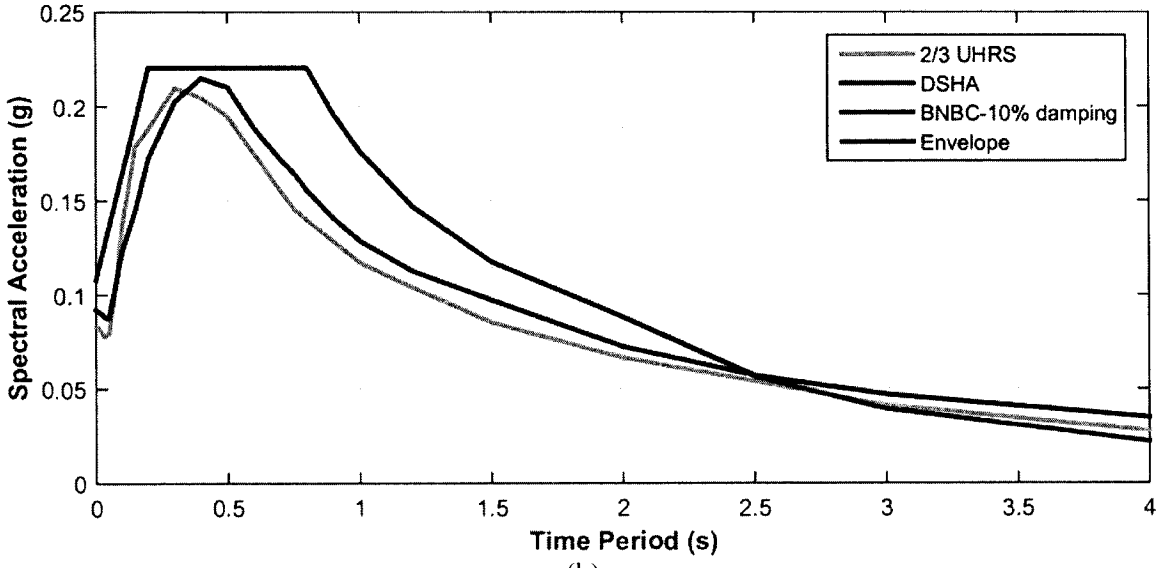


Figure 19. Comparison of response spectra according to Bangladesh National Building code (BNBC) for 5% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, with maximum values obtained from DSHA and (2/3) of UHRS (PSHA analysis) corresponding to 2500yrs RP at BIFPCL, Maitree site, Bagerhat



(a)



(b)

Figure 20. Comparison of response spectra at BIFPCL, Maitree site, Bagerhat

(a) Bangladesh National Building code (BNBC) for 1% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, with DSHA and (2/3) of UHRS (PSHA analysis) corresponding to 2500yrs multiplied by damping correction factors for 1%damping

(b) Bangladesh National Building code (BNBC) for 10% damping, with Z=0.12, 'SD' type soil class and I and R considered as 1, with DSHA and (2/3) of UHRS (PSHA analysis) corresponding to 2500yrs multiplied by damping correction factors for 10%damping

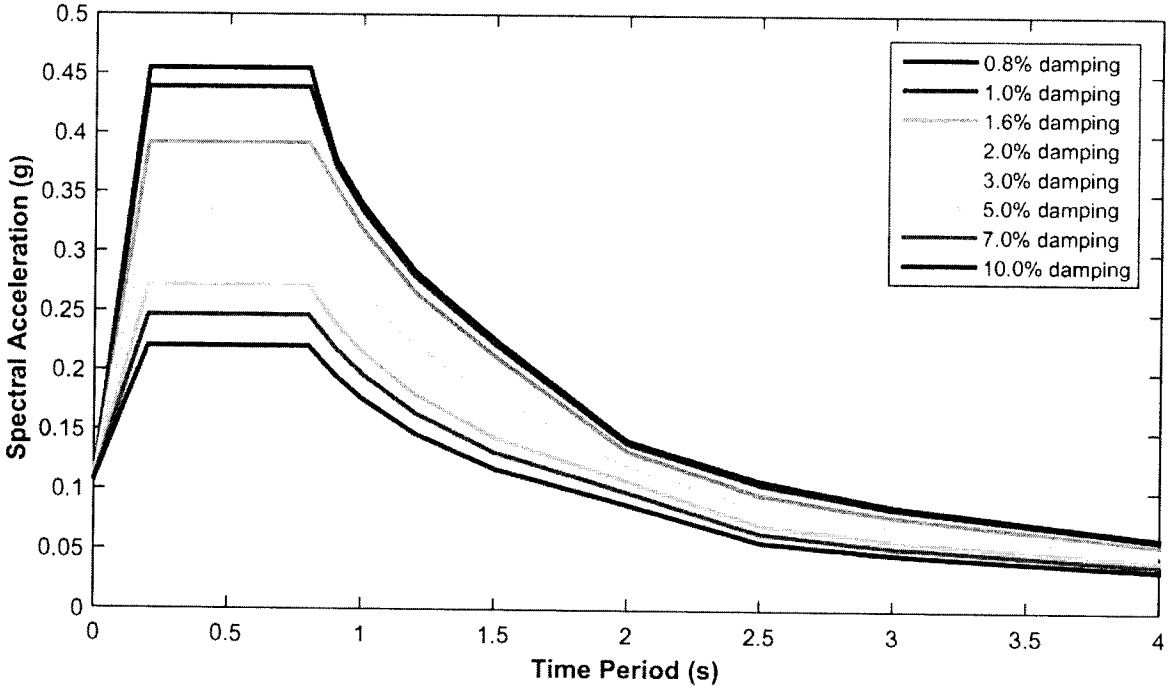


Figure 21. Recomended response spectras for different percentage of damping at BIFPCL, Maitrec site, Bagerhat, Bangladesh

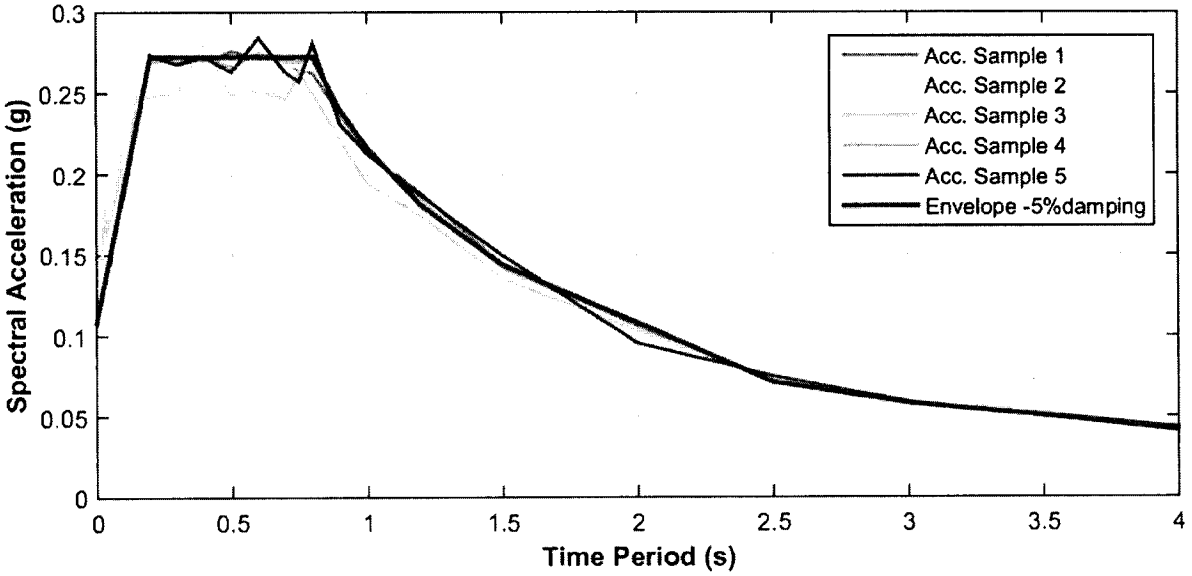


Figure 22. Comparison of response spectra of the 5 sample acceleration time histories with the recommended response spectra for 5% damping, at BIFPCL, Maitree site, Bagerhat, Bangladesh

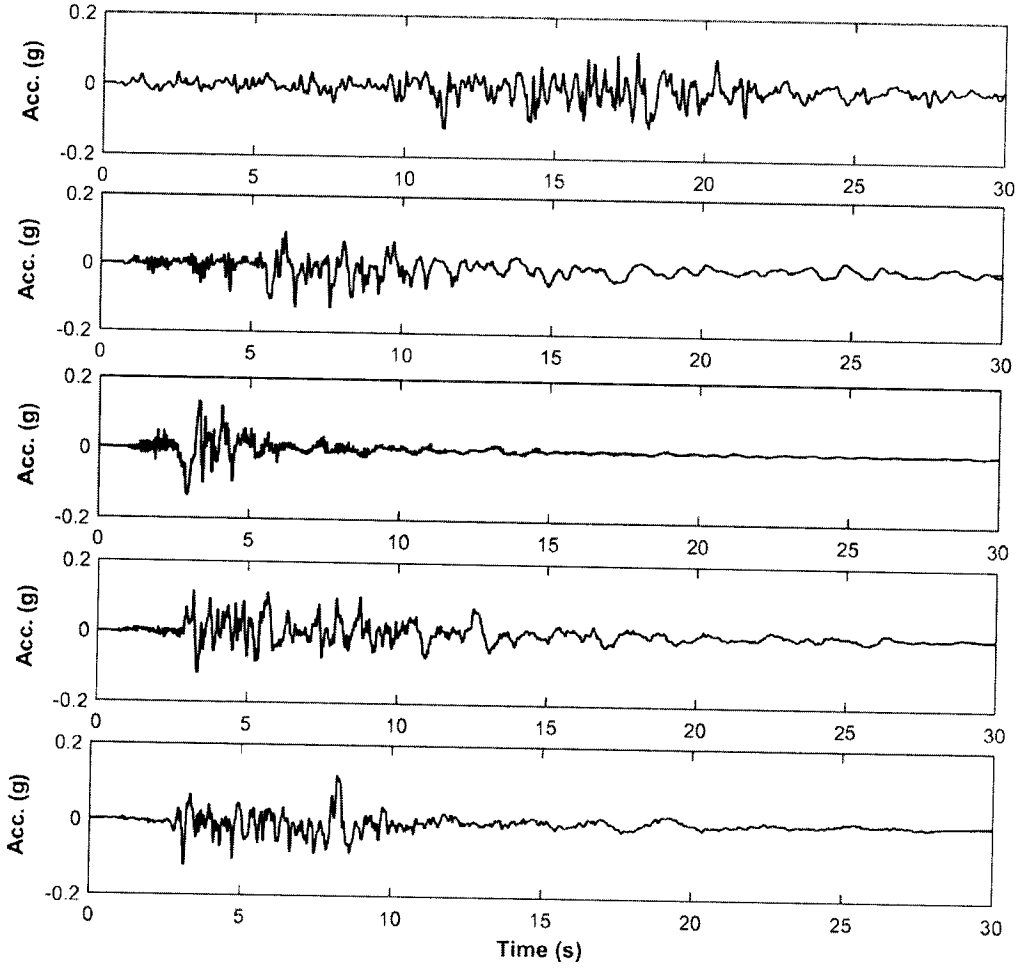


Figure 23. Spectrum compatible acceleration time history samples corresponding to 5% damping for BIFPCL, Maitree site, Bagerhat, Bangladesh

ANNEXURE – E
TO
INTERNAL ORDER NO. INTORD0489

PACKING & SHIPPING INSTRUCTIONS

1. **All units/ sub vendors/ contractors are strictly advised to comply with packing instructions mentioned in contract documents (GCC clause 65: Packaging & Section V, FTS, Clause B0.3.5 Packaging and transportation).**

2. Special Packing Instructions & Inspection Prior to Dispatch

   - Packing (tare) shall be part of the Equipment cost and shall not be subject to return. The packing should ensure integrity and cohesiveness of each delivery batch of Equipment during transportation. In case of Equipment assemblies and unit's delivery in the packing of glass, plastics or paper the specification of packing with the **material and weight characteristics are to be indicated.**

   - All packages to be wrapped in transparent polythene inside the crates for effective weather proofing

   - Each package should have the following inscriptions and signs stenciled with an indelible ink legibly and clearly:

     Destination:
     Package number: BHEL/MTR/BD/XXX/YYYYY where XXX stands for Unit abbreviation e.g. RPT
     YYYYY stands for package no.
     Gross and Net weight
     Dimensions
     Lifting places
     Handling marks and the following delivery marking:

     "BANGLADESH-INDIA FRIENDSHIP POWER COMPANY (Pvt.) LIMITED
     2X660 MW MAITREE SUPER THERMAL POWER PROJECT
     BANGLADESH"
     EPC CONTRACTOR: BHARAT HEAVY ELECTROCALS LIMITED, INDIA

   - Completeness of Contents of each packing case:_Concerned CQA/Unit QC/Third Party Inspection Agency shall verify the completeness of contents of each package w.r.t packing list both in terms of quality and quantity before authorising dispatch of the consignment.

   - Packing commensurate with international standards and accepted norms will be ensured by CQA/ Unit QC/Third Party Inspection Agency. Packing has to be **SEA WORTHY** and secure.

   - As far as possible, the packing has to be rectangular in shape for optimum space utilization in the ship and economize on shipping costs. Projections on packages are prohibited.

   - The packing list has to be checked and certified by the Inspection agency (ies) with due signatures.

   - All packages shall be enclosed in suitable GI sheets on all sides.

   - No loose items / Gunny bag packing are allowed for shipment.

   - Proper pallets and crates are to be used for packing of Oil drums and Structures.

   - Routing of Packing Lists: Packing list is an extremely important document, which forms a part of export documentation in connection with the processing of customs formalities.

Packing List has to be generated by units/Unit vendors and sent to MEPG and ROD (both at the same time), two weeks in advance, for processing and obtaining shipping bills' clearances and avoiding octroi payment through 'N' form at Mumbai.

- Advance intimation to ROD & MEPG: All supplying units/vendors will give at least 15 days advance intimation to ROD & MEPG along with package details before actual dispatches to arrange for storage/shipping arrangements by ROD and customs invoicing by IO. Information must be sent to consolidate the details and arrange for shipments in time.

- Excise Attestation at Works: To avoid opening of big cases for examination by customs at port of shipment, the supplying unit may arrange to get the packing cases sealed by local excise authorities/ self-certification and the relevant invoices and packing lists to be endorsed from Superintendent, Central Excise. For this purpose, Units should send the packing lists to MEPG at least 2 weeks in advance to enable prepare Shipping Invoices for furnishing to the units for requisite attestation and sending to ROD through fastest means for a smoother and faster customs clearance. Also Units to provide "specification of packing with the indication of the number of cargo packages, type of packing and weight of packing in English" along with the packing list.

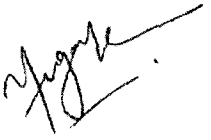
- Provision of Inspection Windows on Packages: Unit/Vendors should provide inspection window of size 6" x 4" (glass perplex) for customs examination for all packages (above 1.5 x 1.5 x 1.5 cu m) involving panels of any kind. Care would be taken to ensure that all packages are properly sealed to avoid ingress of moisture, rodents etc. Packing slip folders to be attached in each box.

- Drawings for Heavy Weight/ODC consignment: Any package/item weighing above 20000 kgs and/or size greater than 2.5 X 2.5 X 4 m. detailed engineering documents (at least 4 sets) for all items of the above category will be furnished by respective units to issue shipment enquiries in a proper manner. The drawing has to include centre of gravity of the item clearly (Units to identify such items and notify MEPG as soon as the engineering documents are released).

- Lifting Beams: All heavy lifts for which safe handling is essential at the port of dispatch shall be accompanied by lifting beam on non-returnable basis.

- "Marking for Safe Handling: To ensure safe handling, packing case shall be marked to show the following:

  - ✓ Upright position.
  - ✓ Sling position and Centre of Gravity position.
  - ✓ Storage category.
  - ✓ Fragile components (to be marked properly with a clear warning for safe handling).



SEAWORTHY PACKING

(PACKING INSTRUCTIONS FOR GENERAL COMPONENTS / ASSEMBLIES / EQUIPMENTS)

1.0 GENERAL

This standard lays down packing instructions for packing of Components /Assemblies/Equipments to be dispatched against Customer's contracts, for which there are no special instructions issued by the Engineering Departments.

The Components/Assemblies need to be packed suitably to avoid physical damage & corrosion during transit for storage. For specific applications the concerned engineering department shall issue a product standard. Reference of this standard, must appear in the Shipping list/Packing List.

2.0 SCOPE:

This procedure gives minimum guidelines to be complied with for packing of Components /Assemblies / Equipments. This packing shall be suitable for different handling operations and for the adverse conditions during transportation and during indoor / outdoor storage for periods more than one year.

3.0 CROSS REFERED SPECIFICATION:

Expanded Polyethylene Foam Sheet	: AA51420
Packing Wood	: AA51401
Silica gel	: AA55619
Thermocole	: AA51416
Packing slip holders	: AA7240901
Corrugated Fibre Board	: AA51414
Rubber sheet	: AA59001
VCI paper	: AA51406

4.0 WOOD SPECIFICATION FOR PACKING:

The wood shall conform to specification AA51401.

5.0 TYPE OF PACKING:

The following 5 types of packings have been standardized for packing of General Components /Assemblies.

'OP' - Open Type
'PP' - Partially Packed
'CP' - Crate Packing - Components/Equipments requiring physical protection
'CQ' - Case Packing - Small medium Components/ Assemblies/ Equipments which require corrosion & physical protection
'CR' - Case Packing - Electrical Components/Assemblies which require special packing viz. Water Proof, Shock Proof, etc.

6.0 DESCRIPTION OF TYPES OF PACKING:

The various types of packing, as standardized above, are described below.

6.1 'OP' - Open Type:

In case, of components which are not affected by water & dust & do not require special protection &, are generally not machined, shall be sent as open packages. However these components may be sent in crates, wherever necessary.

6.2 'PP' - Partially Packed:

Components which need special protection, at selected portions only, shall be dispatched partially packed. Machined surfaces should not be allowed to come directly in contact with the wood. Such surfaces after application of TRP should be protected with Polyethylene Coated Bitumen Hessain Kraft Paper to AA51409 or Polyethylene sheet to AA51408 of at least 100 micron thickness.

6.3 'CP' - Crate Packing – General:

Assemblies/Components which need only physical protection from the point of view of handling shall be dispatched duly packed in crates.

6.4 'CQ' - Case Packing - Machined Components/Assemblies/Equipments:

a) Small & Medium sized components/assemblies/equipments due to size/weight & to avoid handling, and pilferage, problems shall be packed in Case/Containers.

b) Wherever required adequate quantity of silica gel to AA55619 or VCI Powder/ Tablets, packed in thin muslin cloth cotton bags shall be suitably placed.

c) Small machines/components of less weight shall be provided with suitable cushioning. Wood Wool/Expanded Polyethylene Foam Sheet, if used, shall be sandwiched between polyethylene sheets and sealed.

d) The components inside the case shall be entirely covered with a polyethylene sheet of at least 100 micron thickness to AA 51408, where-ever required.

6.5 'CR' - Case Packing - Electrical & Electronic Components/Assemblies:

Delicate components likely to be damaged e.g. Gauges, Instruments etc. are to be wrapped in waxed paper or polyethylene air bubble film and packed in cartons.

a) Adequate quantity of Silica gel to AA55619 packed in cotton bags, of 100 grams each are to be suitably placed in the cartons. The cartons shall be entirely covered with a polyethylene sheet to AA51408 of at least 100 micron thickness, before being packed in the cases.

b) VCI Powder/Tablets can be used as an alternative to Silica Gel to AA55619.

c) Empty space in the cartons shall be filled with small chips of Expanded Polystyrene (Thermocole), Wood Wool etc. Polyethylene air bubble film shall conform to IS:12787/AA51420 Expanded polystyrene (Thermocole) shall conform to AA51416.

d) The cartons shall be manufactured from corrugated Fibre Board, meeting requirements of AA 51414.

6.6 Volatile Corrosion Inhibitor (VCI) Paper:

a) Un-protected surfaces of steel and cast iron components, tools bearing, shaft seals etc. are covered with VCI paper. VCI paper has been impregnated with

corrosion inhibitors which by evaporation and chemical conversion protect metals in an enclosed area against corrosion.

b) 7 m^3 VCI paper is necessary for 1 m^3 of packed item approximately as per AA51406.

Application Limitation:

VCI paper shall not be used for components made of aluminium, aluminium alloys as well as Zinc, copper, brass, cadmium and silver.

VCI powder is sprinkled inside the piping components ends shall be protected with end cover as specified in plant standards, drawings.

6.7 Moisture Absorber:

Silica gel is used for this purpose to protect the contents over sufficiently long time from corrosion. At the time of use, silica gel should be so dried that its colour becomes dark blue. These shall be filled in small cotton bags. Before sealing the equipment, the silica gel bags should be kept inside the polyethylene film cover at different locations. The quantity of silica gel should not be less than 1.0 kg per cubic metre volume of the packing box

7.0 TYPE OF CASES:

For specific requirement of packing the cases are to be provided with Tongue and Groove joints.

8.0 PREPARATION OF PACKING CASE:

8.1. The base of the case shall be made of wooden batons for planks giving necessary reinforcement, such that the bottom of the equipment is at a height of 100 to 200 mm from the ground level depending upon size, ft weight of equipment. However for packing cases of smaller size equipment can be at a height of -40 mm from the ground level.

8.2. In case of 'CR1 - Packing Viz. Electrical ft Electronic components for instruments /assemblies, a rubber sheet, Self-expanded polyethene foam sheet, preferably 10 mm thick, shall be fixed on to the base to act as cushioning to the equipment.

8.3. The four sides, shall be lined, from inside with packing paper water proof bitumen laminated to AA51410 Type – I or polyethylene sheet to AA51408 of at least 100 micron thickness and tacked at suitable places.

Whenever specified in addition to the bitumen laminated paper/polyethylene sheet the top cover will have a layer of bitumen felt over the cover. This should project about 100 - 250 mm on all sides.

It is preferable to have a single piece of the above Kraft paper fixed on the four sides. In case jointing is unavoidable, it should be done by overlapping of approximately 100 mm.

8.4. Place the Components/cartons with corrosion inhibitors duly applied wherever necessary for place suitably, thin muslin cloths bags containing 100 grams (approx.) of activated Blue Silica Gel to AA55619, wherever necessary. Alternatively VCI Powder or Tablet may be used.

8.5. In case, depression is formed, at the top, after the equipment is lowered, provide ply board/wooden batons.

8.6. Cover the whole equipment with polyethylene sheet of at least 100 micron thickness, on all sides preferably by a single piece.

8.7. For indoor panels/equipments, provide suitable packing batons with covering of Thermocole/expanded soft polyethylene foam/polyethylene air bubble film wrapped with suitable cords, to avoid cutting of the polyethylene sheet so that finished surface is not damaged.

8.8. Empty space in the box shall be filled with adequate cushioning material e.g. Thermocole Chips, Wood Wool etc. to avoid movement for shocks. Alternatively put wooden blocks/batons wherever necessary.

8.9. The inner side of the top cover shall be lined with polyethylene sheet, of at least 100 micron thickness, which shall project approximately 25 to 150 mm depending upon the size of the case on all sides of the top cover shall be provided below the top cover. This projection, after nailing the top cover, shall be folded over, on the sides of the crates ft tacked, to, prevent ingress of water from the top.

9.0 STEEL CONTAINERS:

Steel containers for packing can be used in case of repeated supplies of the same equipment. Empty steel containers are to be returned back from customer's end and to be reused for the next supplies.

The containers are to be made of structural steel as per AA 10108 with proper reinforcement with I, C and T Sections.

Following precautions are to be taken during packing:-

Put the Components/Assemblies/Equipments in the steel container properly.

Cover the Components/Assemblies/Equipments with polythene.

To arrest the movement in the steel container necessary wooden Blocks/Batons may be put.

Put cover on steel, container and Bolt Properly.

10.0 SEALED PACKING:

Components sub-assemblies and assemblies sensitive to climatic conditions shall be packed seal tight. All the openings of the sensitive components, sub-assemblies and assemblies shall be blanketed to prevent the ingress of dust and moisture.

The components sub-assemblies and assemblies are completely covered with 2 layers of polyethylene sheet. All sharp corners and edges are to be protected by rubber mats to prevent the polyethylene sheet from damage. Top surface of the case shall be free from dents to prevent rain water pockets.

11.0 SLING PLATE:

Sling plate shall be provided to prevent damage to the packing box during lifting. Size of the sling plate shall be selected depending upon the net weight of the consignment.

12.0 PACKING SLIP HOLDERS:

Two nos. steel packing slip holders, specification no. AA7240901 containing the packing list, sealed in thick polyethylene film, shall be fixed one inside and the other outside the packing box.

13.0 GENERAL PRECAUTIONS:

a) While fixing nails during packing, necessary care shall be taken to ensure that materials used for protection inside the case e.g. paper, polyethylene sheet, coir etc. do not get damaged.

b) Sling protection brackets to be provided on cases wherever required.

c) It shall be ensured that all stencil marks external, front & rear sides of the casing shall beof water proof Material to prevent obliteration in transit.

d) The various caution signs shall be marked with stencil on both sides of the packing box.

e) Do not pack any other Mechanical items with this case.

THE FOLLOWING DETAILS ARE TO BE MARKED ON THE PACKING CASES.

a) Address of consignee.

b) Purchase Order No.

c) Description of item or title of packing list.

d) Case identification Number.

e) Net Weight.

f) Gross Weight.

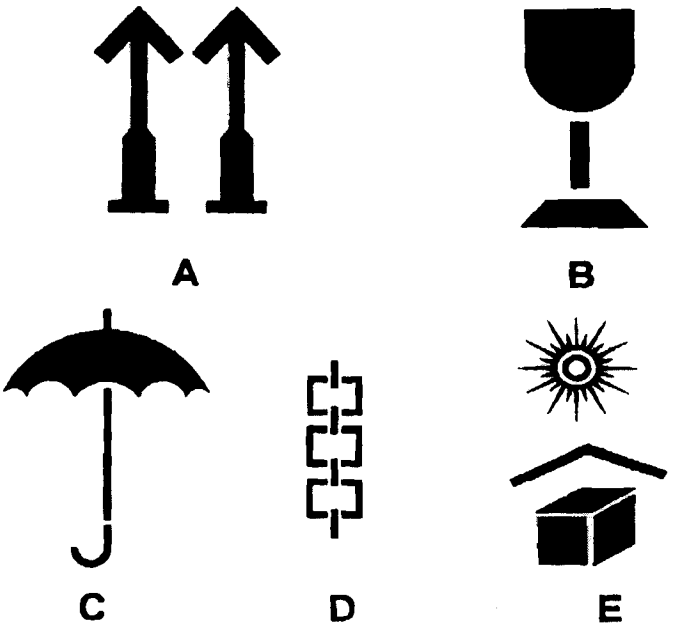
g) Dimensions of box

h) Marking showing upright position.

i) Marking showing sling position.

j) Marking showing umbrella (i.e. for machines/components to be stored under covered storage.

MARKING ON PACKING BOXES



A UPRIGHT
B FRAGILE
C PROTECTION FROM FALLING OR CONDENSING MOISTURE
D SLING POSITION
E PROTECTION FROM DIRECT RADIATION

CORPORATE STANDARD

14.0 PROVISION FOR INSPECTION:

This clause is applicable only where contractual requirement of customer is there. For other packings this is not applicable.

Each transportable packing's shall have provision for inspection by customer authority etc. during transport from origin of dispatched till destination. This inspection may require opening of the package and subsequently closing it again. For this purpose suitable designed opening with bolted cover shall be provided. Such an opening shall be clearly marked as "OPENING" with clear instruction for opening & closing written on this cover. For large consignment the size of the opening shall be suitable to facilitate entry of personnel.

GENERAL GUIDELINE FOR FILLING QA PLAN IN CUSTOMER FORMAT

[1] Suppliers are required to fill the necessary relevant details under each column for **QA activities** planned during realization of final product covering the following stages :

A] Raw material stage –Covers all significant raw materials which are **procured from various approved sources by supplier** and **processed in supplier works** before assembly & final inspection of finished product. Example: Structural material, Pipes , tubes , strips, Sheets, Casting, Rods, Wires, packing material etc.

B] BOI stage – covers all instruments , devices, equipments ,assemblies & sub-assemblies which are **procured from approved sources by supplier** and are **used as sub assemblies / components** in finished product without any processing at supplier works. Example: Motors, transformers, switchgear [Circuit breakers, SFU ,fuses etc.] ,MCC, Resistors, All meters, Relays , Contactors, Displays, CT/PT ,Gears, Fans ,cables etc.

C] In process stage – covers all processes [including outsourced processes] which are required for conversion of raw material & BOI into finished product. Example: Wiring, Fabrication, Soldering, Brazing, Welding , Surface preparation, Painting , Galvanizing , Electroplating, Assembly, Finishing etc.

D] Final inspection stage - covers applicable Routine tests[FRT] for 100% of lot size & Acceptance test[FAT] on samples drawn from population of Offered Finished product.

Routine tests are conducted on 100 % lot size for confirmation of proper manufacturing by checking for manufacturing defects.

Acceptance tests [include most routine test & any other test / check stated in standard/ specification] are conducted on specified sample size [usually mentioned in QA plan / IS /BS/ IEC Standards] for the purpose of acceptance [rejection] of offered lot of finished product.

Type test approval wherever necessary must be obtained prior to Final inspection.

E] Packing stage – covers all process including finishing , preservation & packaging of product prior to dispatch.

[2] For each of above stages, there will be components [in case of Raw material/BOI stage] and operations [in case of In-process stage, Final inspection & packing stages] involved. Under the 'COMPONENTS / OPERATION' column the name of respective item/component/operation will be mentioned.

[3] For each component / operation there will be a list of test /checks involved which will ensure that the desired characteristics [specified in Technical specification, IS/BS/IEC & Plant standards] are confirmed in the lot under test. It could include Chemical composition, Metallurgical examination for grain size , Mechanical properties like UTS/ % Elongation, hardness, Impact test etc, Electrical characteristics like resistivity , capacitance / inductance/ PD/ Tan delta etc. , Functional checks, Operation check, pressure test etc. Sample sizes should be adequate & in conformity with relevant specification & standards [IS/BS/IEC/ Plant standard]. Under the column 'CHARACTERISTICS' the list of relevant characteristics for all component/operation must be mentioned.

[4] The various Characteristics checked for any component /operation are further classified into Critical, Major & Minor categories. Under Critical category, the characteristics which are essential for the finished product to meet the specified performance criteria & the non-conformance of which will harm or impair the product , user/operator and to associated equipment. Under Major category , those characteristics whose non-conformance will impair the ability of final product to deliver the specified performance criteria is included . All other characteristics are under Minor category. Under Column 'CLASS' the relevant category [Critical/Major/Minor] shall be mentioned.

[5] The type of various check[s] for different characteristics for all components /operation shall be detailed as Chemical / Electrical / Mechanical / Measurement/ Metallurgical/ NDT/ Pressure test / Functional/ Visual/Physical etc. in the column 'TYPE OF CHECK' as applicable .

[6] The sample size must be mentioned clearly as % of lot / nos. / nos per lot/ nos. per shift etc. under column 'QUANTUM OF CHECK'. The sample size must be adequate & in line with relevant standards / Plant norms. Two columns are mentioned in Quantum check, first one "M" is for the manufacturer/sub supplier quantum of check, whereas the next column as " C/B" represents the Quantum of check to be verified or witnessed by B and/or C

[7] Reference documents includes all approved Engg. documents [GA & part Drawings/ Schematics/ isometrics/ GTP/ datasheet /catalogue/TT approvals] alongwith relevant plant standards / International standards mentioned in specification for the product. The applicable reference document no. / name for each characteristics of all components/processes shall be listed by supplier under the column 'REFERENCE DOCUMENT' .

[8] Under the column 'ACCEPTANCE NORMS' , supplier shall include the relevant document name in which the acceptance criteria are listed / stated or referred. In cases where no such document exists , supplier shall detail the acceptance criteria itself .

[9] The results of various checks for characteristics of all components /operation are recorded in the form of Inspection reports[IR], Test reports[TR]/ Joint inspection reports[JIR]/ Test certificate[TC]/ Log sheet/ QC register / Job card/ Third party lab report/ Certificate of Conformance [COC] etc. . Under the column ' FORMAT OF RECORD ' , relevant test record type will be mentioned . Wherever applicable the format no. of record format should be mentioned. Also the documents which are to be included as part of Final inspection report [QA documentation] will be identified by "Y" or tick mark under "D" sub column .

[10] Column 'AGENCY' mentions the agency for each of the activity [namely Perform ,Witness , Verification.] Legend details are as below :

P- Performing the relevant characteristic test/check , W- for Witnessing the relevant characteristic test/check & V- verification of records pertaining to relevant characteristic checked.

Under each of the sub columns "M" ,"C" & "B" , supplier shall propose the agency as per below legend .

M- Supplier /Manufacturer / Sub supplier . C- BHEL/ BHEL nominated agency. B- BIFPCL/ BIFPCL nominated agency.

"P" [i.e. perform] shall be mentioned under sub column M always [meaning supplier/sub supplier/ manufacturer shall be responsible for performing the test/check.]

Under activity sub-column "C and /or B", "V" shall be mentioned wherever applicable [i.e BHEL and/or Customer shall verify the necessary records for relevant Characteristics checked.] CHP stages will be identified by "W" in "C and/or B" sub-column

[11] Any special information like name & place of Sub supplier for the component / operation [if outsourced] shall be mentioned by Supplier under 'REMARKS' column.

[12] The Customer format of QA plan has 11 columns [suitable to fit paper of A4 size in Landscape orientation]. The header & footer should be as mentioned in blank format.QA plan must include the supplier name & address and the item name in left hand side of Header. Supplier must fill in the necessary relevant details against Project name, Package detail [like 400 KV Switchyard],QP no., Rev., date must be correctly. The QA plan must be signed & stamped by authorized QA representative of supplier in the left hand side of footer before submission to BHEL.

MFGR.'s LOGO	MANUFACTURER'S NAME AND ADDRESS	MANUFACTURING QUALITY PLAN		PROJECT : PACKAGE : CONTRACT NO. : MAIN-SUPPLIER:
		ITEM : SUB-SYSTEM:	QP NO.: REV. NO.: DATE: PAGE: .... OF....	

SL. NO	COMPONENT & OPERATIONS	CHARACTERISTICS	CLASS	TYPE OF CHECK	QUANTUM OF CHECK		REFERENCE DOCUMENT	ACCEPTANCE NORMS	FORMAT OF RECORD		AGENCY			REMARKS
					M	C / B					M	C	B	
1.	2.	3.	4.	5.	6.		7.	8.	9.	D*	**		10.	11.

		LEGEND: * RECORDS, INDENTIFIED WITH "TICK" (√) SHALL BE ESSENTIALLY INCLUDED BY SUPPLIER IN QA DOCUMENTATION. ** M: MANUFACTURER/SUB-SUPPLIER C: MAIN SUPPLIER, B: BIFPCL P: PERFORM W: WITNESS AND V: VERIFICATION. AS APPROPRIATE, CHP: BIFPCL SHALL IDENTIFY IN COLUM "B" AS ' W"		DOC. NO.: REV..... CAT.....		
MANUFACTURER/ SUB-SUPPLIER	MAIN-SUPPLIER		FOR BIFPCL USE			
SIGNATURE				REVIEWED BY	APPROVED BY	APPROVAL SEAL

ENGG. DIV./QA&I

Page 3 of 3

SN				
				Bidder name
	400 kV/230 kV Substation			
	General Remarks:			
	Unless otherwise noted: • data are per 3-phase unit • data are per initial delivery			
1	**Ambient conditions**			
1.1	Altitude above sea level	m	< 30	
1.2	Isoceraunic level (avarage)	days	80	
1.3	Minimum unified specific creepage distance (USCD)	mm / kV	53.7 (heavy)	
1.4	Other ambient conditions according to Section-3 to be followed	-	yes	
2	**400 kV Switchgear**			
2.1	**Type of 400 kV switchgear**	-	Indoor SF6 gas insulated	
2.2	Manufacturer	-		
2.3	Applicable standard		IEC 62271-1 and 203	
2.4	Nominal voltage (phase to phase)	kV(rms)	400	
2.5	Rated maximum system voltage (phase to phase)	kV(rms)	420	
2.6	Rated lightning impulse withstand voltage:			
2.7	• phase-to phase and between phases	kVpeak	1425	
2.8	• across open switching device and/or across isolating distance	kvpeak	1425+240	
2.9	Rated short-duration power-frequency withstand voltage:			
2.10	• phase-to phase and between phases	kVrms	520	
2.11	• across open switching device and/or across isolating distance	kVrms	610	
2.12	Rated switching impulse withstand voltage:			
2.13	• phase-to-earth and across open switching device	kVpeak	1050	
2.14	• between phases	kVpeak	1575	
2.15	• across isolating distance	kVpeak	900+345	
2.16	Rated frequency	Hz	50	
2.17	Rated short circuit withstand current, 1 s	kA(rms)	50	
2.18	Rated peak short circuit current	kA(peak)	125	
2.19	Rated current (busbar)	A	4000	
2.20	Rated current (diameter)	A	3150	
2.21	Rated current (generator and line feeders)	A	3150	
2.22	Rated current (other feeders)	A	2500	
2.23	Rated line charging breaking current	A	400	
2.24	Puncturing time, higher than (GIS housings)	ms	500	
2.25	Protection class of indoor switchgear system (panels, drives/GIS)	-	IP 52/GIS	
2.26	Material of encapsulation (GIS housing)	-		
2.27	Busbar material	-		
2.28	Maximum annual gas loss from any gas compartment	%	<0.5	

2.29	Total SF6 gas weight (initial scope)	kg		
2.30	Total weight of the GIS (initial scope)	kg		
2.31	Maximum weight of a transportation unit	kg		
2.32	Bay width	m		
2.33	Indoor foorprint of initial GIS	m x m		
2.34	Indoor foortprint including extension	m x m		
2.35	Applicable standard for SF6 pressurized housings		EN 50052, 50064, 50068	
2.36	Construction pressure of housings (CB/ others)	MPa		
2.37	Pressure test of casted housings (CB/others)	MPa		
2.38	Pressure test of welded housings	MPa		
2.39	Pressure test for barrier insulators	MPa		
2.40	SF6 gas filling pressure at 20°C (CB/others)	MPa		
2.41	1st alarm pressure value at 20°C (CB/others)	MPa		
2.42	Circuit breaker blocking pressure at 20°C (Close/Open)	MPa		
2.43	Operating pressure of rupture disc (CB/others)	Mpa		
2.44	Dimensions of the GIS (L x H x D)	m		
2.45	Bay to bay centre line distance	mm		
2.46	Applicable standard for new SF6 gas	-	IEC 60376	
2.47	Volume of largest SF6 gas compartment	m^3		
2.48	Size of maximum transportation unit	m		
2.49	Cross-section of bus bar conductor	mm^2		
2.50	Bus bar material	-		
2.51	Single-phase (1)/three-phase (3) enclosure	-		
2.52	Material of encapsulation	-		
2.53	Diameter of bus bar duct housing	mm		
2.54	Volume of largest bus bar compartment	m^3		
2.55	Cross-section of feeder bus-duct conductor	mm^2		
2.56	Volume of largest feeder compartment	m^3		
2.57	Recommended inspection/maintenance intervals	years		
3.00	**400 kV circuit breaker**		integrated	
3.1	Applicable standard		IEC 62271-100	
3.2	Type of quenching medium		SF6	
3.3	Rated voltage	kV	420	
3.4	Rated lightning impulse withstand voltage:			
3.5	• phase-to phase and between phases	kVpeak	1425	
3.6	• across open switching device	kvpeak	1425+240	
3.7	Rated short-duration power-frequency withstand voltage:			
3.8	• phase-to phase and between phases	kVrms	520	
3.9	• across open switching device	kVrms	610	
3.10	Rated switching impulse withstand voltage:	kVrms		
3.11	• phase-to-earth and across open switching device	kVpeak	1050	
3.12	• between phases	kVpeak	1575	
3.13	First pole-to-clear factor		1.5	
3.14	Rated frequency	Hz	50	
3.15	Number of phases		3	
3.16	Rated current (diameter/reactors)	A	3150/2500	

3.17	Rated short-circuit breaking current, 1s	kA	50	
3.18	Rated short-circuit making current	kApeak	125	
3.19	Rated cable charging breaking current	A		
3.20	Maximum capacitive breaking current	A		
3.21	Number of tripping coils		2	
3.22	Number of closing coils		1	
3.23	Type of operation		single and three phase	
3.24	Rated operating sequence		0 • 0.3 s • CO • 3 min • CO	
3.25	Rated opening time	ms	< 30	
3.26	Rated breaking time	ms	< 50	
3.27	Rated closing time	ms	< 100	
3.28	Dead time with tolerances	ms		
3.29	Breaking time with tolerances (max)	ms		
3.30	Arcing time with tolerances	ms		
3.31	Number of operation under rated short circuit current			
3.32	Number of operation at rated circuit current			
3.33	Drive type	-		
3.34	Motor power	W		
3.35	Number of tripping coils		2	
3.36	Number of closing coils		1	
3.37	Closing coil	W		
3.38	Tripping coils (2 x)	W		
3.39	Number of auxiliary contacts (NO/NC)		12/12	
3.40	Mechanical endurance	-	M2	
3.41	Capasitive current switching	-	C2	
3.42	Power supply (Control/Motors)	V DC	220	
3.43	Power supply (Heating/Lighting)	V AC	415	
3.44	Rated gas pressure at 20 degr. C	Mpa		
3.45	Minimum operation gas pressure at 20 degr. C	MPa		
3.46	Gas filling pressure at 20 degr. C	MPa		
3.47	Total SF6 gas weight of circuit breaker	kg		
3.48	Total weight of the circuit breaker	kg		
4.0	**400 kV disconnectors**		integrated	
4.1	Type			
4.2	Manufacturer			
4.3	Place of manufacturing			
4.4	Applicable standard		IEC 62271-102	
4.5	Type of operation		single break	
4.6	Rated voltage	kV	420	
4.7	Rated current diameter / GT and OHL feeders	A	4000/3150	
4.8	Rated current other feeders	A	2500	
4.9	Rated lightning impulse withstand voltage:			
4.10	• phase-to phase and between phases	kVpeak	1425	
4.11	• across isolating distance	kvpeak	1425+240	
4.12	Rated short-duration power-frequency withstand voltage:			
4.13	• phase-to phase and between phases	kVrms	520	
4.14	• across isolating distance	kVrms	610	
4.15	Rated switching impulse withstand voltage:			
4.16	• phase-to-earth and across open switching device	kVpeak	1050	
4.17	• between phases	kVpeak	1575	
4.18	• across isolating distance	kVpeak	900+345	

4.19	Rated frequency	Hz	50	
4.20	Number of phases		3	
4.21	Rated short time withstand current (1s)	kA	50	
4.22	Rated short-circuit peak withstand current	kApeak	125	
4.23	Number of auxiliary contacts (NO/NC/others)			
4.24	Power supply	V DC/AC	220/240	
5.0	**400 kV current transformers**		integrated	
5.1	Manufacturer			
5.2	Place of manufacturing			
5.3	Type			
5.4	Applicable standard		IEC 61869, IEC 61869-2	
5.5	Type of CT			
5.6	Rated voltage	kV	420	
5.7	Rated short time current (1s)	kA	50	
6.1.0	**Diameter CT core data (CTI, CTIII, CTIV, CTVI)**			
6.1.1	Rated primary current	A	1000-2000-4000	
6.1.2	Rated secondary current	A	1/1/1/1	
6.1.3	Core 1 Class and burden		5P20 30 VA	
6.1.4	Core 2 Class and burden		5P20 30 VA	
6.1.5	Core 3 Class and burden		5P20 30 VA	
6.1.6	Core 4 Class and burden		0.2S FS 30 VA	
6.2.0	**Diameter CT core data (CTII, CTV)**			
6.2.1	Rated primary current	A	1000-2000-4000	
6.2.2	Rated secondary currents	A	1/1/1	
6.2.3	Core 1 Class and burden		5P20 30 VA	
6.2.4	Core 2 Class and burden		5P20 30 VA	
6.2.5	Core 3 Class and burden		5P20 30 VA	
6.3.0	**Line reactor CT core data (CTVIII)**			
6.3.1	Rated primary current	A	250-500-1000	
6.3.2	Rated secondary currents	A	1/1/1	
6.3.3	C1 Class and burden		5P20 30 VA	
6.3.4	C2 Class and burden		5P20 30 VA	
6.3.5	C3 Class and burden		5P20 30 VA	
6.4.0	**GT feeder CT core data (CTXIV)**			
6.4.1	Rated primary currents for bypass & bus coupler bay	A	1000-2000-4000	
6.4.2	Rated secondary currents	A	1/1	
6.4.3	Core 1 Tariff metering (Main)		0.2S FS5	
6.4.4	Core 2 Measuring and trafiff metering (Check)		0.2S FS5	
7	**In case TPX cores recommended detailled data sheets provided**		yes / no	
7.1	**400 kV inductive voltage transformer (bus bars)**		integrated	
7.2	Manufacturer			
7.3	Type			
7.4	Applicable standard		IEC 61869, IEC 61869-3	
7.5	Type of VT			
7.6	Rated primary voltage	kV	420	

7.7	Rated secondary voltages (W2 measuring/protection)	kV	0.110/√3	
7.8	Metering winding (W1)	kV	0.110/√3	
7.9	Open delta winding (WE)	kV	0.110/3	
7.10	Rated output (W1/W2/WE)	VA	100/100/100	
7.11	Thermal capacity of the ground fault detection winding	A	25	
7.12	Accuracy class			
7.13	• for tariff metering	-	0.2	
7.14	• for measuring and protection	-	0.5 / 3P	
7.15	• for protection	-	3P	
7.16	Rated voltage factor	-	1.9/8h	
8.0	**400 kV Maintenance earthing switch**		integrated	
8.1	Manufacturer	-		
8.2	Type	-		
8.3	Applicable standard	-	IEC 62271-102 and 203	
8.4	Drive mechanism	-	motor/manual	
8.5	Motor power	W		
8.6	Rated insulation of brought out connection	kV	10	
8.7	Number of auxiliary contacts (NO/NC/others)	-		
9.0	**400 kV High speed earthing switch**		integrated	
9.1	Manufacturer	-		
9.2	Type	-		
9.3	Applicable standard	-	IEC 62271-104 and 203	
9.4	Drive mechanism (spring assested)	-	motor/manual	
9.5	Motor power	W		
9.6	Rated insulation of brought out connection	kV	10	
9.7	Number of auxiliary contacts (NO/NC/others)	-		
10.0	**400 kV Gas insulated line (GIL)**			
10.1	Applicable standard	-	IEC 62271-203	
10.2	Rated voltages as for 400 kV GIS	-	yes	
10.3	Rated current (GT and OHL / others)	A	3150/2500	
10.4	Rated short circuit current (1s)	kA	50	
10.5	Insulation media (SF6 or N2/SF6 mixture)	-		
10.6	Gas pressure at 20 degr. C (filling/rated/alarm)	MPa	__ / __ / __	
10.7	Capacitance	nF/km		
10.8	Outer diameter	mm		
10.9	Maximum lenght of one tube (max. transport unit)	m		
10.1	Weight per phase	kg/m		
11.0	**400 kV SF6 air bushing**			
11.1	Applicable standard	-	IEC 60137	
11.2	Manufacturer	-		
11.3	Type	-		
11.4	Rated switching impulse withstand voltage	kV(peak)	1050	
11.5	Rated lightning impulse withstand voltage	kV(peak)	1425	
11.6	Power frequency withstand voltage	kV(rms)	650	

11.7	Minimum unified specific creepage distance (USCD)	mm/kV	53.7	
11.8	Current conductor material	-		
11.9	Current conductor dimension	mm		
11.10	Service bending load	N		
11.11	Weight	kg		
12	**Density guard**			
12.1	Manufacturer	-		
12.2	Type	-		
12.3	Amount of contact	-		
12.4	Scale	Yes/No	Yes	
13	**400 kV GIS lightning arrester • gapless zinc-oxide type***			
13.1	Manufacturer	-		
13.2	Type	-		
13.3	Applicable standard		IEC 60099-4	
13.4	Type of LA		GIS	
13.5	Rated voltage (Ur)	kV	390	
13.6	Max. continuous operating voltage (Uc)	kV		
13.7	Rated discharge current	kA	20	
13.8	Rated frequency	Hz	50	
13.9	Discharge class		4	
13.10	Temporary overvoltage withstand capability for 1 sec.	kV		
13.11	Temporary overvoltage withstand capability for 10 sec.	kV		
13.12	Max. residual voltage at switching impulse 2kA	kV		
13.13	Max. residual voltage at switching impulse 3kA	kV		
13.14	Max. residual voltage at lightning impulse 10 kA (8/20)	kV		
13.15	Max. residual voltage at lightning impulse 20 kA (8/20)	kV		
13.16	Short circuit strength 0.2 sec.	kA		
13.17	Equipped with counter	Yes/no	yes	
13.18	Equipped with leakage current indicator	Yes/no	yes	
14.0	**400 kV lightning arrester discharge counter**			
14.1	Manufacturer	-		
14.2	Type	-	GIS	
14.3	Counter indication	-	digital	
14.4	Number per 3 arresters	-	3	
14.5	*The provided values for 400kV GIS lightning arrester are indicative only. The Contractor shall carry out Insulation Coordination Study according to which the lightning protection equipment shall be sized (subject to Employer's approval)	Yes/no	Yes	

SECTION – 5

1. ~~VENDOR LIST~~ ANNEXURE-1

SCHEDULE OF DEVIATIONS

Certified that the following **are the only deviations** from the specification (for the equipment and systems being offered)

S.No.	Page No.	Clause No.	Deviation	Reason / Justification

Notes:

1. It is mandatory for the bidder to furnish Price of Deviation in the above Schedule of Deviation.
2. Acceptance or Non-acceptance of deviation is the sole discretion of the owner.
2. Additional sheets of similar size and format may be Annexd as per bidder's requirement.
3. Deviations listed elsewhere will be summarily rejected and shall be ignored.
4. This schedule to be submitted with Technical Bid.

Date :

Signature :

Name:

Designation :

SECTION – 6
CHECK LIST FOR 400KV GIS

Sl.	Particulars	Reply by bidder.	
1	**TECHNICAL QUALIFYING REQUIREMENT**		
1.1	The bidder should comply with the technical qualifying requirement and furnish the relevant documents	Confirmed	Yes/No
1.2	The bid shall be submitted by the Manufacturer of GIS. The bidder's scope includes supply and services like • supervision of installation, • testing and commissioning. Bids submitted by agents will not be considered.	Confirmed	Yes/No
1.3	All the documents shall be submitted in English. Translated pages should be attested by the bidder.	Confirmed	Yes/No
2	**Un-priced Offer** –.		
2.1	Confirm that all items have been quoted. (If any item has not been quoted, the same shall be specifically brought out)	Confirmed	Yes/No
2.2	Any other item /service required for the execution for the complete job is deemed to be included in the offer, whether specifically mentioned in the specification or not. List of items along with their respective quantities required for completeness (Attach list, if required).	List of Additional items required attached	Yes/No
2.3	Foundation for GIS shall be constructed by Civil contractor based on the input (configuration, loads etc) provided by bidder. The supply of all structural material to be embedded like foundation bolts as well as consumables like grouting material shall be in scope of bidder. The erection of structure shall be done by BHEL.	Confirmed	Yes/No
2.4	Confirm that the consumables (list to be enclosed by bidder during contract stage) with shelf life of fewer than two years shall be supplied before erection after clearance from BHEL.	Confirmed	Yes/No
2.5	Detailed list of Final Spares required for long term routine/ planned and breakdown maintenance	Attached	Yes/No
2.6	Detailed list of Commissioning spares for testing & commissioning of GIS till handing over	Attached	Yes/No
2.7	Detailed list of Tools & tackles (in line with clause no. 3.15 of Section-3) & Testing Equipment	Attached	Yes/No
2.8	The Switchgear shall be complete with all necessary terminal boxes, SF6 gas filling, interconnecting power and control cables (between GIS to GIS/GIS to LCC/ LCC to LCC) , grounding connections, (GIS top GIS, GIS to earth mesh on floor) gas monitoring equipment and piping, inspection windows , support structures.	Confirmed	Yes/No
2.9	The scope of supply shall also include all erection and mounting hardware and interconnecting cables within GIS.	Confirmed	Yes/No
2.10	Design philosophy of earthing submitted with the bid (in line with sec Section 2)	Confirmed	Yes/No

2.11	Supply of Earthing Material and Erection of all Earthing connection for GIS to GIS and GIS to Earth Mesh on Floor shall be in bidder's scope. The quantity shall be estimated by the bidder, based on their design philosophy. Supply of Earthing Material and Erection of Earth mesh on floor shall be done by BHEL in supervision of manufacturer as per manufacturer's design. Design philosophy shall be submitted along with the bid in line with section 2 to be followed for earthing. Only supply of 1. Tinned Cu. conductor (240mm2 for outdoor below ground earth mat) 2. 18mm dia Cu. Clad/ Bonded Steel rod 3. 30mmx8mm bare Cu. Flat/ bar - Busbar for inddor earthing as recommended by bidder 4. 35sqmm for Panels shall be in BHEL's scope. Any other earthing material if required shall be in bidder's scope of supply and erection.	Confirmed	Yes/No
2.12	Length of bus duct shall be estimated by the bidder based on drawings provided in the bid. Any change in bay pitch (distance between bays) as per civil requirement for foundation layout during detailed stage shall be incorporated by bidder without any cost and delivery implication to BHEL.	Confirmed	Yes/No
3	**Technical**		
3.1	Details regarding the design features of equipment which are intended to prevent burn through when an internal arc occurs.	Enclosed with bid	Yes/No
3.2	Material of enclosure - Al.	Confirmed	Yes/No
3.3	Material of bus bar - Al./ Cu. alloy	Confirmed	Yes/No
3.4	Requirement of AC and DC auxiliary loads	Enclosed with bid	Yes/No
3.5	Catalogues of GIS	Enclosed with bid	Yes/No
3.6	Catalogues of all Maintenance equipment. Bidder to confirm that offered equipment meets the requirements of specification.	Enclosed with bid	Yes/No
3.7	All structural steel material shall be minimum S235 for rolled steel shapes, angles, tees, plates, etc. having a minimum yield stress of 235 N/mm^2.	Confirmed	Yes/No
4	**Calculations**		
4.1	All calculations including Thermal calculations based on the climatic conditions indicated in Section 3 shall be submitted during detailed engineering stage.	Confirmed	Yes/No
4.2	Devices or techniques deployed for reducing transients to an acceptable level along with offer.	Enclosed with bid	Yes/No
4.3	The design of the equipment shall be such that the agreed permitted movement of foundations and mechanical or thermal effects do not	Confirmed	Yes/No

	impair the assigned performance of the equipment.		
4.4	Insulation co-ordination study shall be conducted and based on the same the number & location of surge arresters shall be decided. The rating, number and location of surge arresters shall be indicated with the bid. Any increase in quantity at the time of detailed engineering shall be on bidder's account.	Confirmed	Yes/No
4.5	Measures to limit external overvoltage (e.g. surge arresters) should be considered and detailed out based on the site conditions of altitude etc.	Enclosed with bid	Yes/No
4.6	The supplier is requested to provide all structural documents e.g. structural analysis, design calculations, drawings and connecting details etc. for Third Party Verification of structural documents prior to submission for approval.	Confirmed	Yes/No
4.7	The supplier to furnish 3D model of complete GIS along with outdoor arrangement during detailed engineering.	Confirmed	Yes/No
5	**Technical Deviations**		
5.1	Confirm that the Complete systems have been offered as per the requirements of Technical Specification and Technical Deviation sheet has been submitted. Deviations mentioned elsewhere in the bid will not be considered.	Confirmed	Yes/No
5.2	Technical Deviation sheet has been submitted.	Confirmed	Yes/No
6	**Bar chart**		
6.1	Bidder will submit detailed bar chart indicating all the milestones from Engineering till manufacturing/ testing, dispatch to site and commissioning based on the drawing & document schedule attached in section1.	Confirmed	Yes/No
7	**Conditions**		
7.1	• *Covered Store will be provided by BHEL for items which require indoor storage. The size of covered store shall be 10 m X 20 m.* • *Manufacturer to mark Indoor storage requirement on the material to be stored in covered storage. The rest of the material shall be stored outdoor.*	confirmed	Yes/No
8	**Site Test**		
8.1	Only special tools shall be in bidder's scope. Bidder to submit list of tools, tackle, slings, spanners, gauges, slings and other lifting devices, drills, instruments and appliances necessary for the complete assembly and erection at site of the GIS, required for installation, gas filling, maintenance, site testing of the GIS which shall be arranged by BHEL. HV Test kit shall be in scope of bidder.	Confirmed	Yes/No
8.2	Bidder to furnish detailed BOQ for non-returnable Tools and Tackles along with unit prices to be handed over to ultimate customer.	Details given with the bid.	Yes/No
8.3	All field tests including tests during installation, pre-commissioning,	Confirmed	Yes/No

	commissioning, field acceptance tests shall be conducted by the bidder, in presence of representative of the Employer. No separate site test will be conducted by BHEL/Customer		
9	**TYPE TESTS REQUIREMENTS**		
9.1	The 420kV GIS should have been type tested (as per relevant IEC). The GIS and equipment/components shall be of same make and type as that used in type test.	Confirmed	Yes/No
9.2	Type test report for 420 kV GIS shall be submitted along with the bid. Differences, if any, in the items offered and those which have been type tested shall be clearly brought out along with explanation for suitability. Type test reports submitted along with the bid shall be subject to review and approval at contract stage)	Confirmed and enclosed with bid	Yes/No
9.3	In case the test reports are not found technically valid during contract stage by BHEL/BIFPCL/Fichtner, the bidder shall repeat these test(s) at no extra cost to the purchaser and no delivery implication. Technical valid - Any error or incompleteness (any/all additional type tests not carried out) or discrepancy in the test reports vis-à-vis offered equipment due to any design / manufacturing changes (including substitution of components) or non-compliance with the requirement stipulated in the Technical Specification.	Confirmed	Yes/No
9.4	Earthquake - In case the bidder has not type tested a similar module for earthquake withstand test, they shall supply supporting design calculations of simulated parameters of the test.	Confirmed	Yes/No
9.5	The type tests conducted earlier should have either been conducted in an accredited independent laboratory (accredited base on ISO / IEC Guide 25 / 17025 or EN 45001 by the national accreditation body of the country where laboratory is located). The short circuit test should have been conducted in a laboratory which should be a member of STL (Short-Circuit Testing Liaison - www.stl-liaison.org). If the laboratory is not a national laboratory and member of STL, relevant papers of accreditation shall be submitted in English. If the laboratory is in-house, the tests should have been witnessed by a client.	Confirmed. Details provided with bid.	Yes/No
9.6	The type test report shall be complete including list the test objects, photographs, oscillographs, test arrangement, drawing of tested objects (GIS, equipment etc), test connections. The type test report shall be in English. If it is in any other language, it should include an English version (Translation shall be attested by the Bidder). The English version should be complete with measured values and conclusion.	Confirmed	Yes/No
9.7	The contractor /bidder shall submit the type test reports for the tests conducted as per the relevant IEC/IS on the equipment similar to those to be supplied under this contract and the tests should have been conducted at a laboratory not earlier than five (5) years prior to 22.09.2015. In case the contractor is not able to submit valid Report of Type Test(s) or in case Type tests Reports are not found to be meeting the		

	specification requirements, or not including all specified tests the contractor shall conduct all such tests under this contract. The costs of such test shall be deemed to be included in the price. The b BIFPCL/BHEL shall have right to witness the Type Tests. Waiver of Type Tests will not be entertained in normal circumstances. All acceptance and routine tests as per the specification and relevant standards shall be carried out. Charges for these shall be deemed to be included in the equipment price.		

TYPE TESTS

Sl. No.	Type test	LAB	Report No. & Date
A	**List of type test reports to be submitted for GIS equipments** a. Tests to verify the insulation level of the equipment and dielectric tests on auxiliary circuits. b. Tests to prove the radio interference voltage (RIV) level (if applicable). c. Tests to prove the temperature rise of any part of the equipment and measurement of the resistance of the main circuit. d. Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short time withstand current. e. Tests to verify the making and breaking capacity of the included switching devices. f. Tests to prove the satisfactory operation of the included switching devices. g. Tests to prove the strength of enclosures. h. Verification of the degree of protection of the enclosure. i. Gas tightness tests j. Electromagnetic compatibility tests (EMC). k. Additional tests on auxiliary and control circuits. l. Tests on partitions. m. Tests to prove the satisfactory operation at limit temperatures. n. Tests to prove performance under thermal cycling and gas tightness tests on insulators. o. Corrosion test on earthing connections (if applicable). p. Tests to assess the effects of arcing due to an internal fault. **q.** Seismic test		