CENTRAL ELECTRICITY BOARD, MAURITIUS

SECTION- V

EMPLOYER'S REQUIREMENTS

Design, Supply, Installation, Testing and Commissioning of a 2 MWac Floating Solar PV Farm at Tamarind Falls Reservoir, Republic of Mauritius

CPB Ref: CPB/15/2024

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Volume 2 of 2

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2. GENERAL INFORMATION

2.1 The Republic of Mauritius – the Project Country

The Republic of Mauritius is a group of islands in the South West of the Indian Ocean, consisting of the main island of Mauritius, Rodrigues and some outer islands. Mauritius has been successively a Dutch, French and British Colony. It became independent on 12th March 1968 and acceded to the status of Republic on 12th March 1992. The official language is English, but French is widely spoken. As at 1 July 2020, the population of Mauritius stood at around 1,266,000.

2.2 Climate

Mauritius has a tropical oceanic climate with moderately high temperatures and humidity throughout the year. Rain occurs in all months, but the wettest periods is from December to April. During these months tropical cyclones occasionally strike the island or pass near enough to give very heavy rainfall and violent damaging winds in the range of 280km/h. Outside the main rainy season the weather is generally sunny and pleasant with slightly lower temperatures and a strong sea breeze.

The temperature ranges between 12ºCto 38ºC and a relative humidity between 80% and 95%. There is no history of seismic activity in the area.

2.3 Energy Resources

Mauritius has no known oil, natural gas or coal reserves, and is therefore heavily dependent on imported energy carriers. The current electricity sector is dominated by fossil fuel energy source accounting for 76% of electricity production, while renewables (hydro, wind, solar and sugar cane bagasse) represented only 24% in 2020.

2.4 Roadmap 2030 for the Electricity Sector

In May 2022, the Government of Mauritius released its Roadmap 2030 for the Electricity Sector which set a target of 60% Renewable Energy in the energy mix by 2030. The key objectives of the roadmap are to:

1. The establishment of the Green Energy Industry as an economic pillar of activity;
2. An accelerated increase in the share of Renewable Energy in the electricity mix to 60% by 2030;
3. Phasing out of the use of coal in electricity generation by 2030; and
4. Increase of 10% energy efficiency by 2030 (with 2019 as base year).

More information on the Roadmap 2030 for the Electricity Sector, is available for viewing on the CEB website at https://ceb.mu/publications.

2.5 The Central Electricity Board

The CEB is a parastatal body operating under the aegis of MEPU. It is governed by the provisions of the CEB Act 1963. Its objects are, among others, to "prepare and carry out development schemes with the general object of promoting, coordinating and improving the generation, transmission, distribution and sale of electricity" in Mauritius and Rodrigues Island. The CEB Act was amended in 2020 inter-alia to provide for the conduct of RE related schemes.

The CEB produces around 45% of the country's total power requirements from its four thermal power stations and ten hydroelectric plants, the remaining 55% are being purchased from Independent Power Producers (IPPs). Currently, the CEB is the sole organisation responsible for the transmission, distribution and supply of electricity to the population.

2.6 Generation

The total energy generated for the review period (01 July 2019 to 30 June 2020) was 2,760 GWh, which represents a decrease of 5.15% over the last corresponding period (01 July 2018 to 30 June 2019). The CEB generated 1,249 GWh and purchases from IPPs were 1,511 GWh. The energy mix for the review period was composed of 23.45% renewables, 36.09% coal, and the remaining 40.46% from fuel oil and kerosene. CEB's share of the total energy generated amounted to 45.24%, as compared to 54.76% from IPPs.

The maximum peak demand reached 507.2 MW and was recorded on 10 December 2019 at 14.00 hours. This represents an increase of 15.5 MW (3.15%) over the maximum demand of the preceding period (491.7 MW). The highest daily energy demand was 10,437,393 kWh and was recorded on 10 December 2019.

For FY 2020-21, the total generated electricity of the island for public consumption reached 2,663 GWh. The system peak demand reached 462.10 MW. The CEB generated 1,133 GWh and purchases from IPPs were 1,530 GWh. The energy mix for the review period was composed of 20.14% renewables, 40.80% coal, and the remaining 39.06% from fuel oil and kerosene. CEB's share of the total energy generated amounted to 42.56% as compared to 57.44% from IPPs.

2.7 Power System

The electricity power system in Mauritius is a small insular grid with no interconnection tie with any neighboring power system. The transmission network operates at 66 kV, consisting of 442 km of lines It interconnects the major load centres and the generating plants. It consists of a transmission line backbone designed to operate at 132 kV when the need arises in the future. Primary distribution is carried out at 22 kV while secondary distribution is performed at 6.6 kV and 400 volts. The system currently consists of about 181 numbers of distribution transformers, with an installed capacity of 18,425 kVA as at June 2021 and 10,185 km of distribution network.

As per the regulatory requirements, CEB has to maintain a voltage of 230±6% at customer's terminal. Similarly, the CEB has to maintain the supply frequency within ±0.75 Hz of the nominal value of 50 Hz so as to ensure the safe and reliable operation of electrical equipment and appliances.

2.8 Demand Profile

The Mauritian daily demand profile is characterized by peaks namely morning peak, day peak and evening peak. The profile also varies with the day of the week and season of the year. Demand is higher in summer as compared to winter. Socio-economic factors are influencing demand patterns and geographical distribution of electric load centres.

3. GENERAL DESCRIPTION OF WORKS

The CEB (hereinafter referred to as the "Employer") intends to set up a Floating Solar PV Farm at Tamarind Falls Reservoir with an AC power output of 2 MW_{AC} measured at 22kV switchgear feeder in the proposed control room (CMCS) building near the Tamarind Falls Reservoir, the Point of Delivery (POD). The solar farm is to be located in the region of Tamarind Falls Reservoir (hereinafter referred to as the **"Project"**). The Project shall comprise of the design, supply, construction, testing, commissioning of a floating solar PV farm to be connected to the proposed 22kV MV Switchgear. The CEB has appointed NTPC Consultancy Firm (India) which will act as the Engineer (hereinafter referred to as the **"Engineer"**) during the implementation and project management phase.

The Employer shall make available the site to the successful bidder (hereinafter referred to as the **"Contractor"**) and be responsible to secure the EIA license and all other related permits including the Building and Land Use Permit. The Contractor shall provide all required services and materials for the successful completion **of** the Project which include amongst others, procurement of solar PV panels, floaters, inverters, transformers and other equipment, site preparation works, foundations, installation of all equipment, bulk material and commodities supply and site finishing work. The Contractor shall also include project management, construction management, start-up and commissioning, as well as testing of the Works.

The Floating Solar PV Farm will be connected to the 22 kV switchgear at the Tamarind Falls Reservoir. The CEB shall be responsible to interconnect the Floating PV Plant to its 22 kV network. This Floating Solar PV Farm, once operational, is expected to generate more than 3.7 GWh annually and shall contribute in meeting the Government objective, as set out in the Roadmap 2030 for the Electricity Sector, to attain the target of a target of 60% Renewable Energy in the energy mix by 2030.

3.1 Site Location

The CEB owns Tamarind Falls Reservoir and the land proposed for control room (CMCS) building. The site for the floating solar PV farm is located within that area as shown in guide drawings. A-001 Vicinity Map The area of land earmarked for the CMCS building of this project is demarcated by the orange color contour lines, and the area of the reservoir earmarked for the floating solar plant is demarcated by the yellow colour contour lines in the drawing.

District	Plaine Wilhems
Nearest Highway	M2 (11.2 km)
Nearest Port	Port Louis (27.5 km)
Nearest Commercial Airport	Sir Seewoosagur Ramgoolam International Airport (MRU) (32.6 km)
Water Body Available (in Acres)	554,220 m2 of water body. Refer tender drawing no. A-001 Vicinity Map for more

	details.

3.2 Climate – Meteorological Data

Mauritius has a tropical oceanic climate with moderately high temperatures and humidity throughout the year. Rain occurs in all months but the wettest period is from December to April. During these months tropical cyclones occasionally strike the island or pass near enough to give very heavy rainfall and violent damaging winds. Outside the main rainy season, the weather is generally sunny and pleasant with slightly lower temperatures and a strong sea breeze.

The weather pattern, in particular the average daily solar irradiation level, at Tamarind Fall Reservoir is shown on a monthly basis in Table 1.1 below:

Table 3.1: Climatic Data

Region: Centre
Station: Vacoas

MONTH	TEMPERATURE				HUMIDITY	WIND		SUNSHINE		RAINFALL LTM	NO OF DAYS WITH	NO OF DAYS WITH
	Mean Max 1971-2000	Highest Max Recorded	Mean Min 1971-2000	Lowest Min Recorded	%	Mean Wind Speed Km/h	Highest Gust Km/h	Daily Hrs per day	Mean Monthly	1971-2000)	RAINFALL > 1 MM	RAINFALL > 5 MM
January	27.6	31.6	20.4	14.6	83	9.5	164	7.3	225.9	291.6	16	9
February	27.5	31.6	20.7	11.6	85	9.5	201	6.9	193.6	400.2	18	12
March	27.4	31.5	20.4	14.3	84	9.5	130	7.3	225.3	246.6	17	9
April	26.3	30.0	19.6	12.5	85	9.5	100	6.9	205.9	209.9	17	9
May	24.8	29.6	17.7	11.8	83	9.5	77	7.4	228.5	120.3	15	6
June	22.9	27.0	16.0	8.2	82	9.5	86	7.2	215.6	96.1	14	6
July	21.8	26.5	15.3	7.7	83	11.4	87	7.3	225.5	114.0	17	7
August	21.8	25.7	15.1	8.0	82	11.4	82	7.2	222.4	119.4	18	7
September	22.8	27.5	15.4	9.5	83	11.4	80	7.3	218.8	72.7	13	4
October	24.1	28.5	16.5	10.4	83	11.4	71	7.6	236.6	62.9	11	4
November	25.8	30.0	17.8	9.4	83	11.4	108	7.9	236.3	64.7	10	4
December	27.1	31.4	19.4	14.0	82	9.5	175	7.2	223.4	197.1	13	6

Note: LTM = long term mean
Temperature in measured in degrees celsius
Rainfall is measured in millimetres

3.3 Extent of Work

The Contract covers the design, supply, construction, manufacture, testing, insurance, packaging for export, shipping, transport, delivery to site, unloading at site, equipment erection, commissioning and putting in normal operation, performance testing on completion, training and instruction to Employer's personnel and making good of any defects and warrantying the whole installation up to the end of the defect liability period.

3.4 Contractor Responsibility

While every effort will be made by Employer to assist the Contractor in obtaining full and accurate information, the Contractor shall be fully and unrestrictedly responsible for the design of the Works. The Contractor shall carry out a detailed evaluation of the site and of local conditions and shall prepare detailed designs conforming to the requirements of this tender and of any amendments thereto.

The Employer shall allow the Contractor to have access to the available drawings and documentation relating to the site. The Contractor shall check and verify any information taken from these drawings and documents for use in the design of the Works and shall be responsible for its accuracy.

The Contractor shall not be relieved of his obligations under the Contract by any inaccuracy or deficiency in these drawings or documentation, or by the unavailability of any particular drawing or document.

3.5 Project Site Layout

The Contractor shall prepare a detailed site layout and shall include the following:

1) Area map indicating development location and orientations, including local coordinates and sites boundaries.
2) Local view (Google map image) indicating Floating Solar PV farm installations and orientations.
3) Topography, major roads, existing transmission and distribution lines, substation adjacent structures, existing paved roads, existing gravel/dirt roads, as well as other feature such as lakes, rivers and creeks among others.
4) The Contractor shall also submit detailed layouts of the proposed Floating Solar PV farm including the elements mentioned hereunder
    - i) Floating Solar PV Array
    - ii) Floating Platform/Pontoon
    - iii) Anchoring/Mooring details
    - iv) Cable ways, ducts, trenches and draw pits including support details
    - v) Switchgear and Electrical rooms
    - vi) SCADA System and associated Communication equipment
    - vii) Control Room (CMCS) building comprising of electrical switchgear, Inverter and transformer rooms, battery, SCADA, toilet, and stores among others.
    - viii) Lightning protection and earthing system

ix) Electrical metering points

x) Electrical Schematics

xi) Construction staging and laydown area(s) and footprints

xii) Site perimeter dimensions

xiii) Security system and associated equipment (CCTV & Fire Alarm)

xiv) Appropriate Drainage System for CMCS building.

5) Any other drawings as may be requested by the Employer and/or Engineer;

The following drawing plans are required to be submitted:

1). Detail structural drawings for CMCS building .

2). Detailed view of proposed arrays

3). Detailed top view of the proposed Solar PV Floating platform/pontoon (including module dimensions, pathways and row-to-row spacing).

4). Detailed anchoring and mooring system design drawings.

5). Cross-section of electrical ducts for wiring from Floating PV Arrays to CMCS Building, inclusive of road crossing.

6). CMCS building Floor Plan and detailed view of their bases

7). Refurbishment of the existing fencing as required.

8). Location and Site Plan

9). Any other drawings as may be requested by the Employer and/or Engineer.

The above drawings will have to be submitted to the Employer within 4 weeks from the signature of the Letter of Acceptance for application for Building and Land Use Permit (BLUP).

3.6 Use of Site

The Contractor may use the Site only for purposes connected with the Contract

3.7 Security of Site

The Contractor shall ensure that access by unauthorized persons to his working area is prevented at all time during the contract period,

The Contractor shall provide protection to safeguard the materials, stores and any installations on the sites. The Employer will not accept responsibility for any delay, loss or damage to materials or equipment, which may occur during the execution of the contract. The use of unsupervised guard dogs shall not be permitted.

3.8 Privately and Publicly Owned Services

The Contractor shall make his own enquiries, where required, of the Service Authorities and satisfy himself as to the exact position of their apparatus and the depth, size and gradient thereof. The Employer will provide the necessary assistance.

Where any privately owned service for water, electricity, drainage, etc. passing through the Site is affected by the Works, the Contractor shall locate it and with the agreement of the owner provide a satisfactory alternative service before cutting the existing service.

The Contractor shall be responsible for making arrangements with the Service Authorities concerned, for the phasing into his Program of Works of all operations which need to be executed by them or their contractors, concurrently with the Works.

The Contractor shall be responsible for coordinating and integrating all Service Authorities' work so that each may proceed in such a manner as to ensure proper performance and to avoid conflict between them. He shall arrange for the Service Authorities concerned to attend co-ordination meetings.

The Contractor shall take any and all measures reasonably required by any Service Authority, for the support and full protection of its mains, pipes, cables and other apparatus during the progress of the Works, and shall construct and provide, to the satisfaction of the Service Authority concerned, all works necessary for the prevention of damage or interruption of services. If, in the execution of the Works, the Contractor causes either directly or indirectly, any damage to any apparatus or any interruption of any service, the Contractor shall bear and pay the cost incurred by the Service Authority for any loss sustained as a result of such damage or interruption.

The Contractor shall, at all times during the progress of the Works, afford facilities to properly accredited agents of any Service Authority for access to any of their apparatus situated in or under the Site, as may be necessary for inspecting, reporting, maintaining, removing, renewing or altering such apparatus in connection with the construction of the Works or for any other purpose whatsoever.

Where any temporary stoppage, diversion, or reinstatement of any existing services is required by the Contractor, he shall make his own arrangements with the owners of the service and with all other persons affected by such work. He shall rectify any damage caused and shall relieve the Service Authority of all claims in respect of any loss or interruption involved.

When locating existing services on Site, the Contractor shall search, by safe methods which will not endanger the service or others, to determine its precise position. Trial holes shall be dug where necessary and in accordance with the appropriate Service Authority's requirements to locate services before works are commenced in each area.

All work carried out by the Contractor or adjacent to any apparatus owned by any Service Authority shall comply with the Service Authorities' requirements.

If any underground service is encountered unexpectedly, excavation shall cease, and the Employer shall be notified immediately. Emergency measures, as necessary, shall be put in hand without delay and without prejudice to the indemnity of the Service Authority.

Disused services found within the Works shall be notified to the Employer. The Contractor shall obtain confirmation from the owner of such service whether it is abandoned, or whether the owner wishes to recover the service. Upon notification that any service is abandoned, it shall become the property of the Contractor, who shall notify the Employer immediately.

3.9 Working Hours

The Contractor shall comply with all of the provisions of the Mauritian Workers Rights Act. No other restriction will be placed by the Employer on the hours worked by the Contractor. It will be the responsibility of the Contractor to ensure that any work carried out during unsocial hours does not cause a nuisance.

In giving his consent the Employer shall impose such conditions as he considers reasonable to reduce the nuisance and notwithstanding the issuing of any such consent, the Contractor shall comply at all times with the noise limitations and the control of dust limitations laid down in the respective sections.

The Contractor is to bear all costs in respect of overtime shift and night-work allowances.

In addition, for working at the CEB’s Henrietta Substation for integration of the system, the Contractor shall submit a formal Request to Work, at least 1 week in advance. The working hours at the Substation are from 09:00 hrs to 16:00 hrs, for business days, unless otherwise approved by the CEB. Working during Saturdays, Sundays and public holidays will be subjected to the approval of the CEB.

3.10 Meetings

The Contractor shall attend progress meetings as may be required by the Employer and/or Engineer during the contract period. A contract meeting shall be held every two weeks during the contract period commencing with a kick-off meeting not more than four weeks after the date of the Letter of Acceptance. Meetings will normally be held at the Employer’s Office and each party will carry their own cost for travel, board and lodging when participating in meetings.

During the course of the site erection works, weekly site meetings shall be held between the Employer, Engineer and Contractor.

Safety meetings shall be held as part of the weekly site meetings.

3.11 Ordering and Records of Goods and Materials

Whenever required by the Employer/Engineer, the Contractor shall supply two copies of orders for goods and materials at the time when such orders are placed complete with expected time of arrival on site. This requirement shall apply both to orders placed directly by the Contractor and to orders placed by a supplier or sub-contractor for the execution of a subcontract.

Commercial information such as prices may be excluded.

The Contractor shall maintain a detailed record of all materials received on the Site or in his stores or storage and working areas in the vicinity of the Site and shall make such records available to the Employer at such times as the former may reasonably require.

3.12 Subcontracting

Where the Contractor proposes to subcontract any part of the Works, the Employer will require the Contractor to demonstrate that such subcontracting will not interfere with the Contractor's control of the Works.

As soon as practicable after entering into the Contract, the Contractor shall enter into the subcontracts which he considers necessary for the satisfactory and timely completion of the Works.

All sub-orders, and subcontractors and vendors' drawings, shall contain the following reference:

Central Electricity Board, Mauritius

2 MW AC Floating Solar PV Farm

Tamarind Falls Reservoir Site

All sub-orders shall be in the English language.

3.13 Datum

All levels used for the construction of the Works shall be referred to a benchmark agreed with the Engineer/ Employer.

3.14 Setting Out

The Contractor shall agree with the Engineer/ Employer and shall provide such benchmarks and setting out points, in a form approved by the Engineer/ Employer and as are necessary for the correct setting out and control of levels for the Works

The Contractor shall thereafter in accordance with set out the Works. The Contractor shall, as the work proceeds, supply the Engineer/ Employer with records in an approved form relating to all reference pegs and Works benchmarks and shall regularly keep such records up to date by formal notice to the Engineer/ Employer.

Where setting out markers are likely to be disturbed during the progress of the works the Contractor shall transfer such markers to an adjacent point which will not be disturbed. The Engineer/ Employer shall be immediately informed of such changes, including subsequent reestablishment of these markers, and given full details of the relative position of the points. The setting out of the Site boundaries shall be agreed by the Engineer/ Employer before Site clearance commences and the Contractor shall set out the line and level of any sections of the Works as required by the Service Authorities to enable them to carry out temporary or permanent alterations.

The Contractor shall set out portions of the work at such times as may be necessary to enable Service Authorities to carry out temporary or permanent alterations to their mains, services and apparatus.

The Engineer/ Employer will be required to check the Contractor's setting out of all lines, levels and dimensions described for the execution of the Permanent Works and in relation to all measurements made in relation thereto. For this purpose, the Contractor shall make available for the use of the Engineer/ Employer, at such times and places as the Engineer/ Employer may direct, such staffs, ranging rods, pegs, measuring tapes and chainmen as the Engineer/ Employer may reasonably require.

3.15 Site Access and Diversion Roads

The Contractor shall maintain all roads and associated structures to at least the standard at the beginning of the Contract, and for this purpose, the Contractor shall take photographs at a maximum of 30 meters intervals along the road in the presence of the Employer prior to the work commencing. Two copies of these photographs, clearly identifying the location of each photograph and showing the whole of the road surface, shall be lodged with the Employer and will be used to demonstrate any subsequent deterioration of the road surface.

The Contractor shall construct all temporary roads and tracks to his working area and maintain them to the satisfaction of the Employer.

3.16 Precautions to Prevent Nuisance and Noise

The Contractor shall use all reasonable means to prevent or reduce noise and prevent nuisance arising as a result of the Works. This obligation shall extend to all operations necessary to transport all equipment and materials to and from the Site and to dispose of all waste material.

The Contractor shall comply with the general recommendations set out in BS 5228 Code of Practice for Noise Control on Construction and Demolition sites together with the requirements described below.

Without prejudice to the generality of the Contractor's obligations under the preceding paragraph, the Contractor shall comply in particular with the following requirements:

All vehicles and mechanical plant used for the purpose of the Works and the Transport of materials shall be fitted with effective exhaust silencers and shall be maintained in good and efficient working order. Road vehicles shall be maintained to the standards required by the Road Vehicles (Construction and Use) Regulations 1986 and all subsequent amendments thereto.

Where "out of hours" working is permitted, noise levels measured 1 meter from the facade of any residential property shall not exceed the existing background noise level.

3.17 Transport to Site and Existing Roads and Bridges

The Contractor shall be responsible for the importation, offloading and transport to the Site of all plant, material and equipment needed for the purposes of the execution of the Contract including all costs, expenses and other charges.

The Contractor shall be responsible for providing all necessary means of access to the Site and all temporary roads within the Site.

The Contractor shall also ascertain that the vehicles, wagons and loads that he intends to use will not damage, in any way, any roads, bridges, footpaths, etc. The Contractor shall indemnify the Employer in respect of the transport and deposition of the excavated material from the site and any required filling imported to the site.

3.18 Parking of Motor Vehicles

Motor vehicles used by the Contractor or his employees shall be parked in such a way that it does not obstruct traffic flow. The Contractor may make arrangements with adjoining landowners for the parking of these vehicles, but any such arrangement shall be at the Contractor's own risk and to the Contractor's own cost.

3.19 Temporary Dwellings

The Contractor shall not provide or permit any caravans or other temporary dwelling accommodation on the Site.

Temporary dwelling (containerized type) may be allowed for security guards on site. Unsupervised guard dogs are not permitted within the site during the implementation phase.

3.20 Temporary Site Services

3.20.1 Site Electricity Supply

The Contractor shall make all arrangements for any temporary electricity supply that he may require for the execution of the Works; he shall issue any notices and pay all fees, dues, charges and other costs incurred thereby.

The Contractor shall be responsible for providing and maintaining the whole of the installation on the load side of the points of supply, and in relation thereto shall take all reasonable precautions to ensure the safety of every person on the Site.

The Employer/Engineer may require the disconnection or alteration of any parts which he considers may be dangerous. In such cases the Contractor shall pay the cost of making the apparatus safe.

The design, location, utilization and maintenance of the installation must be in accordance with the latest edition of Mauritian Standard MS 63; "Code of Practice for Electrical Installation in Buildings" and must receive approval of the Engineer or his authorized representative. All local Electricity Regulations and Ordinances shall be strictly observed.

All portable lights must be of low voltage and for this purpose the Contractor is to provide his own transformers with centre point earthing.

The Contractor shall undertake not to remove any of the installations until such time as instructed to do so by the Engineer/ Employer.

3.20.2 Water Supply

The Contractor shall make his own arrangements for a suitable and adequate supply of water to cover all requirements in connection with the execution of the Works and he shall issue all notices and pay all fees, dues, charges and other costs incurred thereby.

The Contractor will be required to make his own arrangements for supply of water for construction and also for drinking purposes.

3.21 Notices of Operations

No important operation shall be commenced without the consent in writing to the Employer, and without full and complete notice also in writing being given to the CEB sufficiently in advance of the time of the operation so as to enable him to make such arrangements as he may deem necessary for its inspection.

3.22 Stability of Unfinished Work

The Contractor shall ensure the stability of the Works at all times, he shall pay particular attention in regard to the stability of excavated faces and the sides of stockpiles.

The Contractor shall provide all temporary supports as necessary. Any supports which have been used in contaminated ground shall be cleaned before leaving any contaminated area.

3.23 Proposals for Methods of Construction

Where the Contract requires or the Engineer/ Employer instructs the Contractor to submit information pertaining to methods of construction, the Contractor shall submit such information in good time so that the Engineer/ Employer shall have at least ten full working days from receipt of this information to consider the Contractor's proposals before the commencement of work in question, or in the event that in the opinion of the Engineer/ Employer the Contractor's proposals fail to meet the requirements of the Drawings or Specifications, or will be detrimental to the Works, the Engineer/ Employer shall have at least five full days to consider the Contractor's revised proposals.

No Work shall start without an agreed Methods of Construction.

3.24 Disposal of Spoil, Rubbish and Surplus Materials

No spoil, rubbish or surplus materials are to be dumped anywhere other than at a public or private disposal site controlled or appropriately licensed by a Local Authority.

The Contractor is to comply with all legislation governing the controlled disposal of contaminated material and of rubbish, and he shall state in writing to the Employer the location, for each contaminating substance, of the proposed disposal site areas and the means of transport to be adopted.

Where any excavated spoil, rubbish or surplus material has been deposited elsewhere than at an appropriately licensed disposal site, the Contractor shall indemnify the Employer against all proceedings and costs associated with the unauthorized deposition of such materials and shall bear all costs associated with clearing away such deposits and placing them in an acceptable site.

The Contractor may only temporarily stockpile materials on the site with the sole permission of the Employer. He shall do so only at locations agreed by the Employer. The Contractor shall ascertain that the local authorities have no objection to his proposals for any temporary stockpiling.

Stockpiles shall be formed with smooth stable side slopes.

Scrap metal is to be collected and removed from the site at regular intervals.

3.25 Existing Roads to Be Kept Clean and Maintained

The Contractor shall maintain all routes which he is using clean and free from any material arising from the Works to the satisfaction of the Employer. In particular, when vehicles involved in earth-moving operations are using or crossing any private or public roadway the Contractor shall have road-cleaning plant in attendance.

3.26 Dust Control

The Contractor shall take all reasonable measures, which shall include the provision and use of adequate water spraying equipment, to minimize dust nuisance. Particular attention shall be paid to the danger of dust from any hazardous material and the Contractor shall make adequate provision for damping down all working areas, haul routes, loads and stockpiles containing materials which may be harmful to the environment or health.

Furthermore, any contaminated material stockpile on site shall be sufficiently covered or otherwise contained to prevent release of any airborne material which may be harmful to the environment or health.

3.27 Work on Live Equipment

For working on existing live equipment, the CEB's Safety Rules shall be complied with. The Contractor shall comply with the CEB Permit-to-Work System and Safety Clearance Certificate, where required by the Engineer and the Employer.

3.28 Name Board

The Contractor shall erect at the Site, at the commencement of the Works, a nameboard approved by the Employer showing the project title and the name of the Employer and Engineer. The nameboard may also include the name of the Contractor and of his principal subcontractors. The position, layout and size (which shall not be less than 3 m x 3 m) of the nameboard shall be agreed with Employer. No other advertisement will be permitted on the Site.

3.29 Good Housekeeping

Throughout the period of construction of the Works the Contractor shall carry out his operations in a clean, tidy and safe manner by arranging all materials and arisings and carrying out all operations in an orderly manner. All rubbish, waste materials, debris and the like shall be systematically cleared off the working area as it accumulates and all arising shall be securely loaded into hoppers, containers or lorries, as the case may be, as soon as it accumulates or is excavated and, if not removed directly off the Site shall be deposited at general collection points or in discrete stockpiles as agreed with the Employer pending removal from Site.

3.30 Safety Precautions

3.30.1. General

The Contractor and all persons employed by him on the Site in or about the execution of the Works shall conform in all respects with the provisions of all Acts, Orders and Regulations made by competent authorities in Mauritius that shall be applicable to the Works or any temporary Works and binding upon the Contractor or persons employed as aforesaid and in particular, but without prejudice to the generality of the foregoing, such matters as concern the safety, health or welfare of persons working on the Site.

The Employer may require the immediate removal from the Site of any person who in the opinion of the Engineer/ Employer fails to observe properly the provisions of this Section and such person shall not again be employed upon the Works without the permission of the Engineer/ Employer.

The provisions of this Section shall apply to and be binding upon any subcontractor employed by the Contractor for any part of the Works on the Site and the persons employed by such subcontractor, and the Contractor shall ensure that proper and adequate provisions to this end are included in the subcontract.

The Contractor shall provide to his entire workforce, and to all other persons authorized to be on the Site, safety helmets complying with BS EN 397 and the Contractor shall ensure that all operations are carried out in accordance with the applicable safety recommendations of BS 8004 and BS 8008. At all times during site erection approved hard hats and safety boots must be worn by the Contractor's personnel.

During the construction of the Works, the Site shall be kept clean and tidy to the satisfaction of the Employer. Any waste material shall be removed from the Site at the Contractor's expense as directed by the Employer. Any damage done by the Contractor or his Subcontractors shall be made good at the Contractor's expense.

The Contractor shall have the complete responsibility for the conditions of the Work Site including the safety of all persons employed by him or his Sub-Contractor and all the properties under his custody during the performance of the work. This requirement shall apply continuously till the completion of the Contract and shall not be limited to normal working hours.

All required safety precautions shall be observed to ensure that any erection or mobile cranes used during construction shall in no way interfere with the existing 66 kV, 22kV and LV overhead lines and equipment.

3.30.2. Risk Control Measures

Subsequent to an initial safety audit, remedial measures shall be provided by the Contractor in the design of the floating solar PV farm in order to minimize the risk during the initial construction, transportation and the subsequent operation and maintenance phase of the project.

The Contractor shall submit the risk assessment report to CEB for approval prior to start of work.

3.30.3. Site Safety Officer

A Site Safety Officer shall be employed by the Contractor and will be responsible for all aspects of safety and implementation of environmental impact requirements, including instruction, warning, signs, documentation, and first aid and ensuring that good housekeeping is maintained at site.

The Site Safety Officer shall remain responsible for ensuring that operations at the Site are at all times carried out in a safe manner and in accordance with the requirements of all legislation appropriate to the work in hand.

The Site Safety Officer shall be a competent person experienced in safety and welfare matters, and shall be fluent in the English language.

3.30.4. Fire Prevention/Protection

As part of its Safety Plan, the Contractor shall include a fire prevention and response plan. The Contractor shall perform all work in a fire-safe manner. The Contractor shall supply and maintain on site and on each piece of equipment, adequate firefighting equipment capable of extinguishing incident fires.

The Contractor shall comply with all local fire prevention regulations and secure necessary fire clearance certificate.

3.30.5 Heavy Lifting

The Contractor shall submit a project lift plan to the client addressing the lifting risks and mitigation measures. The contractor shall ensure the adequate stability of any workspace on the floating structure for the workforce.

The Contractor shall ensure that the floating workspace must be safe to carry heavy equipment and provide enough buoyancy to account for additional personnel and equipment.

3.30.6. Working in Water

The Contractor shall always ensure that no worker shall work alone on the FSPV platform. Sufficient availability of life vests shall be ensured by the Contractor and shall always be worn by all workers/ personnel working over the water surface.

The Contractor shall always ensure the availability of trained personnel, at least licensed for first aid, mouth-to-mouth and cardiopulmonary resuscitation (CPR) at the project site during the working hours. Contractor shall ensure availability of trained Divers at site till completion of facilities.

The Contractor shall apply EC Directive 90/269/EEC (EU-OSHA) on manual handling of loads where there will be a risk of injury to workers.

3.30.7 Walkways

The Contractor shall provide a clear indication with physical markers (eg. stickers) to distinguish walkways from fragile elements, in order to prevent workers from setting foot on fragile elements of the system.

The walkways shall have adequate anti-slip surfaces. The Contractor shall avoid cavities within or in close proximity of the walkways in order to prevent stumbling or accidental falls. The Contractor shall provide ample space for (dis)embarkment on the FSPV array.

3.30.8 Boat

Boats shall be used during the installation, maintenance or access to the FSPV array. The Contractor shall ensure the availability of sufficient number(s) of boat appropriate for their intended use and for carrying weight. Boats must adhere to local safety standards. Diesel/gasoline powered motorboats are allowed on the reservoir. These motorboats shall be used mainly during construction phase. However, during operational phase, they shall be kept for emergency interventions and maintenance purposes only.

The Contractor shall include categorisation of boats into the worker safety plan. Aspects regarding the lifting (over an angle) of equipment on/from boats shall be also included in the lift plan.

3.30.9 External Safety

A risk assessment for the FSPV project shall include external safety risks derived from:

- (the combination of) electricity and water
- possibilities to fence off the project
- recreational visitors
- the fencing-off of the project.

The Contractor shall comply to national or international standard, for health and safety signs and lights. Appropriate signage shall be in place where hazards cannot be avoided or reduced. Project plans should, at least, contain provisions to inform visitors and passer-by of risk of injury, emergency escape, first-aid, fire hazards and hazardous moving parts.

It is recommended to install signs to manage external safety both on the FSPV system, as well as on the land near the FSPV system and in proximity of any onshore electrical components.

3.31 Availability of Local Resources

The Contractor shall particularly note that there may be a high level of activity in the local construction industry and he shall take every precaution to ensure adequate availability of labor and materials. No claims will be entertained arising from any oversight by the Contractor in this regard.

3.32 Construction Facilities

Prior to moving onto the site, the Contractor will submit the location and layout of intended staging areas, parking areas, storage areas, security fence, office areas, workshops and other temporary facilities.

3.33 Supervision of Works on Site

The carrying out of work included in the contract is to be supervised by sufficient number of qualified representatives of the Contractor and full facilities and assistance are to be afforded by the Contractor for the Engineer/ Employer to check the Works.

The Contractor's Representative on the Site or his nominated deputy is to be given full responsibility to enter into negotiations regarding points arising out of erection, so that the work may be expedited with as few delays as possible.

3.34 Gender Equality

The Contractor shall incorporate a gender perspective and provide an enabling environment where women and men have equal opportunity to participate in, and benefit from the development of the project.

The Contractor shall emphasize on project development while ensuring gender sensitivity and work culture awareness among the working personnel.

During the project erection and commissioning phase, the Contractor shall enable an environment that shall be intolerant of and enforce disciplinary measures for illegal activities and shall enforce disciplinary measures for gender-based violence, inhumane treatment, sexual exploitation, rape, sexual assault, sexual activity with children, and sexual harassment committed at the project site.

3.35 Items to Be Handed Over to Employer

The Contractor shall obtain a signed receipt by an authorized representative of the Employer for all documents, goods, materials, maintenance equipment, spare parts, instruments, etc., required by this tender to be handed over to the Employer other than the permanent works erected on Site.

3.36 Training

Training on Floating solar PV plant design, control and monitoring, inverter programming and troubleshooting, PV SCADA system, floating structures, anchoring and mooring system, earthing system, surge protection, lightning protection, LV and MV design, testing and commissioning, safety measures at the manufacturer's work place shall be provided to two (2) Employer's technical staffs. The training shall be for at least one week. This shall include classroom lectures and hands-on training. The Employer shall bear the costs associated with the travel from Mauritius and for accommodation and subsistence costs.

The Contractor shall also provide training at the Site on all aspects of operation and maintenance of the Floating Solar PV farm to the technical staffs. This shall include presentations, manuals and on-the-job training.

Classroom training shall cover at least the following:

(i) PV power plant components and systems basics
(ii) Site survey and solar potential evaluation
(iii) PV power plant design and analysis software - PVsyst or equivalent
(iv) PV technology selection: What an I-V curve is and how it is relevant for PV modules
(v) String Sizing
(vi) Inverter technology selection, Matching PV modules to inverters
(vii) What MPPT is and why it is important for system performance
(viii) PV power plant system design
(ix) Anchoring and mooring system design
(x) Mounting Structures/Floaters Structure
(xi) Civil/Structural & Engineering Tips
(xii) DC and AC Cable Sizing
(xiii) DC Voltage Drops and Energy Loss, and Combiner Box Layout and Design
(xiv) AC Voltage Drops and Energy Loss, Layout and Design
(xv) Earthing System Design
(xvi) Lightning and Surge Protection design
(xvii) Switchgear Design
(xviii) PV Plant Protection System design, coordination, installation, testing and commissioning
(xix) PV array structure design, construction and installation

(xx) PV power plant implementation due diligence
(xxi) PV module field performance, plant monitoring (SCADA) and evaluation
(xxii) Safety and quality standards,
(xxiii) O&M and assessment of solar PV plants
(xxiv) 22kV and LV Switchgear operation, maintenance and troubleshooting
(xxv) Transformers, Central Inverters operation, maintenance and troubleshooting

The classroom training, including practical training, shall be of at least 4 weeks at Employer's premises. The training schedule and contents shall be approved by the Engineer/ Employer prior to its start.

On-site training shall include, amongst others:

A. Operation of PV Plant:

(i) Routine operation on SCADA system, programming and maintenance

(ii) Network switches and SCADA programming features

(iii) Rebooting of SCADA

(iv) Control philosophy

(v) Switching and Isolating Operations at Medium Voltage and Low Voltage

(vi) Start Up, Normal and Emergency Shut Down of the Plant

(vii) Fault recognition, tracing and diagnosis of system

(viii) Safety and quality standards to be respected during operation of the PV plant

(ix) Software installation and configuration of SCADA workstation and servers

(x) As required, according to tools and equipment supplied (including, but not limited to, infra-red detector, UAV, automated cleaning solution, PV tester)

B. Preventative Maintenance (PM):

(i) PV Panel cleaning

(ii) Infrared scans of modules, combiner boxes, switchgear and substation

(iii) Maintenance of PV Floaters and Pontoon

(iv) Maintenance of Mooring System and Anchoring points

(v) Maintenance of cable connections (junction box, combiner box etc.)

(vi) Maintenance of inverters

(vii) Upkeep of data acquisition and monitoring systems (e.g., electronics, sensors)

(viii) Maintenance of LV and MV switchgears

(ix) Maintenance of transformers

(x) Calibration, maintenance and cleaning of on-site monitoring stations and sensors

(xi) Upkeep of balance of system including CCTV, firefighting system etc.

(xii) Solar Central Inverters

(xiii) Upgrading of Central Inverter's firmware and SCADA's software

C. Corrective Maintenance (CM):

(i) Lockout-Tagout Procedures

(ii) Replacement of PV panels and Inverters

(iii) Repair of plug-in connections for panels

(iv) Appropriate repair in case of corrosion of mounting structures, module frames etc.

(v) Troubleshooting and repair of inverters

(vi) Replacement of burn-out fuses, fuse holders, circuit breakers, disconnectors, cables etc.

(vii) Troubleshooting and repair of LV, MV switchgears, and step-up transformer(s)

(viii) Troubleshooting of MV and LV switchgears protection system

(ix) Troubleshooting of data acquisition system

(x) Troubleshooting and replacement of instrument in the monitoring stations and sensors

(xi) Safety procedures to be followed during operation and maintenance

The Contractor shall make available to the Employer a Manual elaborating all the safety procedures for above mentioned interventions.

The Contractor shall provide the trainees with training manuals. The training manuals shall be detailed shall be submitted to the Engineer/ Employer for approval prior to commencement of training.

3.37 Design Review Meeting

A Design Review meeting shall be held at the Employer premises for at least one week at a suitable time during the design work in order to expedite agreement and approval of the design.

The Contractor shall bear the costs associated with the travel to Mauritius and for accommodation and subsistence costs. The Contractor shall provide detailed design Review Meeting Schedule.

3.38 Spare Parts

3.37.1. General Requirements

Each item shall be labelled with the makers part number and the Employer 's stock commodity code which will be notified when ordered, be separately packed against damage and sealed to prevent deterioration from corrosion. The protection shall be sufficient for a minimum of 5 to 10 years storage in a dry weatherproof building.

All spare parts shall be delivered to the Site prior to the completion of the Works and the Bidder shall state in his Tender the latest date that spares shall be ordered to meet this requirement. If requested by the Employer, the spare parts shall be placed in bins, racks, drawers, shelves, cabinets, etc., to be provided by the Contractor.

The Contractor shall not use any of the spare parts without written permission from the Employer. All parts so used shall be replaced by the Contractor prior to the issue of the Taking Over Certificate.

3.37.2. Spare Parts, Tools and Equipment

3.37.2.1. Mandatory Spare Parts, Tools and Equipment

The Contractor shall, provide the following mandatory AND optional spare parts, tools and equipment as part of its offers. The price of same shall be included in the Contract price. Specifications of the tools and equipment shall be approved by the Engineer/ Employer prior to ordering. In case any mandatory spare parts will not be applicable as per the design, the bidder shall provide equivalent spare parts as per their design and indicate these deviations in their proposal accordingly.

This pricing for all optional items is **Mandatory** and shall be quoted separately but will not be considered for evaluation purposes.

Table 3.2 (a) Mandatory Spare Parts, Tools and Equipment

Qty	Descriptions
20	PV Modules
10	PV Floaters complete with Fasteners set
5%	Spares for Anchoring points and Mooring Ropes
25%	DC Combiner boxes – If Applicable
30%	Inverters (Spare Quantity representing at least 30% of total installed capacity which are fully programmed and tested with site parameters) – In case of string Inverter
1	Complete Inverter – In case of Central Inverter
50	Fuses of each size (AC and DC)

5	DC Circuit Breakers
5	DC Disconnect (Load Break Switch) of each rating
10	Surge Protective Devices of each type
2	AC Circuit Breakers/MCCB
2	Residual Current Device
1	Configured PV Farm Plant Controller
1 Lot	Recommended Spares for SCADA and Communication system
1	Network switch of each type
1	UPS Power Module Drawer of each type as specified in section 7
1	AC to DC power converter unit as specified in section 8.3
1	DC to DC power converter unit as specified in section 8.3 as applicable
2	Relay and Relay bases of each type
100 Pairs	DC Connectors
1	Drums of 1000m String DC Cable Single Core (for each Polarity)
1	Drum of 500m DC Cable Single Core (for each Polarity) from combiner box to compact stations
1	Dry Type (Inverter Duty) Transformer
1	Dry Type auxiliary transformer

Monitoring Station	
1	Complete set of Weather Monitoring Station Recommended Spares

22kV Switchgear	
6	Voltage Transformers
6	Current Transformers
6	HRC fuses as specified in section
1	Each relay type used on the cubicles.
4	Charging motors
1 no. of each type	Numerical Protection Relay
1 Set	Portable Earth Wire Kit complete with Clamps

Tools	
2	RFID Reader
2	Crimping tool + 1 set of dies for each lug size used
2	Torque Wrench to be used in the installation
1	22 kV insulating mat
2 pairs	22 kV insulating gloves
2	Line tester (Both Visual and Audible)

2	Rescue Rod
1	Portable workstations (Laptop PC) fully loaded with all licensed troubleshooting software, as commissioned configuration files and compatible communication cables
1	Electrical Submersible Pump Spare Set
20	Lifebuoy or life jackets as may be required
1	Multi-functional PV Tester
1	Motorized Dinghy for inspection

3.37.2.2. Recommended Spare Parts, Special Tools and Equipment

The Contractor is required to submit, along with his base bid, the pricing for recommended spare parts, special tools and equipment.

The Contractor shall, other than the requested mandatory spare parts, provide a recommended list of spare parts, tools and equipment, as part of his proposal. The recommended tools and equipment should be proposed for the purpose of operation and maintenance for the solar farm.

The Contractor shall evaluate his design with regards to failure rates, effects and reliability. The Contractor shall consider local availability for replacement/repair of the components proposed in his design and propose spare parts for components with short lifetime and long procurement time. The Contractor shall limit the downtime of the solar farm (partial or full) to an appropriate minimum value which shall be submitted to the Engineer/ Employer, for approval, along with his submission of recommended spare parts, tools and equipment list.

Contractor shall provide a price list for the mandatory & recommended spare parts, special tools and equipment.

3.37.2.3. Optional Tools and Equipment

Contractor shall provide a price list for the below optional tools and equipment in its bid.

Table 3.2(b): Optional Tools and Equipment

Optional Tools and Equipment	
3	Hand-held infra-red detector
1	Unmanned Aerial Vehicle (UAV)
1	Thermal imaging camera for UAV

<u>Optional Item 1: Hand-held infra-red detector</u>

The Contractor shall also recommend a hand-held infra-red detector suitable for the infra-red thermography of the solar farm for preventive and corrective maintenance.

Optional Item 2: Unmanned Aerial Vehicle

A professional drone/UAV shall be recommended as a complete set, ready to use, for the purpose of operation and maintenance for the solar farm. The drone shall weight less than 7 kg and have a diagonal size (excluding propellers) of less than 400 mm. A copy of the type approval certificate from the Information and Communication Technologies Authority, Mauritius must be provided for the UAV supplied. The contractor shall provide training for 3 persons, in view of obtaining the necessary pilot license(s), as per the requirements for commercial use of drone by the Department of Civil Aviation of Mauritius. Operation manual, as per the operation manual template from the Department of Civil Aviation of Mauritius, shall also be provided.

Minimum requirements for the UAV are as follows:

1) Camera with an effective resolution of at least 16 MP, a field of view of at least 70 degrees, frame rate of at least 30 fps and a video resolution of at least 4K.
2) The UAV shall support micro-SD card for storage and a micro-SD card of at least 64 GB shall be supplied for both the drone and the remote controller, as applicable.
3) Gimbal stabilizer with remote gimbal control in least 1-axis shall be present
4) GPS satellite positioning system shall be present.
5) Automatic return to take-off point feature upon low battery level or loss of connection shall be present.
6) Obstacle detection and avoidance features shall be present.
7) The drone shall be able to withstand a wind speed of at least 9 m/s.
8) Stability sensor for the drone shall be present.
9) Remote controller with an LCD display showing real-time telemetry and video image shall be supplied. Operating frequency of the controller shall be 2.4 GHz or 5.8 GHz with a transmission distance of at least 300 m. The controller shall use rechargeable battery, which shall also be supplied. The LCD display shall have a touch screen of at least 5 inches.
10) Spare batteries shall be supplied for the drone and the controller to achieve a total flight time of at least 30 minutes without intermediate charging.
11) All software/applications shall be supplied, as applicable.

Optional Item 3: Thermal imaging camera for UAV

A component that can be mounted on the UAV (proposed as optional item 3) shall be recommended to provide high-resolution thermal imaging solutions. All required additional software/applications/component shall be supplied to form a complete set, ready to use UAV for the easy and fast localization of any damaged photovoltaic panels with FLIR radiometric thermal sensors. The thermal camera shall have a good thermal sensitivity with a low NEDT, suitable for the maintenance of the solar farm.

Spare batteries supplied for the drone shall cater for any additional weight due to the thermal imaging solution so as to achieve a total flight time of at least 30 minutes without intermediate charging.

3.39 Defects Liability Period and Maintenance Contract

The defects liability/notification period for the whole installation shall be 12 months while the defects liability in building and civil works shall not be less than 10 years. Any defects reported by the Employer during the defect liability period shall be remedied by the Contractor within an agreed time frame between both parties. The Contractor shall use all reasonable endeavors to minimize any downtime and fault duration for the solar farm.

The Contract Price includes for the scheduled major inspections/maintenances of the equipment to be carried out by the equipment manufacturer for the period of 12 months during the defect liability/notification period.

4. CONTRACT DOCUMENTATION

4.1 General

The English language shall be used on all documents and drawings and SI units shall be used throughout. Where Imperial units are required on civil works drawings because of the standard sizes of locally available material, these shall be shown in parentheses beside the SI units.

All reports, statements, returns, diagrams or drawings, etc., which the Contractor is required to submit to the Employer during the progress of the Works are, unless otherwise directed, to be furnished in duplicate.

4.2 Documents Required to be Submitted for Approval

The Contractor shall furnish the following documentation, but not limited to, for approval. The documentation shall be in English, well detailed and instructive.

1) Program of Work.
2) Project Procedures Manual
3) Site Safety Procedures Manual
4) Anchoring and mooring system design, floater and mounting structure drawings with structural/ load calculations reviewed and certified by a Registered Professional engineer with the Council of Registered Professional Engineers (CRPE) of Mauritius.
5) Civil work layouts, plans and elevations inclusive of dimensions:
6) Refurbishment of fencing details

   - Layout drawings showing the row spacing and location of site infrastructures
   - Mooring and Anchoring System
   - Layout of all buildings, rooms and sanitary wares
   - Detailed structural and building works drawings and calculations.
   - Detailed building services drawings and calculations.
   - Civil works required for cable trenches, ducts etc.
   - CCTV Camera system layout
   - Connecting road and draining system inclusive of the detailed design
   - Any related site works.

7) Painting Procedure

8) Quality Assurance Manual

9) Electrical (AC and DC) and control wiring diagrams

10) Electrical schematic Diagrams (AC and DC)

11) Electrical specifications:

    a) Array

        - Module type(s)

        - Total number of modules.

        - Number of strings.

        - Modules per string.

    b) PV String Information

        - String cable specifications—size and type.

        - String over-current protective device specifications (where fitted) type and voltage/current ratings.

        - Blocking diode type (if relevant).

    c) PV Floaters and fasteners details

    d) Array electrical details

    e) Array main cable specifications—size and type.

        - Array junction box locations (where applicable).

        - DC isolator type, location and rating (voltage/ current).

        - Array over-current protective devices (where applicable)—type, location and rating (voltage/current).

    f) Earthing and Lightning protection devices

        - Earthing and Lightning protection study with justification for the protection devices being used.

        - Details of all earth/bonding conductors—size and connection points. This includes details of array frame equipotential bonding cable and clamps (where fitted), LV, MV switchgears, Inverters and transformer earthing.

        - Details of any connections for Lightning Protection System (LPS).

        - Details of any surge protection device installed (both on AC and DC lines), to include location, type and rating.

    g) AC system

- AC isolator location, type and rating.
- AC overcurrent protective device location, type and rating.
- Residual current device location, type and rating (where fitted).
- Grid connection details (transformers and switchgear schematics)
- Internal electrical reticulation including transformers switchgears and protection systems.

12) PVSyst Report or any other Solar Simulation Software Report

13) Data acquisition and communication system
    - Details of the communication protocol.
    - Wiring requirements.
    - Sensors and data logging.
    - List of Signals and commands

14) 22kV switchgear Panels
    - Technical Specification and Cubicles arrangement
    - Electrical Wiring Diagrams
    - Protective Relays
    - Uninterruptible power supply (including sizing calculations).
    - Safety Equipment

Solar Central Inverter - Complete Technical Specification

- Electrical Wiring Diagrams
- Protective Relays
- Uninterruptible power supply.
- Safety Equipment

15) Wiring Diagram of the 22kV switchgear

16) Control Philosophy of the PV Plant and interconnection facilities

17) Complete Commissioning plan including test and start-up procedures

18) As-built drawings

19) Test Results

20) Installation manuals, instruction manuals and operation manual for all equipment and sub-subsystems.

21) Decommissioning manual

22) Protection Philosophy, grading study and calculation for the PV Farm including the 22kV interconnection facility certified by a Registered Professional engineer with the Council of Registered Professional Engineers (CRPE) of Mauritius.

23) Repair and Maintenance schedule and manuals

24) Software documentation

25) List of signals, commands and alarms for both the PV Farm SCADA and the System Control Center.

26) PV Farm SCADA Screenshots and list of parameters being monitored

27) Calculation of heat dissipation for solar central inverters and all LV panels.

28) Any other project documentation and drawings that would be required by the Engineer/ Employer.

It is to be noted that all technical specification, drawings, layout and wiring diagrams shall be submitted for approval prior to manufacturing and implementation. The time frame for the submission of the above documentations and any other documentations that the Employer feel deemed necessary for the proper operation of the PV farm shall be agreed with the Employer at negotiation stage.

4.3 Format of Drawings

All drawings prepared by the Contractor shall be in accordance with BS EN ISO 4157, BS EN ISO 6284, BS EN ISO 8560 and BS EN ISO 9431.

All drawings issued for Construction shall be to scale and fully detailed with a preferred maximum drawing size of A1 in 3 sets of coloured copies. All-important dimensions shall be given and the material of which each part is to be constructed shall be indicated.

All drawings shall be black or coloured lines on a white background with all revisions clearly marked and identified on the drawing.

All drawings shall bear an approved title block with the following contract reference:

Client: Central Electricity Board, Mauritius
Project: 2MW AC Floating Solar PV Farm at Tamarind Falls Reservoir
Drawing Number:
Revision:

The Contractor shall devise and use a drawing numbering scheme which shall be specific to the project, and which shall cover all Contractor and subcontractor and suppliers' drawings.

All symbols used on all drawings, diagrams, etc., shall be detailed in an accompanying legend and shall be in accordance with an agreed International Standard.

The Contractor shall be responsible for any discrepancies, errors or omissions in the drawings and other particulars supplied by him, whether such drawings and particulars have been approved by the Engineer/ Employer or not.

Drawings shall be prepared and submitted in the AutoCAD format. In addition to the hard copies of all drawings, soft/electronic copies shall also be submitted.

All manufacturer drawings shall be submitted to the Employer.

4.4 Status of Drawings and Documents

All documents and drawings prepared by the Contractor, subcontractor or supplier and submitted to the Employer shall be clearly marked or stamped with one of the following indications:

- For Approval
- For Comments
- Released for Construction
- For Information
- As Built
- Documents submitted to Employer without one of the above Statuses will not be considered.

4.5 Procedure for Submission and Approval of Documents

4.5.1. General

Contractors Documents (Drawings excluded) shall include a title page followed by a revision record page clearly showing the revision history and showing the status of the document. The name of the author, reviewer and approver shall also be included. Any modifications to a previously submitted drawing shall be clouded and clearly indicated.

4.5.2. Documents "For Information"

Two copies of all equipment list, data sheets, etc. shall be submitted to the Employer **"FOR INFORMATION".** The Contractor shall remain responsible for construction details, dimensions, etc. on the document. The Employer shall not normally respond to these submissions.

4.5.3. Documents "For Approval"

All drawings and documents required for approval shall be submitted to the Engineer/ Employer.

Three prints and one electronic copy of all drawings which are required to be issued "FOR APPROVAL", and one print of all other documents which are required to be issued "FOR APPROVAL", shall be submitted. The electronic copy may be in pdf file format but the final versions will be submitted in hard copies, pdf and AutoCAD formats. A letter of transmittal shall accompany each submittal.

4.5.3.1 Deadlines for submissions

Documents shall be submitted gradually as and when required. Transmittal shall be preferably in batches to ease the approval on both Employer/Engineer and contractor's side.

4.5.3.1.1. Documents Required within Six Weeks from Commencement Date

- Program of Work.
- Project Procedures Manual
- Site Safety Procedures Manual
- Anchoring and mooring system design, floater and mounting structure drawings with structural/ load calculations reviewed and certified by a Registered Professional engineer (Civil) with the Council of Registered Professional Engineers (CRPE) of Mauritius.. Structural stability of floating system with anchoring and mooring design shall be demonstrated at minimum design wind speed of 216 km/h at 0.5 m through reputed software like MOSES, OrcaFlex or equivalent and report of same shall also be submitted.
- Civil work layouts, plans and elevations inclusive of dimensions
- Complete drawings list giving dates for submission, dates when approval is required and dates when drawings will be required at site.
- Document Register identifying projected documentation requirements, including drawings, for the project through to handover.

4.5.3.1.2. Documents Required within Twelve Weeks from Commencement Date

- Confirmation of tender drawings and information
- Plant outline and arrangement drawings including existing infrastructure
- Painting Procedure

- Quality Assurance Manual
- Civil Engineering Report
- Inspection and testing schedules
- Details of Contractor’s storage and laydown requirements
- Detailed civil works drawings and calculations
- Electrical (AC and DC) and control wiring diagrams
- Electrical schematic Diagrams (AC and DC)
- Electrical specifications
- Data acquisition and communication system
- Details of 22kV switchgear Panels
- Details of Solar Central Inverter
- Control Philosophy of the PV Plant and interconnection facilities
- Installation manuals
- Calculation of heat dissipation for solar central inverter and all LV panels.
- Any other project documentation and drawings that would be required by the Employer

Documents shall be either hand-carried or sent by courier service or express mail.

The time for review of the Contractor’s Documents and drawings by the Engineer/ Employer shall be 14 days.

When submitting a document for approval, including those prepared by a subcontractor or supplier, the Contractor shall certify that he has fully examined such drawings and that they comply with the requirements of the Contract. For the purposes of this Section the term drawing shall also include schematic diagrams, plant layout, schedules, performance curves, etc.

Approval by the Engineer/ Employer will imply that:

(1) General arrangement and layout drawings and key diagrams have been examined and appear to be in accordance with the design concept of the project and meet the requirements of the Contract.

(2) Other drawings of plant and equipment have only been examined in relation to compatibility of the plant and equipment with the Contract.

(3) Any approval given by the Engineer/ Employer shall in no way relieve the Contractor of his responsibilities under the Contract.

(4) Modifications made as a result of the Engineer’s/ Employer’s comments must be shown “clouded” on the revisions.

The Engineer/ Employer shall notify the Contractor of the status of the drawings as follows: -

APPROVED - On notification that a drawing is **"APPROVED"** the Contractor shall revise and re-issue it at “RELEASED FOR CONSTRUCTION” status and may then use this for the execution of the Works.

APPROVED SUBJECT TO COMMENTS - On notification that a drawing **is "APPROVED SUBJECT TO COMMENTS",** the Contractor shall revise it by incorporating the comments and showing “Engineer’s/ Employer’s comments incorporated” in the revision block, and re-issue the drawing at “RELEASED FOR CONSTRUCTION” status. Contractor may then use this for the execution of the Works. In the event of the Contractor is not complying with all the Engineer's/ Employer’s comments, the drawing shall be re-submitted for approval.

EXAMINED AND RETURNED WITH COMMENTS - On notification that a drawing is **"EXAMINED AND RETURNED WITH COMMENTS**" the Contractor is notified the drawing is not considered satisfactory and shall be amended and re-submitted for approval.

EXAMINATION NOT REQUIRED - If a drawing is notified as **"EXAMINATION NOT REQUIRED"**, the submitted drawing does not come under the categories shown in Section 3.2 above. Such drawings will include detailed manufacturing drawings which the Contractor would normally only make available to the Engineer/ Employer when requested to do so.

4.5.4. Documents "For Comments"

In order to enable the Engineer/ Employer to review and comment upon the Contractor's design and engineering work, certain drawings, calculations and documents, selected by the Engineer/ Employer, shall be submitted to the Engineer/ Employer "FOR COMMENTS" prior to release.

4.5.5 Documents "Released for Construction"

The Contractor shall observe all comments by the Engineer/ Employer unless he is not in agreement with the comments, in which case the comment in question shall be discussed with the Engineer/ Employer. After implementation of the comments or when notice of no comment has been received, the Contractor shall issue to the Employer two copies of the drawings as "RELEASED FOR CONSTRUCTION”.

The Contractor's documents which have been approved by the Engineer and are thus ready for subsequent action (i.e., for construction, etc.) shall be issued marked "RELEASED FOR CONSTRUCTION".

The Contractor shall ensure that all Contract drawings shall have reached the "RELEASED FOR CONSTRUCTION" stage before site erection has commenced. Work on Site will not be permitted to proceed until the drawings required have reached “Released for Construction” status.

4.5.6. “As Built” Drawings

The final configuration, system logic and spatial arrangements of all permanent works shall be recorded on “as built” drawings. Where changes have been made to “Released for Construction” these drawings shall be back drafted in AutoCAD and the changes shown clouded or otherwise in a manner that makes it clear the nature of the change.

All “Released for Construction” drawings shall then be revised, and the status changed to “AS BUILT”. These “AS BUILT” drawings shall then be submitted to Engineer/ Employer for review.

4.6 Planning and Progress Monitoring

4.6.1. General

To ensure satisfactory interchange of information such that the Contract can be correctly controlled and monitored, the Contractor shall adhere to the following specified procedures with regard to planning and progress monitoring.

4.6.2. Project Procedures Manual

Within four (4) weeks after the Letter of Acceptance, the Contractor shall submit “FOR APPROVAL” a Project Procedures Manual which shall detail the Contractor's standard procedures covering the individual phases of the project over the full Contract period for:

- project management and organisation
- responding to Engineer’s/ Employer’s comments on drawings and documents
- progress reporting
- communication
- controlling and monitoring
- procurement
- manufacturing
- shipping
- completion of all contract documentation
- construction certification
- invoicing and certification

- variations to contract

Organograms shall be included to show head office, site, shipping and transportation departments together with overall interfaces between the different sections. The Manual shall include: -

- proposed dates of meetings between the Contractor and the Employer/Engineer.
- dates required by the Contractor for review and approval by the Employer /Engineer of drawings and documentation.
- a draft inspection schedule detailing all items that require third party inspection. The Employer will determine and inform the Contractor of the level of inspection in which the Employer wishes to be involved.
- a flow and routing diagram for drawings and Contract documentation which shall indicate the Contractor's procedure for producing, quality controlling and submitting drawings and documents for review by the Engineer/ Employer. The documents shall include bills of lading, inspection procedures/ notification of inspections, reports and annuals.
- Documentation distribution schedule which shall detail the recipients and total number of copies required for significant documentation including minutes of meetings, progress reports and manuals.

4.6.3. Subcontractors

Where the Contractor subcontracts major items of the Solar PV installations it will be the Contractor's responsibility to instruct his subcontractors as to the requirements for programs and documentation which they shall also comply with the requirements of this Specification.

The Contractor shall notify the Engineer/ Employer prior to any change in sub-contractor and their scope of works.

4.6.4. Program

The program to be submitted by the Contractor shall be in the form of a bar chart clearly identifying each separate activity and showing the earliest and latest start and finish dates against each activity. The critical path shall be clearly identified. The program shall show completion of the Works within the Time for Completion as specified in this Tender. The program shall clearly show the key dates required to be met by others and interconnections with the medium voltage network system. All similar disciplines shall be grouped together.

4.6.5. Modifications to the Contract Program

If at any time during the execution of the Contract, the Contractor considers it necessary to modify the Contract Program he shall inform the Engineer/ Employer in writing and re-submit the modified program without delay. Approval of changes to the program shall not constitute approval of any extension to the guaranteed completion dates including the Time of Completion.

4.6.6. Contractor's Document Register

The Contractor shall maintain an up-to-date computer-based document register based initially on the requirements of drawings being submitted to the Engineer/ Employer for different categories. An updated document register will be enclosed at weekly intervals or as agreed with the Engineer/ Employer. This register shall list all documents including drawings produced by the Contractor and shall contain the following information for each drawing:

- Document title, number and revision
- Planned issue date for Engineer/ Employer review
- Estimated issue date for Engineer/ Employer review
- Actual issue date for Engineer/ Employer review
- Percentage completion
- Review status
- Planned date of issue "Approved" or "released for construction"
- Actual date issued "approved" or "released for construction"

Updates to the register shall be issued monthly throughout the Contract, or more frequently if required by the Engineer/ Employer.

4.6.7. Progress Reports

In addition to the reports and returns described in the Conditions of Contract, the Contractor shall submit to the Employer and Engineer fortnightly reports of the progress achieved on Site. These reports shall be submitted to the Employer/Engineer by the subsequent Monday noon following the works undertaken during the 2 weeks.

The Contractor shall issue TWO hard copies of a progress reports, showing the progress of the work as of the end of the previous 2 weeks.

The progress report shall comprise, but not be limited to: -

A detailed written summary of this progress

1) A copy of the approved Programme or Revised Programme as may be appropriate, marked up to show percentage progress achieved during the previous month on each activity detailed on the programme.
2) A detailed written summary of planned progress demonstrating the Contractor's proposals to complete the Works in accordance with the Contract and identifying those decisions, consents and approvals which will be required from the Employer/Engineer and the reasonably required timings thereof, in order that the Contractor may achieve his planned progress.
3) A graphical summary of progress showing the 'S' curve with planned and actual progress.
4) Payments schedule planned and actual.
5) Detailed status report of all plant and contract items.
6) List of all accidents which have occurred at site during the month.
7) Coloured photographs showing the status of construction.
8) Contract Drawings Status Schedule.
9) List of equipment, materials and drawing approval status and procurement schedule.
10) Change Order and Variation to contract Status Schedule.
11) Major items that could have an impact on cost or Schedule.
12) Summary of claims issued by the Contractor.
13) Any major problem encountered, and remedial solutions proposed

4.6.8. Environment Monitoring Plan

Contractor shall submit an Environment Monitoring Plan as per the requirements of Environment Protection ACT 2002. Regular updates as per the requirement of the Ministry of Environment shall be submitted.

The Contractor shall ensure adherence to the guidelines of EIA report and comply with the requirements of the EIA license for the project.

4.6.9. Progress Monitoring and Control

If at any time it should appear to the Engineer/ Employer that the actual progress of the Works does not conform to the approved programme referred to above, the Contractor shall produce, at the request of Engineer/ Employer, a revised programme showing the modifications to the approved programme necessary to ensure completion of the Works within the time for completion.

4.7 Site Safety Procedures Manual

Within six weeks after the issue of the Letter of Acceptance the Contractor shall submit two copies of his site safety procedures manual and shall also indicate the name and contact details of the person responsible for site safety matters.

The Contractor shall adhere, but not limited. to the following safety compliances:

Safety of personnel

The Contractor shall adhere to the site safety procedures as well as safety measures recommended by the local authorities.

Personal Protective Equipment & Safety Equipment

The Contractor shall ensure the sufficient availability of Personal Protective Equipment and Safety Equipment and ensure utilization of these equipment by the workers. The Contractor shall ensure the quality of all PPE and Safety Equipment as per national or international standards.

Safety Induction and Training

The Contractor shall adhere to the requirements of imparting safety training to workers. The Contractor shall maintain written record of Safety trainings imparted to its Employees/ workmen. These records shall be available for review of Project Manager / Safety Officer all the time.

Medical and First Aid Amenities

The Contractor shall make available the Medical and First Aid Amenities for workers at the project site.

The Contractor shall also maintain written record of incidences when requisite Medical and first aid amenities were not available.

Compliance to Work Permit System

The Contractor shall adhere to Local Work Permit System for construction and erection of power plants and shall be solely responsible to secure necessary permits and approval lodging facilities

4.8 Civil Engineering Report

A Civil Engineering Report shall be submitted to the Employer for approval within four weeks of the Award of Contract. Information to be provided shall include but not be limited to the following:

1) Details of personnel employed for the design of civil works including positions held and curriculum vitae.
2) Details of key personnel to be employed on site during the construction period. These shall include the site management team and quality control engineers.
3) Information on types of foundations and structures selected for the works.

4) List of codes of practice to be used for the designs.

5) Details of all loadings, both actual and assumed, incorporated into the designs. Where interpretation of codes of practice is required (e.g., for wind loading) the results shall be clearly stated.

6) Details of any computer programs to be used for the design.

4.9 Commissioning Procedures Manual

The Contractor shall submit two copies of his comprehensive commissioning procedures manual "FOR APPROVAL". These documents shall be submitted two months prior to commencement of pre-commissioning of the Works. Following approval, the Contractor shall supply three copies of the final documents.

The documents shall include detailed checklists and test sheets of all checks and tests to be carried out on all equipment during the commissioning phase of the Work. Each checklist and test sheet shall have included a space for the Contractor’s signature which must be signed by a competent representative of the Contractor when the Floating Solar PV farm has been successfully commissioned. Each sheet shall also include a space for the Employer’s representative’s signature which may be signed if the particular test/check has been witnessed by the Employer and Engineer representative. However, absence of the Engineer or Employer’ representative in witnessing such checks or tests shall in no way relieve the Contractor’s contractual liability in this regard.

4.10 Documents Required for Final Records

4.10.1. Introduction

“As Built” versions of all drawings are required for the final records. In addition to the documents and drawings required for procurement and construction, the Contractor shall supply the documents listed below for final record purposes.

4.10.2. Operating Manuals and Maintenance Instruction Manuals

Regarding the requirements for submittal of these manuals, Contractor’s standard format for Operating and Maintenance Manuals will be acceptable provided that they contain the information required below and are well laid out and professionally presented.

Not later than one month prior to the commencement of commissioning of the Works the Contractor shall deliver direct to the Employer three (3) completed and approved sets of the relevant operating manuals and three (3) sets of the relevant maintenance manuals as detailed herein, and two (2) sets of the relevant operating and maintenance manuals in electronic data (CD/DVD ROM) format. The documents submitted shall not be a general one for a range of equipment. It shall be very specific of the equipment being delivered on site.

Failure to comply with the submission requirements will result in delayed progress payments from the Employer.

Any approved modifications completed to the Works during erection and commissioning shall be reflected in the O&M Manuals. In this event the relevant sections shall be amended as “As-Built” and issued within one month after the issue of the Taking-Over Certificate.

The manual contents shall conform to the Table of Contents and be as complete and specific as possible. Every attempt shall be made to use material specific to the Contract. Nomenclature or reference to any one item shall be consistent throughout the manual.

The information provided shall be complete for main and auxiliary equipment and systems provided by the Contractor. Material that does not contribute to the understanding of the design, operation and maintenance of the equipment shall be excluded from the manual.

Use shall be made of drawings, diagrams, pictures or actual photographs when they add to the understanding and clarity of the text.

All material shall be free from stamps commonly used for identification of customer, order number, etc.

Precautions and warnings relative to the safety of life and equipment shall be included where practicable.

The manuals shall be divided into volumes specific in respect of the complete Contract works. The Operating Manuals shall be separate from the Maintenance Manuals.

Arrangement and Format of Operating the Manuals shall be approved by the Engineer/ Employer prior to printing and submission to the Employer.

4.10.3. "As Built" Drawings

“As-Built” drawings shall be issued at “AS-BUILT” status and are required as part of the Final Record. All “Issued for Construction” drawings are to be re-issued as “As-Built”.

During the construction and commissioning period any variations between the **"RELEASED FOR CONSTRUCTION"** and **"AS BUILT"** situations shall be agreed between the Contractor and Engineer/ Employer.

Within one month after issue of the Taking-Over Certificate, the Contractor shall submit all final revisions of all original drawings depicting the “AS BUILT” situation of the Works. All drawings and documents prepared exclusively for the project shall become the property of the Employer.

Final drawing prints shall be size A1 or A2 formats and colored. Final drawings shall be supplied as follows:

- 3 x print of each drawing included in the Operation and Maintenance Manuals.
- 1 x DVD-ROM to the Employer containing original AutoCAD drawing files.

Where drawings are reduced an appropriate scale shall be included on the reduced print.

To accompany the drawings, the Contractor shall provide a Master Schedule of "As Built" drawings.

4.10.4. Commissioning Reports

The Contractor shall submit three (3) copies of his comprehensive Commissioning Reports covering the commissioning periods at site including tests to the Engineer and Employer. The reports shall be submitted within two (2) weeks of the issuing of each Taking- over Certificate.

The reports shall include at least the following:

- Description of the tests performed including the acceptable limits of test results as per related standards.
- A written summary of commissioning noting particularly the problems that were encountered and the actions undertaken to resolve these.
- Defects which have occurred and the remedial action to resolve.
- Signed Checklists and Test Results
- FAT reports for PV modules, Solar Central inverters, transformers and switchgears among others.
- Drawings where necessary for ease of referencing.
- Equipment and tools used to perform the different tests on site.
- Calibration Certificates of the different test equipment and tools used

Weather Monitoring stations sensors' calibration certificates.

4.10.5. Decommissioning Manual

The Contractor shall develop and submit a decommissioning and deconstruction conceptual plan. Decommissioning can occur after the intended service life or because of premature failures or damages which prevent the FSPV system to be operating as intended

A time schedule for each step and activity, taking into consideration weather constraints and seasonal weather conditions, should be included.

Decommissioning procedures for specific components included in the decommissioning plan shall be in accordance with instructions from the components' manufacturers.

Decommissioning plans may be updated during the installation and O&M phases of an FSPV project, in case of changes in assumptions, conditions or applicable regulations.

Any change shall be justified, documented and in accordance with local, national, and international regulations. The decommissioning plan shall be developed based on a risk assessment considering safety and environmental risks which might occur during the decommissioning activities.

Potential risks identified within the risk assessment shall be properly documented and mitigated. The impact of the decommissioning phase on the environment should be minimized and the project site should be returned as close as reasonably possible to the conditions prior to the installation of the FSPV system, unless otherwise planned, documented and agreed in the relevant permits and plan.

The following potential impacts on the environment for the decommissioning phase shall be taken into consideration by the Contractor, including but not limited to:

- disturbances to fauna in and around the water body
- impact on local aquatic and non-aquatic flora
- impact on water quality and water composition
- potential release of pollutants in the water body during decommissioning
- permanent modifications of bathymetry and physical characteristics of the water body
- emissions related to decommissioning activities
- emissions related to transport, disposal and recycling of scrap components and materials.
- The impact of decommissioning activities on other commercial and recreational activities in and around the water body shall be assessed.

The decommissioning plan shall include instructions for future management of scrap components and residual materials from the FSPV system, including both hazardous and non-hazardous material. It is recommended to maximize recycling of materials and components, when possible. Any non-recycled material shall be correctly disposed per local, national and international requirements. In case the decommissioning plan includes parts of the FSPV system being withdrawn from service, but not removed, this shall be properly documented and managed in accordance with local, national and international regulations. In addition, any unretainable component or tool lost underwater during decommissioning phase shall be recorded and documented.

5. PROJECT REQUIREMENTS

5.1 General

The scope of the proposal for the design engineering, procurement, supply, construction, testing, commissioning, and start-up of Floating Solar PV Plant at Tamarind Falls Reservoir on turnkey basis completely covering the following activities and services in respect of all the equipment & works specified and covered under the specifications and read in conjunction with "Scope of Supply & services" elaborated at section 5.2. The scope of the project also includes the design and construction of a Control room (CMCS) building which comprises of MV and LV switchgears, Inverter duty and Auxiliary Transformers, Inverters, Battery and chargers, control room and appropriate access roads and drains for the site.

The AC output of the floating solar PV Plant is 2MW Measured at the outgoing feeder in the proposed 22KV Switchgear.

5.2 Scope of Supply and services

Detailed design of Grid Interactive Floating Solar PV Plant and its associated floating units, civil, electrical & mechanical auxiliary systems including preparation of foundation drawings, single line diagrams, installation drawings, electrical layouts, design calculations etc. Design memorandum and other relevant drawings and documents required for engineering of all facilities within the scope to be provided under this contract, are covered under contractor's scope of work.

All equipment, materials and services whether explicitly stated or otherwise and that are necessary for the satisfactory operation of the Floating Solar PV system and its integration as described in the specification shall be deemed to be included in the scope of work of the bidder and shall not be limited to the following:

DC SIDE	
•	Solar PV Modules
•	DC Cables including MC4 connectors, Double Wall Corrugated (DWC) pipes, ducts and trenches
•	String Combiner Boxes
•	Power Conditioning unit (Central Inverter Unit/ String Inverters)
AC SIDE	
•	LT Switchgear
•	HT Switchgear
•	Inverter Transformer& Auxiliary Transformer

•	LT Cables
•	HT Cables
•	Plant Controller, SCADA & Time Synchronization Equipment
•	Communication cable
•	Earthing System
•	Lightning and Surge Protection System
•	Plant Illumination system
•	Auxiliary Power Supply System
•	Battery and Battery Charger
•	UPS
•	Grid interfacing metering so as to meet statutory requirements and comply with CEB code.
GENERAL SYSTEMS	
•	Weather Monitoring Station
•	Fire Detection and protection system
•	Module Washing system
CIVIL	
	Anchoring System
	Mooring System
	Floating system inclusive of all accessories
	CMCS Building
	Access Road
	Cable Ducts and Trenches

a. Basic Engineering of the plant and systems.
b. Detailed design of all the equipment and equipment system(s) including civil works.
c. Providing, Review and approval of engineering drawings, data, process.
d. Calculations, test procedures, structural design calculations, Equipment layout, Drawings/Data sheets of bought out items, Civil structural/architectural Drawings, Performance & Guarantee Test procedure etc.
e. Providing Operation & Maintenance/ instruction manuals, as built drawings and other information.
f. Providing classroom and onsite training to Employer’s personnel.
g. Finalization of sub-vendors, manufacturing quality plans and Field quality plans.
h. Perform all design calculations. It is to be noted that all design calculation shall be approved by the Engineer/ Employer prior to implementation.
i. Submit to Engineer/ Employer for approval of all design calculations, drawings, O&M manuals, and miscellaneous documentation required to provide a complete installation
j. Complete manufacturing including conducting all type, routine and acceptance tests;

k. Packing and transportation from the manufacturer's works to the site including customs clearance & port clearance, port charges, (if any).
l. Receipt, storage, preservation, and conservation of equipment at the site; Fabrication, pre-assembly, (if any), erection, testing, pre-commissioning and commissioning and putting into satisfactory operation all the equipment including successful completion of initial operation.
m. All required equipment / materials labour and tools necessary to install, test, and commissioning of the Floating PV farm.
n. Cable sizing considering the voltage drop, power loss and current carrying capacity, supply, laying, test and commissioning of AC & DC cables.
o. Design, supply, install, test and commissioning of the 22kV indoor MV Switchgear, LT switchgear complete with all accessories including CT, PT, CB, Isolators, Meters and Protective relays as indicated in the Tender drawings.
p. Design, install, testing and commissioning of the interface required to allow monitoring and controlling of the Floating Solar PV system from the local SCADA system which will be located in the local Control Room under this contract by the successful bidder. Scope shall also include the provision of providing the control of the project envisaged under this contract from the Owners SCADA at the 8 MW Henrietta Phase II Solar PV farm as well.
q. Bidder shall arrange one additional Operator Workstation (OWS) which will be placed at 8MW Henrietta Phase II Solar PV Farm with communication link (OFC or Wireless Access or combination of both as feasible), required software, hardware and Desk for monitoring and control of this Tamarind Falls Reservoir FSPV Plant.
r. Design, supply, install, test and commissioning of any required communication equipment (Multiplexers, converters and patch chords) interface between the Floating Solar PV farm and remote communication to 8MW Henrietta Phase II Solar PV Farm including commissioning of whole communication system from Floating Solar PV Farm to System Control Centre via Remote Terminal Unit (RTU) at Henrietta substation.
s. Installation, test and commissioning of CCTV camera and associated systems and all images shall be viewed from the control room.
t. Design, Install, testing and commissioning of protective devices including lightning, surge, and earthing systems.
u. Supply of any special equipment and tools required for the operation and maintenance of the plant.
v. Providing all as built drawings for this project.
w. Design, Supply, test and commissioning of fire alarm and firefighting system.
x. Design, supply, Installation and Commissioning of lighting in electrical switchgear rooms, control rooms, PV Farm, parking areas, driveways buildings and external lighting.

y. Design, supply, Installation and Commissioning of emergency lighting, in particular, to enable the performance of emergency operational procedures and for illumination of escape routes.
z. Provision of general services socket outlets within the buildings and PV Farm.
aa. Providing Air conditioning system for all building spaces and rooms as applicable.
bb. Reliability and Functional guarantee tests after successful completion of trial operation.
cc. Supply of Mandatory Spares and tools as indicated in Table 3.2 (a).
dd. Satisfactory completion of contract.
ee. Ownership of packing materials (except of mandatory spares) shall be of the bidder. Hence, responsibility of removal and disposal of the packing material shall be in the scope of bidder.

CIVIL WORKS:

The broad scope of work under this package shall include Civil Structural and architectural works related to but not limited to the following areas, System, Structures / Substructures, Buildings and Facilities:

a. Cutting of bushes, other vegetation. Clearing, transporting and disposal of bushes, other vegetation, roots, stubs etc. for CMCS Building.
b. Site Preparation: Site grading including slope protection, ground preparation/ filling/ levelling (if required) of the Identified area for CMCS Building.
c. Civil, Structural and Architectural works to the extent applicable, including construction facilities and construction power distribution.
d. Perform Geotechnical Survey, including identification of land contamination, earth resistivity, and earth resistance among others.
e. Carry out necessary excavation works to set up cable trenches, earthing and lightning protection systems among others.
f. Foundation: Requisite foundation and structures wherever required.
g. Construction of a Solar facility/Central Monitoring and Control Station (CMCS) building comprising of the control room, a hall to accommodate 22 kV switchgear room, Inverters and Inverter Duty Transformers, Auxiliary Transformers, LV Switchgear, Battery Charger, DCDB, Battery room, office room, store, toilets and among others.
h. All buildings are of RCC.
i. Provision for refurbishment of appropriate drainage system, and fencing.
j. Requisite cable routing through cable ducts/trenches/ trestle and/ or cable tray, wherever required.
k. Anchoring and Mooring System
l. Floating System and accessories
m. Access road and drainage system

Electrical System studies:

a. The Contractor shall design the electrical installation, including the consumption of the Floating Solar PV Farm, to ensure that the internal consumption of the PV farm shall at all-time be greater than 0.95 pf. Necessary reactive power compensation study shall be done by the bidder and submit to Engineer/ Employer for approval.
b. Provide the Dynamic Model of the PV Farm in Digsilent Power factory format (Version 2021).
c. The studies: Conduct Load flow, Short Circuit, Reactive power compensation, Transient analysis and Harmonic studies including flicker shall be conducted by the Employer.
d. Comprehensive Protection Study, with all protection calculations complete with graphs (the graphs shall demonstrate discrimination for faults at both the MV and LV level taking into consideration the fault level at each level of the Solar Facility) and the grading of the interconnection protection with CEB substation protection;
e. Lightning and Surge Protection Study;
f. Earthing Protection Study;
g. Any other studies as per the requirement of CEB Grid code.

<u>Electrical Engineering Services:</u>

a. The Contractor shall provide all electrical engineering design services. Electrical engineering design shall be based upon a thirty (30) year service life, meeting applicable codes and standards and the requirements of the interconnecting utility.
b. The engineering and design shall include the appropriate sizing and cabling (above and below ground) that will connect all applicable equipment to the point of interconnection. The project electrical system shall be designed for electrical system losses no more than three (3) percent on the DC wiring system and the AC wiring system totalled.
c. All protection equipment used throughout the system shall be sized and specified to reduce damage to all components and to the interconnection point in the event of electrical failure.
d. The above ground portion of the electrical systems shall be neatly routed to facilitate access, troubleshooting, maintenance, etc.
e. The electrical design shall include the design of equipment grounding and lightning and surge protection for the entire PV Plant site. The Contractor shall ensure that the new earth system shall provide safe touch and step voltages designed in accordance with the latest edition of IEEE 80. Bidder has to submit the sizing calculation report for approval.
f. The Contractor shall design, supply, install and commission a lightning protection system, materials and components fully in compliance with IEC 62305 or NFC 17-102. Bidder has to submit the Lightning and Surge Protection Study for approval.
g. The Contractor shall design and specify all communications hardware and software required for system protection and remote monitoring and control. All monitoring and communication supplemental equipment and cabling shall be designed and specified, subject to Engineer’s/ Employer’s approval.
h. The Contractor shall design 22kV step up transformers and associated switchgears. The design shall be such that, isolation of a section of the solar farm for maintenance or repairs does not exceed 1 MVA.

i. The Contractor shall design and specify any necessary power, communications, and internet facilities required for PV Plant operation and control, remote monitoring, and the Facility security system.
j. The Contractor shall provide a comprehensive statement on the overall power factor control strategy for the entire solar farm from inverter output to MV system to CEB grid delivery both during day and night-time.
k. The power delivered to the grid must at all times meet the interconnection requirements for power factor both during day and night-time. A capability curve is required to illustrate the power factor control strategy.
l. The Contractor shall provide provisions to isolate equipment to facilitate panel/inverter maintenance and minimize impact to Facility production.

The work to be carried out as per the above scope shall be all in accordance with the requirements, conditions, appendices etc. given in Technical Specifications together with those stated in other Sections/Sub-sections of Bid Documents which shall be considered as a part of this volumes completely as if bound herewith. It is not the intent to specify herein all aspects of design and construction nevertheless, the equipment's and civil works shall conforming all aspects to high standard of engineering, design and workmanship and shall be capable of performing in continuous commercial operation in a manner acceptable to the Engineer/ Employer, who will interpret the meaning of the specification and drawings and shall have a right to reject or accept any work or material which in his assessment is not complete to meet the requirements of this specification and/or applicable International standards mentioned elsewhere in this specifications.

The detailed scope of work of the contractor shall be deemed to include all such items which although are not specifically mentioned in the bid documents and/or in contractor's proposal but are needed to make the system complete in all respects for its safe, reliable, efficient and trouble-free operation and the same shall be furnished and erected unless otherwise specifically excluded as per Section Terminal Points & Exclusions.

<u>Specifications for Module Washing System</u>

i. Bidder shall provide permanent arrangement for module washing in the FSPV Plant. This shall include installation of submersible pumps and laying network of HDPE pipe conforming to relevant codes. The complete scheme shall be subject to approval of the owner including inputs & output points, design and drawings for the system. Opening from the HDPE pipe with manual isolating valves should be provided at regular intervals. Stainless steel bib taps for fixing the movable/hose pipes for spraying water on module shall be provided in between the arrays.

ii. Reservoir water shall be used through two (2) electrical submersible pumps. The location of the submersible pumps shall be determined during design review meetings. The pumps shall be connected by a Control Panel and electrical power drawn from the auxiliary electrical distribution boards from the CMCS Building.

iii. Design of solar PV module cleaning system shall be such that complete solar plant shall be cleaned with fresh water once in a month. Module cleaning system piping network shall be closed looped pipe network configuration consists of Main pipe, sub-main and branches. Module cleaning system piping network may be design for dead end/tree pipe network configuration. Minimum 3 tapping /washing point shall be functional at same time. Cut-off valves shall be provided at suitable junction point so that the repair works may be conducted at a particular area without disturbing the whole area. The water used for cleaning should be of appropriate quality fit for cleaning purpose as per the recommendations of module manufacturer.

iv. Bidder shall provide the piping and the instrumentation diagram (P&ID) of water washing arrangement including the physical sequence of branches, reducers, valves, pressure gauge, couplers and cleaning points at the location of the pump(s) for approval during design review meetings.

v. HDPE pipes shall run along separate floaters with suitable tapping points at appropriate locations. The floaters used for cable routing arrangement may be utilized for HDPE pipes. Maximum length of hose pipe shall be 50 meter from tapping point.

vi. After laying and jointing, testing of main pipe, service pipe and fitting shall be checked by charging with water. The test pressure shall be minimum 0.5 N/mm2 or double the maximum working pressure, whichever is greater. The pressure shall be applied by means of a manually operated test pump, or, in the case of long mains or mains of a large diameter, by a power-driven test pump, provided the pump is not left unattended.

vii. End of the branch pipes/tapping points to be bent horizontal/downward to avoid entry of foreign materials like, earth, sand leaf, gravels, etc.

viii. Bidder to ensure interconnection between the sub-systems of module washing system through isolating valve, so as module cleaning may be continued in case of outage of any sub-system.

BASIC ENGINEERING DESIGN PARAMETER OF SOLAR PV PLANT

- Plant Capacity: **2 MW AC**.
- Minimum DC Capacity: **2.6 MWp** (DC: AC Ratio as 1.3 (MIN))
- Power Conditioning Unit (PCU) (Central Inverter/ String Inverter):

  i. Capacity: The continuous combined rating of all PCUs shall not be less than Plant capacity at

  a. Unit power factor at ambient temperature of 50 deg.

  b. 0.95 power factor at ambient temperature of 45 deg.

  ii. DC Overloading: -Maximum PCU DC overload loading shall be limited to its design PV Array Power to PCU nominal AC power ratio. Bidder needs to submit all the relevant technical document/test report from PCU manufacturer (OEM) during details engineering stage in support of declared PCU design DC overloading capacity

- Reservoir & Floating Details:

a. Tamarind Falls Reservoir is a man-made. The reservoir on river Tamarin and its water is used for irrigation purpose and generation of hydro power.
b. Maximum water level - 1624 ft ASL (Above Sea Level)
c. Minimum water level – 1614 ft ASL (Above Sea Level)
d. A design water depth of at least 3m shall be considered with a water level variation of +/-1.5m for the anchoring and mooring design.
e. Floating system: The Floating system comprising of floating unit, PV fixation system, and associated anchoring system shall be designed as per base wind speed of 3s gust of 280 km/hr (77.78 m/s) with a return period of 50 years. However, Floating structure shall be designed for minimum design wind speed of 216 kmph at 0.5 m height. EPC contractor shall submit duly approved design calculations signed by a Professional Registered Engineer (Civil) with the Council of Registered Professional Engineers of Mauritius certifying that the Floating Solar Photovoltaic (FSPV) plant is safe for 280 kmph wind speed as per requirement of applicable Building Codes. Geotechnical investigation report is available for a Ground Mounted Solar Project at 500m away from the proposed CMCS building. Topographical survey has been carried out at proposed project location. Further, Bathymetry report in form of Google KMZ file is also available. All these documents/results are attached in the Tender documents. **However, Detailed investigations like Geotechnical investigations, Topographical survey and Bathymetry shall be carried out by the successful Bidder during Detailed Engineering.** The Bidder may base his tender on the data made available by the Employer to be cross checked from his own inspection and examination, all as aforementioned. The Bidder must ensure himself whether any soil improvement will be required on site prior to the start of the construction works. All expenses required for soil improvement survey and soil improvement works must be included in the bid price.

- 22 kV MV Switchgear
  a. Bus Bar Rating of HT Switchgear: As per Table 5.1
  b. System Fault Current Rating: As per Table 5.1
  c. Dynamic withstand Current rating: As per Table 5.1
  d. Spare 22 kV breaker panels with VCB, relay and all other accessories shall be provided, as per Single Line Diagram
  e. DC supply shall be used for control and protection system of switchgear. In case UPS AC supply are considered for auxiliary control and protection supply for switchgear, then suitable rated AC/DC converter/power pack shall be used to meet the DC control supply requirement of switchgear panels
  f. The 22kV Switchgear shall have an internal Arc Classification of IAC FLR 25 kA, 0.5 sec.

- Earth Pit for DC System: Minimum 1.0 Nos per MW
- Basic Wind Speed for Civil and Electrical design: 280 km/hr for 3s.
- Tilt angle: Fixed tilt as per Floater manufacturer design.

- **Metering:** Provision for metering arrangement shall be provided as indicated in Single Line Diagram if applicable. However, energy meters will be provided by the Employer.
- Licenses for Remote Monitoring of SCADA: Min .3Nos with provision of Concurrent viewing for all users. All of the required software for PV Farm operation, testing and commissioning shall be provided by the Contractor with permanent licenses that shall be registered in the name of the Employer.
- **DC and LT Power cable voltage drop criteria:** From PV Module to Inverter Transformer shall be limited to 2% of rated voltage. For all other LT cables, Maximum Voltage drop shall be limited to 2% of rated voltage. The project electrical system shall be designed for electrical system losses no more than three (3) percent on the DC wiring system and the AC wiring system totalled.

5.3 System Design Optimization

The performance of a Solar PV Farm shall be optimised by a combination of several enabling factors: premium modules and inverters, a good system design with high quality and correctly installed components and a good maintenance and monitoring regime leading to low operational faults.

The Contractor shall use the following mitigating measures in order to optimize the plant performance:

Table 4.1: Mitigating Measures for System Design Optimization

Shading	Choose a location without shading obstacles. Ensure that the plant has sufficient space to reduce shading between modules.
Incident angle	Use anti-reflection coatings, textured glass
Module temperature	Choose modules with an improved temperature coefficient for power at high ambient temperature locations.
Soiling	Choose modules less sensitive to shading/dust.
Module quality	Choose modules with a positive tolerance as specified in section 4.6 below. Choose modules with a low degradation rate and a linear power guarantee as specified in section 4.6 below.
Module mismatch	Sort modules with similar characteristics into series strings where possible. Avoid partial shading of a string. Avoid variations in module tilt angle and orientation within the same string.
DC wiring resistance	Use appropriately dimensioned cable. Reduce the length of DC cabling.
Inverter Performance	Choose correctly sized, highly efficient inverters.

AC losses	Use correctly dimensioned cable. Reduce the length of AC cabling. Use high-efficiency transformers.
Plant downtime	Use a robust monitoring system that can identify faults quickly.
MPP tracking	Choose high-efficiency inverters with maximum power point tracking technology on multiple inputs. Avoid module mismatch.

5.4 Structural Engineering

All structures and foundation designs must include suitable evidence to show that their design is commensurate with a minimum of 25-year life. Design calculations certifying that the FSPV plant, CMCS building is safe for 280 kmph wind speed (3s gust, 50 years return period) as per requirement of applicable Building Codes. Further, the calculations and design shall be submitted to Engineer/ Employer for approval prior to implementation.

The Contractor is required to fill the Technical Schedules (Section VII- Schedule of Guaranteed Particulars) and submit the terms for product warranty.

All drawings and installation details shall be approved by the Engineer/ Employer prior to installation.

5.5 Solar Photovoltaic Modules

5.5.1 General

The Solar PV module comprises of PV cell(s) connected in any combination to achieve the required module power output. PV cells directly produces DC power on receipt of solar irradiation.

5.5.2 Part-A: Crystalline Silicon Modules (C-Si)

The PV cells in a crystalline silicon module shall be protected by encapsulation between front glass and back sheet/back glass. The glass shall be made of high transmissivity and front surface shall give high encapsulation gain.

The module type must be qualified as per IEC 61215 latest edition and the technical details of Solar PV Modules shall be as given below.

Sl. No.	Description	Details

1	Type of SPV Module	Mono Crystalline Silicon
2	Peak Power rating of Module	Shall not be less than 500Wp
3	Module Efficiency	Minimum 19 % at Standard Test Conditions
4	Fill Factor	0.7(Minimum)
5	Maximum Static Loading (Front / Rear)	2400 Pa (Minimum)

5.5.3 Codes and Standards

The applicable codes and standards are as mentioned below:

PV Modules	
IEC 62804 – 1	System voltage durability test for crystalline silicon modules – design qualification and type approval
EN 50380	Datasheet and nameplate information of photovoltaic module.
IEC 61215	Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
IEC 61701	Salt mist corrosion testing of photovoltaic (PV) modules
IEC 61730	Photovoltaic (PV) module safety qualification
IEC 61853-1	Photovoltaic (PV) module performance testing and energy testing – Part 1: Irradiance and temperature performance measurements and power rating
IEC 61215	Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC61701– Edition 2.0 2011-12	Salt mist corrosion testing of photovoltaic (PV) modules
IEC 62804-1:2015	Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation- part1: Crystalline silicon

5.5.4 Technical Requirements

a. The temperature co-efficient of Power for the module should be better than -0.45% per deg C.
b. Each and every SPV module shall conform to standards mentioned in 5.5.3 above.
c. The power tolerance of the modules shall be between 0 to at least 3% and no negative power tolerance shall be accepted under this bidding exercise.
d. Additionally, the Module wattage band/bin offered shall not be less than 5Wp.

e. The Experimental modules or those under research are not allowed.
f. Concentrating Solar PV (CPV) systems are also not being considered for this tender. Modules should have a product warranty of at least 10 years and a linear power output warranty of at least 25 years.
g. Each inverter shall use only one type (Make and Nominal rating) of module.
h. The SPV module shall perform satisfactorily in humidity up to at least 85% with ambient temperature between 0ºC to 55ºC and shall withstand wind gust up to 280km/h for 3s.
i. Solar PV modules used in solar power plants/ systems must be warranted for the product Workmanship for a period of minimum 10 years. Further, they shall also be warranted for their output peak watt capacity, and the predicted electrical degradation at the end of the period of 12 years shall be less than eleven (11) per cent of the full rated original output and 80% at the end of 25 years from the completion of the trial run. The Contractor shall also be required to submit the terms for product and power warranties.
j. Since the modules shall be used in a high voltage circuit, the high voltage insulation test shall be carried out on each module and a test certificate to that effect provided.
k. Module shall be made up of mono-crystalline silicon cells. The module should be PID resistant.
l. The front surface module shall consist of impact resistant, and high-transmission toughened low iron glass with minimum thickness of 3.2 mm (2.5mm for glass-to-glass module) for 72 cell modules. The glass used shall have transmittance of above 90% and with bending less than 0.3% to meet the specifications.
m. The modules shall be capable of resisting damage when subjected to hailstorms of a maximum diameter of 28 mm with impact speed of 86 km/h, IEC 61215 standard test procedure is also acceptable. The module supplier shall have to furnish a certificate to ensure that the front glass surface is capable of withstanding such impact.
n. The module shall not be subjected to any point load during transportation, handling and erection and complete care has to be taken to avoid any undue loading on either side of the module.
o. The interconnected cells shall be laminated in vacuum to withstand adverse environmental conditions. The EVA used for the modules should be of UV resistant in nature with gel content of more than 70%. The back sheet used in the crystalline silicon-based modules shall be of 3 layered structures. The thickness of back sheet should be of minimum 300 microns with water vapour transmission rate less than 2.0g/m2/day (38°C at 90% RH). The Back sheet can be fluoropolymer based or of any other well proven technology details of which shall be submitted and reviewed during detailed engineering and shall be subject to Engineer's/ Employer's approval. The back sheet shall have globally benchmarked durability properties on Moisture barrier, Tensile Strength (Machine Direction & Transverse Direction), Elongation retention and UV stability and shall be able to withstand system voltage. In case of glass-to-glass module the back glass shall have a minimum thickness of 2.5mm.
p. The module frame shall be made of corrosion resistant materials, preferably having aluminium anodized finish. The anodizing thickness shall be 15 microns or better. In case the offered module is frameless, suitable retaining clips/clamps used for installing the modules shall not damage the glass surface in contact with the retaining clamp.
q. Module(s) shall be provided with minimum three (03) bypass diode.
r. The module junction box shall have hinged, weatherproof lid with captive screws and cable gland entry points or may be of sealed type and IP65 rated. The module junction boxes shall in compliance with IEC 60670 and rated insulation 1000Vac:1500 Vdc. Moreover, since module side of the DC PV system remains alive during the day, a clear visible warning sign should be

provided to inform anyone working on the junction box. Each Junction Box shall contain Bypass Diode".

s. The bidder shall provide the sample solar PV module electrical characteristics including current-voltage (I-V) performance curves and temperature coefficients of power, voltage and current.
t. All the modules in the PV plant should be arranged in a way so as to minimize the mismatch losses.
u. Each module should have two suitably sized stranded UV resistant cables and terminated with DC plug-in connector directly. The positive (+) terminal has a male connector while the negative (-) terminal has a female connector. The connectors used for interconnecting the modules and connectors used for connecting the strings and/or to the String combiner Box, i.e., field connectors shall be of same make for better compatibility (refer Connectors chapter elsewhere for detailed Specification of Field Connectors). In case, 1500 V modules are used, the connecting cable shall be as per the relevant standard.
v. Each PV module deployed must use a Radio Frequency identification (RFID) tag for traceability. RFID shall either be placed behind name plate sticker or behind bar code label pasted on the back glass of PV module and must be able to withstand harsh environmental conditions during the module lifetime. One number RFID reader has to be supplied by the bidder which has to be compatible to read the data from the RFID Tag & download the data to Computer. All associated Software & Cables are to be provided along with the RFID reader. The following information must be mentioned in the RFID used on each module:
   - Name of the manufacturer of PV Module
   - Name of the Manufacturer of Solar cells
   - Month and year of the manufacture (separately for solar cells and module)
   - Country of origin (separately for solar cells and module)
   - I-V curve for the module
   - Peak Wattage, Im, Vm and Fill Factor (FF) for the module
   - Unique Serial No and Model No of the module
   - Date and year of obtaining IEC PV module qualification certificate
   - Name of the test lab issuing IEC certificate
   - Other relevant information on traceability of solar cells and module as suitable international standards.

   All information pertaining to solar PV modules shall be provided in the Technical Schedule list (Section VII- Schedule of Guaranteed Particulars) provided along the bidding document.

5.5.5 Name Plate

All individual modules shall be provided with Name Plate label at the back of module which shall provide the information given below for identification. They shall be clearly visible and shall not be hidden by equipment wiring. Type of labels and fixing of labels shall be such that they are not likely to peel off/ fall off during the life of the panel.

1. Manufacturer's Name
2. Model Number, Serial Number
3. Overall Dimensions (W x L x D)
4. Weight (kg)
5. Maximum Power (P_{MAX}), Voltage (V_{MP}), Current (I_{MP})
6. Short Circuit Current (I_{SC}), Open Circuit Voltage (V_{OC})
7. Main System Voltage
8. Relevant standards, Certification lab. Name
9. Warnings, if any

5.5.6 Type Tests:

SPV modules must be tested and certified by any of the accredited certifying agencies according to above mentioned International Standard clause and the type test reports shall be submitted for approval.

Note:

1. The Module Manufacturer, along with the Module datasheet, shall also provide the Details about the PV Cells used for the offered PV Modules. The information shall contain Cell Source, Type, and Electrical Parameters including efficiency, Size, Number of Bus bars and any other relevant information**.** *(For Crystalline Silicon Modules)*

2. In case the successful bidder supplies PV Modules of different make and/or model or from different agencies, the fixing holes in the frame/ location of retaining clips, their location, diameter, centre-to-centre distance between them and all other attributes related to mounting should be same, *if applicable.*

Bidder shall submit **third-party verified** PAN files **for one module in each wattage bin offered** and **self-certified** Electro- Luminescence (EL) Test reports **of all the** PV Modules being offered to the Engineer/ Employer.

5.6 DC Distribution

5.6.1 DC Distribution Cabinet

5.6.1.1 General

The DC Distribution cabinet/String Combiner and monitoring Box (SCB) is used in multi-string photovoltaic systems to combine the individual strings electrically and connect them to the Inverters. It shall have the string interconnection systems along with associated over current protection device, disconnectors, surge protection devices to protect the PV modules from current/voltage surges and monitoring equipment.

Nos. of input to each SCB shall be decided during detail engineering based on the approved Single Line Diagram (SLD) submitted by contractor.

Vendor to note that DC system of both 1000 V- and 1500-Volt rating is accepted based on solar string/array design offered by contractor. Accordingly, component/assembly shall comply with 1000/1500 V ratingas applicable.

Voltage rating of the selected component shall be 1000V or 1500V (Min.) as per system requirement during detail engineering. SMB offered for 1500 V Application shall have already been type tested and in satisfactory operation in Solar plant with 1500 V DC system.

5.6.1.2 Codes and Standards:

Codes	Description
UL 94 V	Fire Resistant/ flammability for Enclosure
UL 746C	UV Resistant for Enclosure
IEC 62262/EN 50102	Mechanical Impact Resistance for Enclosure
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 61643-12	Surge Protection
IEC 62208	Enclosure for low voltage Switchgear and control gear assemblies

Vendor shall submit the suitable Test Certificate/Report from accredited lab(s) indicating compliance of mentioned codes and standard if asked for the offered component or assembly.

5.6.1.3 General Requirement

SCB shall be equipped (but not limited to) with the following.

i. DC Disconnector /Breaker to disconnect the PV strings from the Inverter for maintenance purpose as per specification mentioned in this chapter.
ii. All component in the SCB shall be suitable for operation within temperature range of 0-65 Deg C.
iii. Fuse in each SCB input (both positive and negative) shall be provided to prevent the reverse short circuit current flow. However, in case of negative string fuse is not required as per recommendation of inverter manufacturer, string cable shall preferably be terminated with field connector with SCB.
iv. Strings current, Bus Voltage, DC Switch Disconnector Status, SPD Status and Box Temperature shall be monitored. Values and Status shall be made available on the local SCADA System
v. Surge Protection Devices for protection against surge currents and voltages as per

specification given in separate clause. Other associated items like cable glands, lugs, vents and items required for the protection and completeness of the system shall be provided

- **vi.** The common collection bus bars should be made up of zinc/tin coated copper and shall be suitably size to limit temperature rise within safe operating limits.
- **vii.** Vendor shall ensure adequate clearance with suitable insulated separator between positive bus and negative bus if it is in same enclosure. Positive and Negative section shall be orientated horizontally (Landscape orientation) on the either side of separator. Separate compartment for negative section and positive section for termination of positive and negative string input shall be preferred.

5.6.1.4. Fuse

In order to provide protection to all cables and modules, string fuses shall be provided with strings. The fuse and fuse holder shall be in compliance with IEC 60947-3. The contractor shall define the number of PV string inputs depending on the scale and topology of the PV installation. Each string input shall be individually and independently protected, controlled and monitored. Each string input shall be protected by a properly sized fuse.

String fuses shall be of PV category and dedicated to solar applications and conform to IEC 60269-6 or UL-2579 standards and fuse base shall comply to IEC 60269-1. String fuses should be so designed that it should protect the modules from reverse current overload.
The rated current and breaking capacity of the fuse shall be defined by the Contractor in line with the design of the system. In case of negative grounded system, string fuse as well as inverter input fuses on negative side shall be based on Inverter manufacturer's recommendation.

Each fuse or Isolation link shall be housed in a properly rated PV fuse holder with fuse blown indicator Fuse holders shall be suitable for DIN rail mounting. PCB mounted fuses are not acceptable.

The input current per string shall also be measured and made available to the local SCADA system. Depending on the incoming cable cross sections, the string input connection can be directly on fuse holder terminals through cable glands or on terminal blocks through cable glands.

5.6.1.5. SCB/DC Distribution Cabinet Enclosure:

SCB/Distribution cabinet enclosure shall satisfy the following requirement.

The SCB/Distribution cabinet shall be suitable for tropical environments. The enclosure shall be made of fire-retardant material with self- extinguishing property and free from Halogen, UV Resistant, ISO 4892-2. Material of the enclosure shall be made of GRP/FRP/Polycarbonate.

- i. Degree of protection for enclosure shall be at least IP 65 with vent plugs. All the part shall be corrosion resistant and enclosure surface shall be free from crazing, blistering, wrinkling, color blots/striations. There should not be any mending or repair of surface. The SCB if mounted on the floater shall confirm to IP-67.
- ii. The mechanical impact resistance of enclosure shall be IK 10.
- iii. The DC distribution cabinet shall have doors with hinged opening mechanism and

horizontal opening direction. Also, the DC distribution cabinet shall have a door opening greater than 90° for ease of access. The DC distribution cabinet shall also be equipped with door locks. Furthermore, the DC distribution cabinet shall be composed of a base plate supporting the functional mounting and paneling elements, uprights, wiring ducts and DIN rails.

iv. Additional canopies shall be provided to the SCB when installed in areas exposed directly to harsh weather conditions (To prevent UV Degradation and Water Ingress).

v. The size of the enclosure and general arrangement of the component shall be designed in such a way that the temperature rise of at any point of enclosure shall not rise more than 12 deg C above the ambient temp of 50 deg C. The components mounted inside the SCB shall have higher temperature withstand capability and shall continuously operate under such conditions.

vi. Complete assembled SCB shall be subject to heat run type test to be witnessed by owner after manufacturing. In case it is found that the temperature rise is beyond the acceptable limits, bidder shall redesign the assembly and perform the test free of cost to verify that temp. rise is within acceptable limit.

vii. In each SCB 5 % spare terminals along with cable glands and fuse rounded off to next higher integer shall be provided to connect the PV strings.

viii. All terminals' blocks shall be rated for min 1000V/1500 V and rated continuously to carry maximum expected current.

ix. In case, SCB is proposed to be mounted on ground, it has to be protected from top, suitable canopy/rain shed shall be provided on top of SCB extending minimum 50mm from all four sides. Design and dimensions of SCB structure must be such that minimum 600 mm of ground clearance is ensured at site for repair and maintenance. All the erection hardware and mounting accessories shall be galvanized steel.

x. All internal wiring shall be carried out with stranded copper wires with voltage rating mentioned elsewhere in the specification. All internal wiring shall be securely supported, neatly arranged readily accessible and connected to component terminals and terminal blocks. Wire terminations shall be made with solder less crimping type of tinned copper lugs which firmly grip the conductor and insulation. Insulated sleeves shall be provided at all the wire terminations. Engraved core identification plastic ferrules marked to correspond with the wiring diagram shall be fitted at both ends of each wire. Ferrules shall fit tightly on wires shall not fall off when the wire is disconnected from terminal blocks.

xi. Copper busbars and copper cables of appropriate cross section shall be provided for earthing and bonding. The low voltage DC distribution cabinet shall have a nameplate installed and mounted to the front cover and indicate, at a minimum: number of input circuits, ampere rating of input circuits, voltage rating, short-circuit current rating, and integrated disconnect ampere rating if provided.

xii. If metallic hinge is being used with enclosure cover, it shall be made of SS 304 and shall be rust proof. Enclosure shall be provided with captive screws so that it screw don't fall off when cover is opened. Screw shall be made of corrosion free material. Suitable non-conducting protection cover shall be provided for any metallic hinge/screw/fastener to avoid contact with live part of the assembly.

xiii. Mounting plate inside the SCB for mounting/fixing of devices shall be made of FRP/GRP or equivalent non-conducting material.

xiv. Input and Output Cables shall be done through appropriate Cable Glands.

5.6.2 DC Switch Disconnector / On-Load Isolator

The DC switch disconnector or Solar PV on-load Isolator shall comply with IEC 60947 and shall be suitable for minimum 1000Vdc or 1500 Vdc operational voltage.
The DC switch disconnector shall be selected with number of poles and current ratings to suit the circuit and application as appropriate. Any multipolar device achieving this configuration with Shorting links will not be acceptable.

Air Insulation distance shall be higher than 25 mm and the creepage distance shall be higher than 50 mm. The PV Isolators shall be type tested to carry the nominal current till Min. ambient temperature of 60 Deg C without any de-ration inside the String Junction box. Switching part shall necessarily contain reinforced break chamber, with an integrated magnetic arc-extinguishing system for the PV arc. The terminals of the DC switch disconnector shall be shrouded against accidental contacts. Isolator terminals need to be Silver plated. The Solar PV Isolators need to have a positive break indication and will have to comply with IEC 60947-3 and PV-2 for critical current.
The DC Switch disconnector handle shall be mounted externally on the door of the SCB for rapid isolation. Padlocking facilities shall also be provided to enable the device to be locked in the "off" position. The voltage on the incoming terminals of the DC switch disconnector shall be measured and be made available to the local SCADA system. The contacts of the DC switch disconnector shall be visible. Alternatively, positively linked externally visible indication for the "on", "off" may be provided subject to approval of the Engineer/ Employer. In addition, the “on” and “off” position of the switch disconnector shall be made available to the local SCADA system.

5.6.3 Type Test

Vendor shall submit the following Type Test/ Product Certification fromany National/International accredited lab for approval.

a. Temperature rise test on complete assembled Box as peracceptable limit mentioned in relevant clause.
b. Type test for enclosure as per code and standard mentioned inrelevant clause.
c. Thermal ageing at 70 Deg C for 96 hours as per IEC 60068-2
d. HV Test

5.6.3.1 Technical Requirements

Rated Current, IEC (85°C)	30 A (4 mm^2, 6 mm^2), 40 A (10 mm^2)
Rated Voltage	Min1000/1500 Volts as per system Requirement
Connector Design	Snap-In locking Type

Protection Degree	IP68 (Mated)
Ambient Temperature	(-) 40^0 C to (+) 85^0 C
Protection/Safety Class	Class II
Contact material	Cu
Contact surface material	Silver/Tin
Contact resistance for plug connecter	< 0.5 milli-ohms
Stripping length	10 mm
Inflammability class	UL 94-V0
Insulating Material	PPE / PPO/Polyamide
Pollution degree	3
Certification	UL/TUV/CSA/EAC or Equivalent

5.6.3.2 Type Test for DC Plug-In Connectors

a. Protection Degree (IP)
b. Operating Temperature
c. Inflammability
d. Pollution Degree
e. Voltage Withstand (Rated Voltage/Test Voltage)
f. Product Certification

5.6.4 DC Plug-In Connectors for Field Cabling General Requirement

Field connectors are electrical connectors/coupler used for connecting solar panels and also strings of panels to String combiners box. Cable connector to be used for connecting SPV modules and String monitoring boxes shall be in accordance with IEC 62852: 2014.

Connector shall be of plug and socket design to be plugged together by hand but can be separated again using a tool only. Contractor shall ensure that field connectors to be mated shall always be of same make and model or shall be tested Inter-compatible as per clause no.6.3.11 of IEC 62852: 2014 for offered make(s).

Mating of connectors of different makes/model shall not be acceptable if not tested for inter-compatibility by any accredited lab.

5.6.5 Surge Protective Device

DC output SPD shall consist of three Metal Oxide Varistors (MOV) type surge arrestors which shall be connected from positive and negative bus to earth. The surge protective device shall be suitable for the PV system in accordance with IEC 60364. The type, the discharge current and the impulse current of the surge protective device for the DC system shall be defined by the Contractor and shall be submitted to the Engineer/ Employer for approval.

The surge protective device shall have a feature of local visual status indication and shall incorporate remote contact signaling to indicate normal operating state to local SCADA.

The discharge capability of the SPD shall be at least 12.5kA at 8/20 microsecond wave as per IEC 61643-12 and shall be rated for MCOV 1000/1500 Volt DC. During fault and failure of MOV, the SPD shall safely disconnect the healthy system. SPD shall have thermal disconnector to interrupt the surge current arising from internal and external faults. In order to avoid the fire hazard due to possible DC arcing in the SPD due to operation of thermal disconnector, the SPD shall be able to extinguish the arc. The status of the disconnection and operation of short-circuiting device for safe electrical isolation in event of arcs should also be made available to the local SCADA system

5.6.6 Earthing

The DC system shall be negatively grounded. All non-current carrying metalwork shall be effectively and securely bonded. In case of armored cables, the earth tape shall be bonded to the earth ring on the cable gland. All incoming and outgoing earth continuity conductors shall be effectively and securely bonded together and to earth.

5.6.7 Inverter Module

Power Conditioning Unit

The Power Condition Unit may be either String Inverter or Central Inverter. The Power Conditioning Unit (PCU) is Solar Inverter designed to convert solar PV DC power to 3-phase AC power and fed into utility grid. The PCU shall consist of solid-state electronic switch along with all associated control & protection, filtering, measuring instruments and data logging devices. The PCU shall have maximum power point tracker (MPPT) for operating the inverter at its maximum power point. The PCU output shall always follow the grid voltage & frequency by sensing the grid voltage and phase and the PCU shall always remain synchronized with the grid. The PCU shall use only self-commutated device which shall be adequately rated and shall utilize a circuit topology and components suitable for meeting the specifications at a high conversion efficiency and with high reliability.

5.6.7.1 Codes and Standards

The PCU shall conform to all applicable IEC standard. Where an applicable IEC standard is not available, any applicable international standard shall be referred to as best practice.

Codes	Description
EN 50524	Data sheet and name plate for photovoltaic inverters
IEC 61000-3-2	Limits - Limits for harmonic current emissions (equipment input current up to and including 16 A per phase)
IEC 61000-3-3	Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with

	rated current ≤ 16 A per phase and not subject to conditional connection
IEC 61000-3-7	Assessment of emission limits for the connection of the connection of fluctuating installations to MV, HV and EHV power systems.
EN 61000-6-1	Electromagnetic Compatibility (EMC). Generic Standards. Immunity for Residential, Commercial and light industrial environments.
EN 61000-6-3	Electromagnetic Compatibility (EMC). Generic Standards. Emission for Residential, Commercial and light industrial environments.
IEC-61683	Photovoltaic Systems – Power conditioners – Procedure for measuring efficiency
IEEE 519-2014	IEEE Recommended practice and requirements for harmonic control of electric power systems, Institute of Electrical and Electronic Engineers, March 2014
IEC 60068	Environmental Testing
IEC 62116	Test Procedure for islanding prevention measures for Utility connected photovoltaic inverters
IEC 62109-1 & 2	Safety of power converters for use in photovoltaicpower systems
EN 50530	Overall efficiency of grid connected photovoltaic Inverters
BDEW 2008	Technical Guidelines for Generating plant connected to medium voltage network
IEEE 1547	Standard for interconnecting distributed resources with electrical power systems.
IEC 60529	Ingress protection test

5.6.7.2 General Requirements of PCU

a. The PCU shall comply with the Central Electricity Board (standards for connectivity to the grid) with all latest amendments.
b. The minimum euro efficiency of the PCU as per IEC 61683 shall be 97%. The bidder shall specify the conversion efficiency at following load conditions i.e., 25%, 50%, 75% and 100% during detail engineering, which shall be confirmed by type test reports.
c. In case auxiliary supply of PCU is met internally, then it should have sufficient power backup to meet the LVRT requirement. Bidder needs to submit the detail auxiliary supply arrangement for PCU during detail engineering stage.
d. The PCU shall be capable of operating in the frequency range of 47.5 Hz to 52 Hz and shall

be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz.

e. The monitoring/measurement of DC inputs (for central inverter) and AC output shall be done using transducers/instruments having sensor accuracy of 0.5 class or better. In case of String Inverter, String Inverter should have feature of Remote Monitoring for the measurement of DC Input current.

f. Internal Surge Protection Device (SPD) shall be provided in the PCU on DC and AC side. It shall consist of Metal Oxide Varistor (MOV) type arrestors. The discharge capability of the SPD shall be at least 12.5kA at 8/20 microsecond wave as per IEC 61643-12.

g. The PCU shall be capable of supplying reactive power as per grid requirement (manual intervention through SCADA) during solar generation hours.

h. The solar farm shall be designed with the capability to supply rated power (MW) for power factors ranging between 0.95 lagging and 0.95 leading, available from 20% of rated power measured at TFR Substation. When operating below 20% of the rated output, the power factor may be less than 0.95 lagging.

i. The PCU shall have protection against any sustained fault in the feeder line and against lightning discharge in the feeder line.

j. The Contractor shall ensure by carrying out all necessary studies that the PCU will not excite any resonant conditions in the system that may result in the islanded operation of PV plant and loss of generation. Incase there is excitation of any resonant condition in the system during PV plant operation that may result in the islanding/tripping of the PVplant and affect the power transfer, it shall be the responsibility of contractor to rectify the design and carryout required modification in the equipment of his supply.

k. The PCU must be self-managing and stable in operation.

The PCU shall include appropriate self-protective and self-diagnostic feature to protect itself and the PV array from damage in the event of PCU component failure or from parameters beyond the PCU's safe operating range due to internal or external causes. The self-protective features shall not allow signals from the PCU front panel to cause the PCU to be operated in a manner which may be unsafe or damaging. Faults due to malfunctioning within the PCU, including commutation failure, shall be cleared by the PCU protective devices and not by the existing site utility grid service circuit breaker.

j. PCU shall have active power limit control, reactive power and power factor control feature. Plant operator shall be able to provide (manual intervention) Active power, reactive power and power factor control/limit set point through SCADA HMI and local control display unit (or Laptop computer). All parameters should be accessible and configurable through and industry standard communication link and displayed on the local SCADA in the control room. PCU shall be provided with remote start and stop facility from SCADA HMI. All required hardware and software required for this purpose shall be provided by Bidder.

k. PCU shall have necessary limiters in build in the controller so as to ensure safe operation of the PCU within the designed operational parameters.

l. PCU shall have thermal overloading protection to prevent failure of switching devices (i.e. IGBT) and other components of Inverter. PCU controller shall automatically regulate/limit the power output in order to reduce the PCU cabinet and switching devices temperature. Bidder to submit the PCU power vs ambient temperature curve during details engineering stage. PCU shall be able to provide inverter inside cabinet and IGBT's (switching device) temperature (in soft analog value) to SCADA system for remote monitoring, storing and report generation purpose.

m. PCU shall have the following feature,

- Automatic morning wakeup and nightly shut down.
- Mains (Grid) over – under voltage and frequency protection
- AC & DC overcurrent protection.
- Synchronization loss protection.
- Over temperature protection.
- DC & AC under and over voltage protection.
- Under & over frequency protection.
- Cooling system failure protection
- PV array ground fault monitoring & detection
- PV array insulation monitoring
- LVRT
- Anti-islanding protection
- Grid monitoring
- Loss of Main Protection
- DC Reverse Polarity
- Fool proof protection against Islanding
- Accidental open circuit
- Included authentic tracking of the solar arrays maximum power operation voltage (MPPT)
-
- Automatic fault conditions reset for all parameters like voltage, frequency and /or black out.

q. One number of laptop/PC shall be supplied for PCU configuration and troubleshooting purpose. Laptop shall be supplied with complete set of hardware & software accessories. Laptop detailed configuration must ensure suitability for the required applications. Supplied Laptop shall be protected with the latest anti-virus software and shall be provided 5 Years onsite warranty including its battery. At least two sets of communication cable for Laptop to PCU communication shall be provided.

r. PCU shall be provided with Mobile user (Mobile App) interface facility for monitoring status of inverters. The system should give message alert in case any inverter is tripped due to any fault. An inverter event list is stored with important messages highlighted to enable the user to keep track ofinverter status at all times for better O&M and highest yield from the PV plant. In additional to this facility, the Bidder shall interface same with the plant SCADA system. All required hardware and software including Mobile App required for this purpose shall be provided by Bidder.

s. The power circuits of the inverter shall be separated from the control circuits. The internal copper wiring of the inverter shall have flame resistant insulation. All conductors shall be made of standard copper.

l. PCU shall meet the following technical parameter

Design	Modular type
Control type	Voltage source, microprocessor assisted, output regulation
Nominal output voltage frequency	50Hz
Continuous operating frequency range	47.5 Hz to 52 Hz
Continuous operating AC voltage range	± 10% rated AC voltage
Operating power factor range	Operating power factor (adjustable) shall be 0.95 Lead to 0.95 Lag.
Maximum input DC voltage	1000V or 1500V as per application requirement.
Current THD value	< 3 % at maximum power output
Inverter Efficiency	>97.5% at full load
Power Control	Maximum Power Point Tracking (MPPT)
Overloading capacity	At least 120%
Operating ambient temperature	5 to 60°C
Humidity	95 % non-condensing
Maximum Noise level (at 1meter distance)	75 dBA for indoor type PCU
DC Injection	<0.5 % at rated current
Flicker	As per IEC61000
Remote Start and Stop Facility from SCADA	Required
Night SVG (Q at Night)	Required

5.6.7.3 Earthing of Inverters

The PCU shall be earthed as per manufacturer recommendation. During detail engineering the Bidder needs to submit the details earthing arrangement of PCU and system earth pit requirement during detail engineering stage. The detail specification for panel earthing for safety has been mentioned elsewhere in this specification

5.6.7.4 Operating Modes of PCU

a. **Low Power Mode:** The PCU shall be able to wake-up automatically when PV array open circuit voltage value is equal/more than preset value in the PCU program. Once its start generation the PCU shall automatically enter maximum power mode after achieving threshold parameters.

b. **Maximum Power Point Tracking (MPPT):** Maximum power point tracker (MPPT) shall be integrated in the Inverter to maximize energy drawn from the array. The MPPT should be microprocessor-based to minimize power losses. The details of working mechanism of MPPT shall be provided by the Manufacturer. MPPT shall be able operate the PV array at its maximum power point by adjusting output voltage of PV array system according to atmospheric condition. PCU MPPT controller shall ensure that it operate the PV array system at its global maximum power point and it shall not have trapped into PV array local maximum power point during cloudy atmospheric condition. The PCU shall operate within its MPPT operating input DC voltage range (window). The PCU MPPT operating DC voltage range shall be large enough so that it shall be able to satisfactorily operate the PV modules exposed to the maximum ambient temperature of 50^0C. In case the solar PV array operating maximum power point voltage fall below (or above) the PCU MPPT operating voltage range, then the PCU controller shall automatically adjust the PCU input voltage so that PCU shall not enter into sleep mode. If the PV array output power fall below the PCU minimum preset power value, then PCU shall automatically switched to sleep mode.

c. **Sleep Mode:** PCU shall automatically go into sleep mode when the output voltage of PV array and/or output power of the inverter falls below a specified limit. During sleep mode, the inverter shall disconnect from grid. Inverter shall continuously monitor the output of the PV array and automatically start when the DC voltage rises above a pre-defined level. During evening and night (non-solar generation hours) the PCU shall be in sleep mode in order to minimize the internal power loss. Maximum loss in sleep mode shall be less than 0.05% of PCU rated power.

d. **Standby Mode:** In standby mode the PCU DC & AC contactor are open, inverter is powered on condition and waiting for start command.
The inverter shall go to shut down/standby mode, with its contacts open, under the following conditions before attempting an automatic restart after an appropriate time delay:

Insufficient Solar Power Input:
When the power available from the PV array is insufficient to supply the losses of the inverter, the inverter shall go to a standby/shutdown mode.

Situation of Over or Under Voltage on CEB Grid:
The inverter shall restart after an over or under voltage shutdown when the utility grid voltage has returned within its limits after a minimum time delay of three (3) minutes.

Situation of Over or Under Frequency on CEB Grid:
The inverter shall restart after an over or under frequency shutdown when the utility grid frequency has restored within limits after a minimum time delay of three (3) minutes.

e **Disconnection, Islanding and Automatic Reconnection after the Grid Failure Is Restored**

Disconnection of the PV generator in the event of loss of the main grid supply is to be achieved by in built protection within the inverter. This may be achieved through rate of change of current, frequency, phase angle, unbalanced voltage or reactive load variants.

Operation outside the limits of power quality as described in **relevant chapters** should cause the inverter to disconnect from the grid. In case of the above, tripping time should be less than 0.5 seconds, unless otherwise requested by the Engineer/ Employer.
Inverters shall have the ability to reconnect automatically to the grid following restoration of grid supply, subsequent to grid failure condition within a minimum time delay of three (3) minutes.

5.6.7.5 Central Inverter

i. PCU must have provision to be isolated from grid through Air Circuit Breakers/MCCB's (geared motor for remote closing and opening via SCADA, Local and Remote Selector Switch). The ACBs/MCCBs as required can be provided as shall be a part of PCU/its Modules or separately based on standard design and configuration of PCU manufacturer.

ii. PCU shall have suitable rated DC isolator/contactor for isolation of PV array from inverter. Suitable rated fuse shall be provided (at inverter end) in incoming DC cable from each string combiner box (SCB). Fuse requirement (at inverter end) in the negative side of incoming DC cable shall be as per inverter manufactures recommendation. One set spare terminal with fuse/link (as applicable) and holder shall be provided for the future use. DC MCCB are also acceptable in place of DC fuse based on standard design and configuration of PCU manufacturer. In case MCCB are provided, then one spare MCCB (mounted inside PCU panel) shall be provided with each PCU.

iii. String Monitoring facility: PCU shall be provided with current monitoring transducer at incoming DC cables from each string combiner box (SCB) for PV array zone monitoring purpose. The current transducers used for this purpose shall have accuracy of 0.5 class or better. The PCU shall be able to provide the measured DC current value and calculated DC power and energy value of incoming SCB DC cable to SCADA system for remote monitoring, storing and report generation. In case PCU does not have the facility/capability for power and energy calculation within its controller, then Bidder can provide the same facility in SCADA system.

iv. The PCU should be designed for parallel operation through galvanic isolation. Solid state electronic devices shall be protected to ensure smooth functioning as well as ensure long life of the inverter. Parallel operated PCU system are also accepted subjected to recommendation of PCU manufacturer. In such case, PCU design shall also ensure that no abnormal interaction shall take place among the PCU unit during any grid operating condition which may result in outages.

v. The inverter shall have an appropriate display on the front panel for viewing important parameters, configuration and troubleshooting purpose. Display shall include all important parameter such as DC input voltage, DC input current, AC output voltage, AC output current, AC output power, frequency etc. Each of these measurement displays shall have an accuracy of 1 percent of full scale or better. The display shall be visible from outside the inverter enclosure. Operational status of the inverter, alarms, trouble indicators and AC and the DC disconnect switch positions shall also be communicated by appropriate messages or indicator lights on the front cover of the inverter enclosure and SCADA. The parameters of the inverter shall be configurable via the communication bus on the local SCADA system. Inverter shall also be provided with required software along with accessories (2 sets) for interface with Laptop PC for viewing, configuration, troubleshooting purpose.

vi. PCU shall have suitable communication card (Modbus/Ethernet) for networking and SCADA integration. Communication port shall be TCP/IP protocol. PCU shall include all important measured & internal calculated analog values and alarm & trip signals for remote monitoring, storing and report generation purpose in SCADA system. Details list of above such parameters shall be provided along with their IP address during detail engineering stage.

vii. In case of modular design of PCU is offered, the Contractor shall ensure that no abnormal interaction shall take place among the various PCU modules during any grid operating condition which may result in outages. The PCU controller offered by the Contactor shall be such as to ensure stability, reliability and a good dynamic performance. The Bidder shall indicate the control scheme adopted for modular PCU and its merits and the test which will check its performance.

viii. The Inverter shall have suitable arrangement for negative grounding of solar PV array system and the ground current shall be limited to safe limit. Ground current shall be measured continuously, and alarm shall be generated in case ground current reaches to predefined set value. Inverter shall trip in case ground current more than safe operating limit.

ix. Inverter shall have emergency stop push button for tripping of inverter with complete AC electric isolation.

x. The inverter shall withstand a high voltage test of 2000 Vrms, between either the input or the output terminals and the cabinet (chassis). The inverter shall not produce Electromagnetic Interference (EMI) in accordance with EN 61000-6-1 and EN 61000-6-3, which may cause malfunctioning of electronic and electrical instruments including communication equipment, which are located within the facility in which the inverter is housed.

xi. The Contractor shall submit the assumptions, factors taken into consideration and calculations for the inverter and array sizing for approval by the Engineer/ Employer. The Contractor shall provide a full warranty of at least 10 years on inverters used in this project. The Contractor is required to fill the Technical Schedules (Section VII- Schedule of Guaranteed Particulars) and submit the terms for inverter warranty.

5.6.7.5 String Inverter

i. The string inverter enclosure protection class shall be IP 65 or better protection.

ii. The inverter AC output power shall be rated **between 200 – 355kWac**. Inverters with AC output power rating outside the specified range of 200 – 355kWac will not be accepted.
The inverter shall be sized to provide a power output of between 200 – 355kWac without being in overloading condition and taking into consideration losses.

iii. The String Inverter should be placed inside a canopy shed with atleast 15cm in all direction, if installed in open. Alternatively, the Bidder can also install the inverter on the column post of the module mounting structure, below the modules. In such case, the canopy is not required, and the column and foundation shall be designed accordingly.

iv. String Inverter shall have suitable communication port (TCP-IP/PLC) for SCADA integration. All necessary hardware, software and accessories used for communication with SCADA (including smart logger Data logger) at both the ends shall be provided by the bidder. String Inverters system shall support dual master communication.

v. String inverter shall have string monitoring capability and reporting to SCADA system. Any special software if required for this purpose shall be provided for local and remote monitoring and report generation.

vi. Anti-PID device along with all hardware and communication cable/device shall be provided in case negative grounding of PV string provision is not available in string inverter.

vii. DC fuse requirement for PV string at string inverter end shall be as per string manufacturer/system requirement and same shall be finalized during detail engineering stage.

viii. Provision for AC and DC electrical isolation device (such as MCB/MCCB/Isolator) inside string shall be as per string inverter manufacturer practice. In case standard design of string inverter does not include display, then string inverter shall be provided with required software along with accessories (2 sets for complete plant) for interface with inverter or facility for mobile viewing and configuration with laptop.

ix. LT Junction box, switchboard, and switchgear requirement for string inverter system as per chapter C-1 (LT Switchgear).

x. The String Inverters can be mounted on the floating platform or inside the CMCS building. If the String Inverters are mounted on the floating platform, it shall withstand wind gust up to 280km/h for 3s (Detailed design to be submitted after award).

5.6.7.6 Enclosure:

a. The PCU enclosure protection class shall be IP 20 (for Central Inverter) and IP65 (for String Inverter) or better protection.

b. COOLING AND VENTILATION: Ventilation shall be designed such that the temperature rise of the inverter rooms doesn't exceed 3 deg above ambient. The air velocity through the filter shall be taken at max 1.5 m/sec and the filter shall be chosen accordingly to pass the required intake air through the filter to remove heat from the inverter room. the inverter room. All exhaust and fresh air fans shall be provided with thermostat control

c. To prevent the maximum permissible temperature in the inverter room from being exceeded because of internal heat emission of inverters and other auxiliaries in the inverter room, the inverter room in the PV plant shall be adequately ventilated. The Ventilation plant capacity and air quality of inverter room shall be as per inverter and other auxiliary's system manufacturer's recommendations. Filter banks at the air inlet of the inverter room shall be provided to prevent dust ingress. Bidder shall furnish peak power consumption of cooling system (cooling fans, pumps etc.) of the PCU along with the data sheet.

5.6.7 Type Testing for Central/String Inverter During detailed engineering, the contractor shall submit all the type test reports including temperature rise test and surge withstand test (for Central Inverters) carried out within last ten years from the date of techno-commercial bid opening for Engineer's/Employer's approval. These reports should be for the test conducted on equipment similar to those proposed to be supplied under this contract and the test(s) should have been either conducted at an independent laboratory or should have been witnessed by a client.

However, if the contractor is not able to submit report of the type test(s) conducted within last ten years from the date of techno-commercial bid opening, or in the case of type test report(s) are not found to be meeting the specification requirements, the contractor shall conduct all such tests under this contract at no additional cost to the owner either at third party lab or in presence of Engineer/Employer representative and submit the reports for approval.

5.7 AC Distribution

5.7.1 Low Voltage AC Cabinet

The low voltage AC switchboard shall be rated at the nominal output voltage of the inverter and shall meet the requirements of IEC 61439. The low voltage AC switchboard shall have an insulation voltage of 1000 Vac. The low voltage AC switchboard shall not be of less than 2.0 mm metallic sheet, shall be of at least IP31 for indoor and shall be weatherproofed IP65 for exterior use. It shall have a segregation of at least Form 2b. The low voltage AC switchboard shall be free standing with at least front access and bottom entry.

The arrangement of incoming and outgoing ways shall be made in a logical consistent manner taking into consideration speed and safety during installation, operation and maintenance. The fault rating of the main switchboard shall be defined by the Contractor for 1 second fully type tested and shall be fitted with air circuit breaker, molded case circuit breaker, miniature circuit breaker as required by the design of the system.

Cable glands and conduit entries shall be provided as required by the design of the system. Sufficient space shall be provided in the low voltage AC switchboard to cater for the cables to bend and spread from the cable gland plate or bar to the terminals in a logical consistent

manner without crossing of cores of a cable or of adjacent cables. Moreover, adequate space shall be provided to facilitate the removal of any cable termination without the need to remove any other termination.
All conductors and busbars, with the exception of the earthing bars or tape, shall be clearly marked with the appropriate phase and neutral colors in accordance with IEC 60446. Operating handles, locking devices etc. shall be located within the limits of 450mm and 1900mm above floor level. The low voltage ac switchboard shall also incorporate On/Off/Trip status indicators on the front panel for all circuits.
Copper busbars and copper cables of appropriate cross section shall be provided for earthing and bonding.

5.7.2 Busbar and Busbar Connections

Busbars and busbar connections shall be of high conductivity copper and shall be extensible at both ends. Busbars shall be continuous and of constant cross section throughout their lengths with connections as short and straight as possible. Access to busbars and the busbar connections shall be gained only by the removal of covers secured by bolts and screws. Such covers shall be clearly marked "BUSBARS" along with the short circuit current rating and the fault level at the rated voltage. All neutral busbars shall be of the same cross-sectional areas as the associated phase busbars. All joints and connections to the busbars shall be tin coated. The busbars and busbar support shall be arranged to withstand, without damage, the effects of any fault current up to and including the maximum rated breaking capacity to the switchboard.

5.7.3 Air Circuit Breaker for LV Systems

The air circuit-breaker shall be constructed and tested in accordance with IEC 60947. The air circuit-breaker shall have a rated service voltage of inverter output voltage and a rated insulation voltage of 1000 V. The rated uninterrupted current and the rated short time withstand current (1 sec) of the air circuit breaker shall be defined by the Contractor based on the design of the system. The air circuit breaker shall be in withdrawable version. For withdrawable version, the position (connected, test, isolated) of the moving part shall be clearly indicated. It shall be impossible to rack-out the air circuit breaker unless the contacts are open. The withdrawable version shall be pad lockable in "test position" and in "isolated position". The fixed version shall also be pad lockable in open position.
The following accessories shall be available for the air circuit breaker:

- Shunt opening/closing release
- Second shunt opening and second shunt closing release for redundancy
- Geared motor for the automatic charging of the closing springs, with limited inrush power, with local and remote selector switch.
- Mechanical and electrical signaling of overcurrent release trip
- Trip reset release
- Auxiliary contacts (status, connected/test/disconnected position, ready to close, spring charged), pre-wired, to a small wiring terminal block. The Auxiliary contacts shall be used to provide status on the local SCADA system.

The shunt devices and geared motor shall be suitable for 110 Vdc. If applicable and where necessary, interlock system among circuit-breakers shall be provided. In addition, the interlock system of main circuit breakers shall consider the status and conditions of other associated systems in the PV farm to ensure safe operation of the system.

The air circuit breaker shall be equipped with electronic trip release. The protection ANSI 49, ANSI 51, ANSI 50 and ANSI 51N shall be provided and adjustable. A watchdog shall be available. The configuration of the unit shall be password protected. The electronic trip release shall also be able to export information, including indication of tripped protection after a fault, alarms and warnings among others, and receive command through the local communication bus.

5.7.4 Moulded Case Circuit Breaker

The Moulded case circuit-breaker shall be constructed and tested in accordance with IEC 60947. The Moulded case circuit-breaker shall have a rated service voltage of of inverter output voltage and a rated insulation voltage of 1000 V. The rated uninterrupted current and the rated short-time withstand current (1 sec) of the Moulded case circuit-breaker shall be defined by the Contractor based on the design of the system. The Moulded case circuit-breaker shall also be pad lockable in open position.

The following accessories shall be available for the Moulded case circuit breaker:

Shunt opening/closing release

Auxiliary contacts for open, close and trip status, pre-wired, to a small wiring terminal block. The auxiliary contacts shall be used to provide status on the local SCADA.

The shunt devices shall be suitable for 110 Vdc. If applicable and where necessary, interlocks among circuit-breakers shall be provided.

The Moulded case circuit breaker shall be equipped with thermomagnetic or electronic trip units as required by the design of the system. The thermomagnetic trip unit shall be fitted with a protection threshold against overload and a protection threshold against short-circuit. The threshold setting of the thermomagnetic trip unit shall be adjustable. The electronic trip unit shall be self-supplied and shall provide protection against overload and against short-circuit with intentional delay. It shall be possible to adjust the trip threshold for the protection against short-circuit independently of the protection against overload.

5.7.5 Surge Protective Device

The surge protective device shall be suitable for the PV system in accordance with IEC 60364. The type, the discharge current and the impulse current of the surge protective device for the AC system shall be defined by the Contractor and shall be submitted to the Engineer/ Employer for approval. The surge protective device shall feature a local visual status indication and shall incorporate remote contact signaling to indicate normal operating state. In case of surge protective device having the technology combining disconnection and short-circuiting device for safe electrical isolation in event of arcs, the status of the disconnection and short-circuiting device should also be made available to the local SCADA System and remotely.

5.7.6 Fuse

The fuse and fuse holder shall be in compliance with IEC 60947-3. The rated current and breaking capacity of the fuse shall be defined by the Contractor in line with the design of the system. Each fuse shall be housed in a properly rated fuse holder with fuse status indication which shall be made available to the local SCADA system.

Medium Voltage Dry Type Transformer

Dry Type Inverter Transformer

Sr. No.	PARAMETERS	INVERTER TRANSFORMER
i)	**Type**	Epoxy cast resin/resin encapsulated
ii)	**Duty, Service & Application**	Continuous Solar Inverter application and converter duty (Indoor)
iii)	**MVA & Voltage ratio**	As per system requirement and SLD.
iv)	**Vector group**	
v)	**Frequency**	50 Hz
vi)	**Tap changer type & range**	As per system requirement and SLD. OCTC +/-5% (min.)
vii)	**Impedance**	As per system requirement and SLD & as per Inverter manufacturer recommendation.
viii)	**Number of phases**	Three (3)
ix)	**Type of cooling**	**Natural Circulation (AN)** Transformer shall be provided with suitable ventilation system to ensure the temperature rise limits under most severe condition while in service however all tests and performance guarantee shall correspond to air natural (AN) cooling.
x)	**Bushing rating, Insulation class (Winding & bushing)**	As per relevant IEC (However, Inverter Transformer LV side winding & bushing insulation class shall be of at least 3.6 kV)
xi)	**Maximum Temperature rise of winding over 50 deg. C ambient.** **(By resistance method) with Air Natural (AN) cooling.**	**90** deg.C. (class F) **115** deg.C. (class H)

xii)	**Medium voltage(22KV) system short circuit current**	At least 16 KA for 1 Second
xiii)	**Low voltage system short circuit current**	At least 50 KA for 1 Sec
xiv)	**SC withstand time (thermal)**	2 sec
xv)	**Noise Level**	Not to exceed values specified in NEMA TR-1.
xvi)	**PD Level (max. Allowable)**	10 pc
xvii)	**Loading Capability**	Continuous operation at rated KVA on any tap with voltage variation of +/-10% corresponding to the voltage of the tap as well as in accordance with IEC60076-12.
xviii)	**Flux Density**	Not to exceed 1.9 Wb/sq.m. at any tap position with +/-10% voltage variation from voltage corresponding to the tap. Transformer shall also withstand following over fluxing conditions due combined voltage and frequency fluctuations: a) 110% for continuous rating. b) 125% for at least one minute. c) 140% for at least five seconds.
xix)	**Power frequency withstand voltage**	50 KV
xx)	**Rated lightning impulse withstand**	125 KV

Codes and Standards

Dry type transformers	IEC 60076-11; IEEE Std C57.159-2016
CEB Grid Code	

Design and Constructional Features

a. The dry type transformer shall comply with IEC 60076, specifically to IEC 60076-11. For the design of the transformer and relevant accessories, the bidder shall refer to the ambient conditions given by IEC 60076-11 and adapt to the site conditions.
b. The dry type transformer shall be air-cooled by means of natural circulation (AN). The dry type transformer shall be explosion-resistant and fire- resistant.
c. Wherever required by the mounting arrangement on site, anti-vibration pads shall be provided to prevent the transmission of sound to the supporting structure.

d. The core shall be constructed from high grade non-ageing cold rolled grain-oriented silicon steel laminations of M4 grade or better quality. The core laminations shall be specially treated to avoid moisture absorption and consequent core corrosion.
e. The material used for the magnetic core shall have a low core loss factor and its laminations shall comply with the requirements of IEC 60404.
f. The maximum magnetic induction of the transformer shall be chosen to limit local and overall temperature rise of the magnetic circuit.
g. The insulation of core to clamp-plates shall be able to withstand a power frequency voltage of 2 kV (rms) for one (1) minute.
h. The transformers shall be housed in a metal protective housing, having a degree of protection of IP-23. The housing door shall be interlocked such that it should be possible to open the door only when transformer is off. Suitable bi-directional rollers shall be provided with suitable locking arrangement.
i. The transformer shall be fitted with appropriate lifting lugs.
j. The primary and secondary coils of the dry type transformer shall be wound separately and encapsulated in cast resin using a vacuum pressure impregnation process.
k. Winding conductor shall be electrolytic grade Copper. Windings shall be of class F insulation or better. All windings are to be uniformly insulated.
l. The transformers insulation system shall have temperature class F and the transformer shall be designed for a temperature rise class B (in accordance with IEC 60076-11 and IEC 60076-12).
m. In particular, windings and magnetic core temperature protection shall be provided.
n. Transformer HV bushings and LV bushings can be either solid porcelain or epoxy type. Bushing shall be suitable for satisfactory operation in the high ambient temperature inside Bus Duct enclosure (if applicable). LV flange area shall be of non-magnetic material.
o. An off-load tap changer shall be provided for the MV/LV.
p. The transformer shall be capable of withstanding, on any tap position, the thermal and dynamic effects of external short circuit conditions without damage. The value of percentage impedance measured at the mid tap position shall be in accordance with the standard values set out in IEC 60076-11. The transformer short- circuit withstand shall be verified in accordance with 60076-5 and the short circuit withstand time duration shall not be less than 2s.
q. Windings and connections to the bushings and to the tap changers (if any) shall withstand mechanical and electro-dynamical stresses caused by handling or short- circuits.
r. The transformers shall be designed for operation in over fluxing (as per IEC 60076- 11) and over-excitation (as per IEC 60076-1). The transformer shall be designed so that the mechanical and electrical stresses due to the inrush current cannot cause damage and/or rapid aging of the windings, the insulating material or any other parts.
s. Bushing CTs shall be provided in the LV neutral side of adequate rating for REF protection, WTI, etc. (as applicable).
t. The core of the transformer shall be electrically grounded. Two earthing terminals, each capable of carrying the full lower voltage fault current for a period of not less than 3 s, shall

be provided. They shall be located one on either side and near the bottom of the transformer to facilitate connection to the local earthing system.

u. For Marshalling Box the sheet steel used shall be at least 1.6 mm thick cold rolled. The box shall be tank mounted type. The degree of protection shall be IP-54 in accordance with IS-13947. Wiring Scheme shall be engraved in a stainless-steel plate with viewable font size and the same shall be fixed inside the Marshalling Box door.
v. The transformer environmental, climatic and fire behavior classes shall be chosen in accordance with IEC 60076-11, taking in consideration the transformer ambient conditions and installation criteria. The transformers insulation system shall have temperature class F and the transformer shall be designed for a temperature rise class B (in accordance with IEC 60076-11 and IEC 60076-12).
w. Transformer room shall be provided with suitable ventilation system to ensure the temperature rise limits under most severe condition while in service however all tests and performance shall correspond to air natural cooling.
x. The enclosure, where applicable, shall be chosen in order to ensure the compliance of the above-mentioned temperature rise, in accordance with the specifications given by IEC 62271-202 Annex DD. The temperature of the core, metallic parts and adjacent materials shall not reach a value that shall cause damage or undue ageing to any part of the transformer.
y. The measured losses and electrical characteristics of the transformer shall comply with IEC tolerances. In particular, no tolerances shall be applied for sound level and temperature rise limits.
z. The transformer shall be equipped with all the accessories, instrumentation and protections necessary for easy maintenance and for a safe and reliable operation.
aa. All alarms and tripping signals for transformers shall be individually connected to the SCADA for control and monitoring.

Special Requirements of Inverter Duty Transformer

a. Inverter Transformer shall have copper/Aluminum electrostatic grounding Shield winding between LV & HV windings.
b. It is recommended that the design of the electrostatic shield considers the effect of the eddy losses due to the magnetic field. As thinner the shield metal, the less are the eddy losses. Higher conductivity shielding (copper foil) has less eddy losses than lower conductivity (aluminum strip) material. Hence it is preferable to use the copper as shielding winding.
c. It is recommended that care be taken in the design of the electrostatic shield so as not to create a harmonic heating problem.
d. Each LV winding must be capable of handling non-sinusoidal voltage with voltage gradient as per relevant applicable standards and Inverter manufacturer recommendation. Also, each shield winding shall be taken out to tank with two separate connections from shield to bushing with proper support with 2 nos. 3.6 kV shield bushings and same shall be brought down along with support insulator from tank & copper flat up to the bottom of the tank for independent grounding.
e. As Inverter transformer is provided indoor, it shall be necessarily dry type.

f. Harmonic Factor as per Inverter manufacturer recommendation must be taken into account while designing the transformer. The extra no load loss due to voltage harmonics and load and stray load loss due to current harmonics (as applicable) and must be taken into consideration in transformer design. In addition, the dc bias component of 0.5% of rated Inverter output current is to be accounted for its effect on the transformer design.
g. The adverse effect on life of transformer due to cloud intermittency and solar generation loading cycle must be compensated through suitable design (as applicable).
h. The thermal design of Inverter Transformer needs to consider the temperature dependent performance of the Inverter. It is to in accordance with Inverter output and under worst condition it should not limit Inverter output.
i. The transformer needs to be designed for long term operating conditions with asymmetrical load on LV side i.e., the transformer needs to operate reliable with Inverter supplying power to LV winding.
j. For multi winding transformer, it is recommended to have close coupling and equal impedances on each of LV winding to HV winding and to have high enough impedance (8% min. based on one LV winding rating) between two LV windings in order to decouple these windings.
k. In case of inverter transformer, it shall be proven and of successfully type tested design
l. Contacts from Inverter transformer fittings/protection devices shall be wired for tripping of Inverter transformer Circuit Breaker. Detailed scheme regarding same shall be finalized during detailed engineering.
m. Cumulative kVA rating of inverter transformer shall not be less than total rated kVA capacity of respective Inverters

Painting

The inside of enclosure and accessories (except M. Box) shall be painted with two coats of fully glossy white color with total DFT of 25 to 60 microns. The external paint color of transformer & accessories shall be blue corresponding to RAL 5012. The external surface of transformer & accessories shall have two coats of chemical resistant epoxy zinc phosphate primer and two coats of polyurethane finish paint with total DFT of 80 to 150 microns. The internal surface of M.Box shall have two coats of chemical resistant epoxy zinc phosphate primer and two coats of chemical & thermal resistant epoxy enamel white paint with total DFT of 80 to 150 microns.

Fitting

a. Winding temperature indicator (WTI) Shall be Platinum resistance type temperature detector in each limb.
b. Single Indicating meter may be provided for display of temperature of all limbs. Accuracy class of Indicating meter shall be +/- 1% or better and it shall have least count of 0.1ºC or better. 1 no. 4-20 mA signal shall be provided for remote monitoring of winding Temperature.
c. RTD/Thermistors: 1 No. PT-RTD shall be embedded in each limb with alarm and trip contacts for remote annunciation. Additional 1 No. thermistor/RTD shall be embedded in each limb.

d. Fittings which are generally required for satisfactory operation of the transformers are deemed to be included, in the scope of supply of the Contractor.

Tests and Inspection

In case the bidder/contractor has conducted type test(s) within last ten years, he may submit the type test reports to the owner for waiver of conductance of such type test(s). These reports should be for the tests conducted on the equipment similar to those proposed to be supplied under this contract and test(s) should have been either conducted at an independent laboratory or should have been witnessed by a client.

In case the Bidder is not able to submit report of the type test(s) conducted within last ten years from the date LOA by the Employer, or in case the type test report(s) are not found to be meeting the specification requirements, the Bidder shall conduct all such tests under this contract at no additional cost to the Employer and submit the reports for approval.

Short Circuit Test: -

In case short circuit test has not been conducted or the test report not meeting the specification requirement for the offered transformer manufacturer, Bidder /Sub-vendor shall establish" Ability to withstand the dynamic effects of short circuit "for the offered transformer as per latest IEC 60076-5.The ability to withstand the dynamic effects of short circuit can be established either by performing actual short circuit test or by method of calculation with reference to short circuit tested reference transformer as per IEC-60076-5/Annexure-A&B. Bidder shall choose any one the two options mentioned below;

Option-1:- Performing actual short circuit test as Type Test. In order to meet project schedule, Bidder/Sub vendor shall take suitable steps quite in advance to ensure successful conduction of short circuit test within three months time from date of LOA failing which the offered make of the transformer shall not be considered.

Option-2: **<u>By theoretical evaluation of the ability to withstand dynamic effect of short circuit based on 'Calculation and Design and Manufacture Consideration'</u>**. In this regard the guidelines given in Annexure-A with applicable tables of the IEC 60076-5 is to be followed. The reference transformer chosen shall be of same application, winding configuration, conductor current density and as per Annexure-B of latest IEC-60076-5. Necessary Design document and reference test reports related to theoretical comparative evaluation must be submitted by Manufacturer/Bidder as required by Employer in this case.

S.N.	ROUTINE TESTS	
1.	All routine test shall be carried out in accordance with IEC 60076.	√
2.	Measurement of Voltage Ratio & phase displacement (as per IEC 60076-1)	√
3.	Measurement of winding resistance on all the taps (as per IEC 60076-1)	√

4.	Vector group and Polarity Check (as per IEC 60076-1)	√
5.	Magnetic Balance and Magnetising Current Test	√
6.	Measurement of no load current with 415 V, 50 Hz AC supply	√
7.	Measurement of no load losses and current at 90%, 100% & 110% of rated voltage (as per IEC 60076-1)	√
8.	Load Loss & Short Circuit Impedance Measurement on principal & Extreme Taps	√
9.	IR measurement (As per IEC 60076-1)	√
10.	Measurement of capacitance & tan delta to determine capacitance between winding & earth.	√
11.	Separate Source Voltage Withstand Test /Applied voltage test (as per IEC 60076-3)	√
12.	Induced overvoltage test/Induced voltage withstand (IVW) test as per IEC60076 part 3	√
13.	Repeat no load current/loss & IR after completion of all electrical test	√
14.	Oil leakage test on completely assembled transformer along with radiators (as per relevant clause of this sub section)	√
15.	Jacking test followed by D.P. test	√
16.	Marshalling Box/Cable box: It shall not be possible to insert a thin sheet of paper under gaskets and through enclosure joints.	√
17.	IR measurement on wiring of Marshalling Box.	√

S.N.	**TYPE TESTS #**	
1.	Lightning impulse (Full and chopped wave) test on windings (as per IEC 60076-3) (Not applicable for LV)	√
2.	Short circuit test (special test) as per IEC 60076-5 (if applicable).	√
3.	Temperature Rise test at a tap corresponding to maximum losses as per IEC 60076. Gas Chromatography shall be conducted on oil sample taken before & immediately after temp. rise test. Gas analysis shall be as per IS: 9434 (based on IEC: 60567), results will be interpreted as per IS: 10593 (based on IEC: 60599).	√
4.	Measurement of harmonics of no-load current (special test)	√
5.	Measurement of acoustic noise level as per NEMA TR-1 (special test)	√

S.N.	TYPE TESTS #	
6.	Tank Vacuum & Pressure Test (as per CBIP norms)	√

(#) NOTE:-

i) All the type and special tests shall be conducted after performing Short Circuit Test. If Tank Vacuum & Pressure Test is to be carried out, then it shall be conducted before SC test.

ii) Inverter Transformer LV winding Di-electric tests (except for lightning impulse test for LV winding) shall be carried out corresponding to levels (as per IEC 60076) for 3.6 kV class.

iii) All Type tests should be done as per Engineer's approved procedure.

5.8 Routine / Type Tests (Dry Type Transformers)

Transformer shall be short circuit tested after conducting the routine tests. Rest of the type tests shall be conducted after successful short circuit testing.

All routine tests in accordance with the respective IEC standards shall be carried out on each transformer.

And All Type tests should be done as per Engineer's/ Employer's approved procedure.

Routine / Type Tests (Dry Type Transformers)			
a.)	Measurement of winding Resistance for each tap position.		Routine
b.)	Measurement of voltage ratio at each taps position.		Routine
c.)	Vector group and polarity check		Routine
d.)	Measurement of impedance voltage/short circuit impedance & load loss at principal tap and extreme taps		Routine
e.)	Measurement of no-load losses and magnetising current at rated frequency and 90%, 100% and 110% rated voltage.		Routine
f)	Measurement of insulation resistance		Routine
g)	Measurement of capacitance and tan delta		Routine
h)	Dielectric Tests		
	1)	PF/Separate source AC withstand voltage test.	Routine
	2)	Chopped wave lightning impulse voltage test on windings (as per IEC 60076-3) (Not applicable for	Type

		LV)	
	3)	Induced over voltage withstand test	Routine
i)	Partial discharge measurement		Routine
j)	Measurement of iron loss & IR (repeat after induced voltage test)		Routine
k)	Short Circuit test as per IEC (if applicable)		Type
l)	Noise Level Measurement		Type
o)	Temperature rise test as per IEC (HV & LV winding)		Type

Dry Type Auxiliary Transformers:

a. The auxiliary loads inside the compact station shall be supplied by an auxiliary transformer fed from the solar compact station.
b. The Auxiliary Transformer shall be dry type transformer in ventilated steel metal protected housing having a degree of protection of IP 41 enclosures. The enclosure shall be provided with suitable hardware (as required).
c. Transformer shall be suitable for continuous indoor duty application. Transformer shall be complete & functional in all respect.
d. Dry Type Transformer shall be constructed in accordance to IEC 60076.
e. Transformer rating and all related technical parameters including tap changer (if applicable) shall be as per system requirement/SLD and relevant standards.
f. The transformers shall be housed in a metal protective housing, having a degree of protection of IP-23.
g. The conductors shall be of electrolytic grade copper free from scales & burrs.
h. Dry Type Transformer windings shall be of class F insulation or better. Cooling shall be AN.
i. The transformer shall be protected by MV fuses.
j. The core shall be constructed from non-ageing, cold rolled, grain-oriented silicon steel laminations (M4 or better).
k. LV nominal system voltage is 400 V. Rated transformer LV voltage (which is the open circuit voltage as defined in IEC 60076) is stated here as 415 V to ensure 400 V at transformer terminals on full load.
l. Depending on voltage drop in the transformer, this 415 V value may vary slightly to suit the transformer manufacturer's standard design. The 22/0.415 kV common auxiliary transformer shall be properly sized to accommodate the low voltage load of the solar compact station and plus 25%. The final sizing shall be based on load calculations carried out by the Contractor and subject to approval by the Engineer.

m. Full details of the transformers shall be finalized by the Contractor at detailed design stage where calculations shall be submitted to the Engineer/Employer for approval prior to any ordering.
n. The fittings/accessories including protection/monitoring device (temperature scanner) generally required for satisfactory operation of the transformer, are to be provided.
o. All alarms and tripping signals for transformers shall be individually connected to the SCADA for control and monitoring.

5.9 Weather Monitoring Stations

The Contractor shall provide one (1) weather monitoring stations which would record meteorological data to evaluate PV farm performance. The station shall be located on the CMCS building located adjacent to the Floating Solar PV Farm. The monitoring station shall be capable of collecting the data points at every one-minute interval. The station shall be equipped with a sufficiently high data storage capability thus ensuring the data are recorded for at least one year. Moreover, the Contractor shall also have to make provision for a UPS system such that even in the absence of AC power for two (2) days, the data are still recorded.

Additionally, the recorded data shall be displayed on real-time on the SCADA screen available in the Control Room. The following three (3) main parameters should mandatorily be monitored by each station:

1) Solar irradiance (W/m2) – pyranometers (measuring, global, direct and diffused solar irradiations) with a measurement tolerance within ± 2 % shall be installed
2) Ambient air temperature - accuracy better than ± 1 % shall be installed next to the irradiation sensors
3) Relative humidity - accuracy better than ± 1 % shall be installed next to the irradiation sensors

The monitoring systems shall be supplied complete with its available software/hardware, user manuals and appropriate technical support. Measurement of key technical parameters shall be done at one-minute intervals.

6. 22 kV MEDIUM VOLTAGE SWITCHGEAR

6.1 General

The 22KV MV switchgear shall provide the interface between the MV system of the floating solar PV farm and the MV distribution network of the Central Electricity Board.

The 22KV MV Switchgear shall be designed for indoor operation on a nominal system voltage of 22KV, 3-Phase, 50Hz.

The MV switchgear shall be modular metal-enclosed high voltage SF6/ Vacuum switchgear manufactured to the requirements of IEC 62271

The Switchgear Shall fulfill the internal arc classification IAC AFLR, according to IEC 62271-200 and shall have a degree of protection of at least IP3X.

There should be a metallic demarcation barrier installed between the main Circuit Breaker panel and transformer outgoing panel. The demarcation barrier shall be installed at the front and back of the switchgear panels. The height of the demarcation barrier shall be from floor to roof level. The demarcation barrier shall be solidly earthed. 22KV MV Switchgear shall be air conditioned separately on both demarcated sides in the switchgear room. Condensation may be prevented by use of de-humifying equipment. The Switchgear shall have anti-condensation heaters inside MV cubicles and let them run continuously, i.e., without automatic or manual control.

The Tenderer shall determine the requirements and dimensions of the building as part of his Tender. The substation building shall be constructed of reinforced concrete. The design of the switchgear room and switchgears shall be approved by the Engineer/ Employer prior to construction. In addition, the wiring diagram of the complete switchgear shall be approved by the Engineer/ Employer prior to mounting of the switchgear panel.

The Contractor shall submit all relevant data of the proposed switchgears and associated equipment in the provided Technical Schedule List (Section VII- Schedule of Guaranteed Particulars). The Engineer/ Employer shall require all test certificates/ documents before commissioning the MV switchgear panels. It is important to note that the MV switchgear room, switchgears, transformers and any material and equipment forming part of the switchgear room shall be approved by the ENGINEER/ EMPLOYER prior to manufacturing and ordering.

The subsequent section described hereunder makes reference to tender drawings in the document.

6.2 Electrical Characteristics

The 22 kV switchgear shall comply with the general requirements specified in IEC 62271-1 as detailed below:

Table 6.1: Technical Requirements for 22kV Switchgear

Description	Unit	Requirement
Nominal System Voltage	kV	22
Highest System Voltage for Equipment	kV	24
Rated Voltage	kV	24
Rated Frequency	Hz	50
System Earthing		Effectively Earthed.
Type of Installation		Indoor
Number of Phases		3
Rated Voltage	kV	24
Rated Frequency	Hz	50
Rated Lightning Impulse Withstand Level (1.2/50 µs peak value)	kV pk	125
Rated Normal Current (Busbar)	A	630
Rated Normal Current (Feeder)	A	630
Rated Normal Current (Transformer Incomer)	A	630
Rated short time withstand current	kA	16 kA (min)

Rated duration of short circuit	Sec	1
Rated peak withstand current	kA	40 kA (min)
Degree of protection (enclosure)		IP3X
Loss of service continuity category		LSC2A
Class of partitions and shutters		PM
IAC Classification		Accessibility Type A (authorized personnel)
Type of Accessibility		AFLR
Short circuit current for IAC	kA	16
Short circuit duration for IAC	S	0.5
Particulars of the Operating Devices		
Type of operating device		Motor charged spring
Rated supply voltage		110V d.c.

6.3 Medium Voltage Switchboard of Substation

The Cubicles arrangement shall be from left to right as follows (Pl. refer Key SLD as well):

Cubicle No. 1 (Incoming No. 1)

22 kV load break switches for the control of first incoming feeder (see item 1).

Cubicle No. 2 (Incoming No. 2)

22 kV load break switches for the control of first incoming feeder (see item 1).

Cubicle No. 3

Voltage Transformer (V.T) Cubicle. (see item 2).

Cubicle No. 4

CEB Circuit breaker cubicle with double Isolation. (see item 3).

Cubicle No. 5

Voltage Transformer (V.T) Cubicle. (see item 2).

Following Safety equipment for switching operations Shall be provided.

(i) 22 kV insulating mat.
(ii) One pair of 22 kV insulating gloves.

(iii) Appropriate Line tester with both visual and audible features.
(iv) Rescue rod.

Cubicle No. 6 (Incoming from FPV Tranformer-01)

22KV Circuit breaker for the control of Incomer from FPV Transformer-01 (See item 4)

Cubicle No. 7 (Incoming from FPV Tranformer-02)

22KV Circuit breaker for the control of Incomer from FPV Transformer-02 (See item 4)

6.3.1 Item 1 - Incoming Feeder Cubicle :

The 22 kV Incoming Feeder Cubicle shall comprise the following basic equipment: -

S.No	Description
1.	Three-phase 630 A busbar
2.	Motorized load break switch disconnector of rating 630A and housed in SF6/ Vacuum filled enclosure having padlocking facilities.
3.	Motor operated spring charged operating mechanism for quick closing and opening independent of the operator. Manual spring charged operating mechanism should also be provided in case of failure of motor.
4.	Earthing switch located in such a position to allow its contacts to be seen easily through the cubicle window
5.	Mechanical interlocking system between disconnector and earthing switch
6.	Neon lamp for live cable indication
7.	Cable compartment with cable terminations for the reception of 3-core aluminum or copper cable to IEC 60502-2. The cable entry is to be at the front of the panel.
8.	Bottom Plate with the Cable Gland
9.	Built-in Padlocking device of the cubicle door.

Switch Disconnector

The switch disconnector shall comply with IEC 62271-102 and should be fully insulated by SF6 gas or Vacuum. The switch disconnector shall be triple pole with integral fault making earth switch. The rated current of the switch disconnector shall be 630 A. The switch disconnector shall be capable of making on to a fault whose magnitude is equal to the specified short circuit level for the time specified in elsewhere.

The switch disconnector shall operate by means of a motor-operated spring stored energy system, featuring a rapid acting mechanism, independent of the operator. The motor shall be suitable for 110 Vdc. Mechanical indicator for “charged-discharged” position shall be provided. In the absence of auxiliary power supply, the manual operation of the spring charging system shall be possible. The switch disconnector shall also be equipped with closing and
opening coils suitable for 110 Vdc.

Auxiliary contacts shall be provided on the switch disconnector to indicate its status to the local SCADA system. The switch disconnector shall be equipped with a SF6 pressure switch with two (2) levels of alarms for low pressure and very low pressure respectively.

Mechanical indicators of the switch disconnector position shall be provided on the front fascia. A selector switch shall also be provided for the remote and local operation of the switch disconnector. Remote operation shall only be possible from CEB System Control Centre located in Curepipe. The key interlocking system shall be release only in local mode. Push buttons shall be made available on the front fascia of the low voltage compartment for the opening and closing of the switch disconnector.

Voltage Presence Indicators

The switchgear cubicle shall be equipped with voltage presence indicators according to IEC 62271-206. The voltage presence indicators shall allow the visualization of voltage presence on each phase with LED indication.

The front facia should be equipped with appropriate padlocking facilities that will allow the operator to lock the disconnector switch and earth switch in close/open position independently.

The Incoming 3-Core Power Cable shall be centered below the Panel Base / Bottom Plate and Cable Terminations (Indoor) shall be Mounted Inside the MV Compartment of The Incomer Switchgear Panel. Rubber Bushings shall be Provided for Sleeve Protection for cable of size ranging from 65mm to 100mm.

The front facia should be equipped with appropriate padlocking facilities that will allow the operator to lock the disconnector switch and earth switch in close/open position independently.

The load break switch disconnector shall have both local and remote modes of operation via a key selector switch which should be mounted on the front facia. The key should be released in local mode only.

6.3.2 Item 2 – Voltage Transformer Cubicle

The 22 kV Voltage transformer Cubicle shall comprise the following basic equipment: -

S.No	Description
1.	Three-phase 630 A busbar
2.	Triple pole Isolator
3.	Manual operating Mechanism
4.	HRC Fuses to DIN Specifications rated to suit VTs Rating. Access to fuses shall only be possible with the switch in the Earth Position in such a way that both sides of the fuse are affectively earthed.
5.	Auxiliary switch connected to the VT Secondaries and opening with the 22KV Isolator to prevent feedback from the LV side.
6.	Single Phase Voltage Transformers
7.	Secondary windings. Each PT shall be equipped with 2 winding one for metering and second one for open delta Protection.
8.	LV Fuse box containing 3 LV Fuses of appropriate rating + 3 Neutral links
9.	Built-in padlocking facility on the cubicle door.

3-position disconnector

The 3-position disconnector shall be positioned between the DIN fuses and busbars. The 3-position disconnector shall be integral with fault making earth switches and shall be in one of three positions: “closed”, “open” or “earthed”. Mechanical indicators shall be provided for the switch position on the front fascia. Auxiliary contacts shall be provided on the 3-position disconnector to indicate its status to the local SCADA system.

Medium voltage fuses

The medium voltage fuses shall be of the DIN type featuring striker pins, suitable for the protection of the MV/ LV transformer for auxiliaries. The rated voltage of the fuses shall be 24 kV. The rated current and the rated breaking capacity of the fuses shall be determined by the Contractor based on the rating of the MV/LV transformer for auxiliaries. The mechanical signaling and auxiliary contacts for blown fuses shall be provided.

Access to the fuses shall only be possible with the switch in the “Earth” position in such a way that both sides of the fuse are effectively earthed.

Voltage Transformers

The voltage transformers shall comply with IEC 61869-3 and shall be of the dry type. Three (3) single phase voltage transformers shall be provided for both protective relay and metering purposes.

The primary windings shall be connected through DIN fuses featuring striker pins. The mechanical signalling and auxiliary contacts for blown fuses shall be provided. Access to the fuses shall only be possible when both its sides are effectively earthed. Proper interlocking should be provided between upstream 3-position disconnector and the downstream control and protection device on the secondary side of the voltage transformers to prevent power infeed from the secondary side of the voltage transformer.

The metering core shall have an accuracy Class 0.2 and rated burden of not less than 10VA. The protection core shall have an accuracy class of 3P a rated burden of not less than 15 VA. The burden calculation for the metering core shall be rated correctly to operate within the optimum range (i.e. between 0% and 100% of the rated burden). It can be assumed that the maximum burden for the meter is 3VA per phase and secondly, the supervisory cable used is 1.5 mm2 Copper cable. The contractor shall perform calculation for the burden, taking into consideration a spare capacity of 20%, to be submitted for approval prior to ordering.

The front facia should be equipped with appropriate padlocking facilities that will allow the operator to lock the disconnector switch and earth switch in close/open position independently. Provision shall also be made to prevent or damp any ferro resonance effect in the voltage transformers.

Voltage transformers shall be designed so that saturation of their cores does not occur when 1.732 times normal voltage is applied to each winding.

The ratio for the voltage transformers shall be as follows:
Core 1: Metering Purposes : $22000/\sqrt{3} : 110/\sqrt{3}$
Core 2: Protective Relay Purposes : $22000/\sqrt{3} : 110/3$ or $110/\sqrt{3}$

Secondary circuits shall not be connected in parallel.

The voltage transformer secondary circuits shall be earthed at one point only and metal cases shall be separately earthed. Secondary protection (fuses and miniature circuit breakers) shall be provided as close as possible to each voltage transformer and labelled to show their function and phase color. Auxiliary contact shall be provided for the status of the secondary equipment.

All calculations for voltage transformer design shall be submitted to the Engineer/ Employer for review at an early stage, prior to manufacture. In addition, the Contractor shall send the voltage transformers (including the spares) to CEB Meter Laboratory for necessary tests before commissioning. The Contractor shall bear the cost for the testing of the VTs.

Voltage Presence Indicators

The switchgear cubicle shall be equipped with voltage presence indicators according to IEC 62271-206. The voltage presence indicators shall allow the visualization of voltage presence on each phase with LED indication.

6.3.3 Item 3 – CEB Circuit Breaker Cubicle with double isolation:

The 22 kV circuit breaker cubicle shall be of double isolation and comprise of the following basic equipment: -

S.No	Description
1.	Three-phase 630 A busbar
2.	Triple pole Isolator on both sides of CB
3.	SF6 Gas/ Vacuum Circuit Breaker
4.	Motor operated spring charged operating mechanism for quick closing and opening both locally by push button and remotely.
5.	Tripping coil 110 V dc for emergency tripping
6.	Trip release device to work in conjunction with the relay
7.	Current Transformers with dual Primaries.
8.	Voltage test terminal block
9.	Current test terminal block.
10.	Tripping test terminal block
11.	Mechanical interlocking between earthing switch and triple pole Isolator
12.	Earthing switch located in a position to allow its contacts or position to be seen easily through the cubicle window
13.	Bottom plate with cable gland
14.	Neon lamp for live cable indication
15.	Built-in padlocking device for the cubicle door

Position Disconnectors

The 3-position disconnectors shall be positioned in such a way as to provide double isolation of the circuit breaker from the busbars. The disconnectors can only be operated when the circuit breaker is maintained in open position. The 3- position disconnectors shall be integral with fault making earth switches and shall be in one of three positions: “closed”, “open” or “earthed”. The two (2) 3- position switch disconnectors shall be interlocked with each other. Mechanical indicators shall be provided for the switch position on the front fascia. Auxiliary contacts shall be provided on the 3-position disconnectors to indicate its status to the local SCADA system and the remote System Control Centre in Curepipe.

Circuit Breaker of SF6 Type or Vacuum Type

The circuit-breaker shall be of the SF6 or Vacuum type and shall comply with IEC 62271- 100. The circuit breaker mechanical and electrical endurances shall be chosen from IEC 62271-100 in accordance with their duty. The rated current of the circuit breaker shall be 630 A. The rated short circuit current of the circuit breaker shall be 16 kA.

The circuit breaker shall operate by means of a motor-operated spring-stored energy system, featuring a rapid acting mechanism, independent of the operator. The motor shall be suitable for

110 Vdc. Mechanical indicator for “charged-discharged” position shall be provided. In the absence of auxiliary power supply, the manual operation of the spring charging system shall be possible. The circuit breaker shall also be equipped with opening, closing and tripping coils suitable for 110 Vdc.

Auxiliary contacts shall be provided on the circuit breaker to indicate its status to the local SCADA system and the System Control Centre in Curepipe. In case of SF6, the circuit breaker shall be equipped with a SF6 pressure switch with two (2) levels of alarms for low pressure and very low pressure respectively.

Mechanical indicators of the circuit breaker position shall be provided on the front fascia. A mechanical interlocking shall be implemented between the earthing switch and the triple pole isolator.

A selector switch shall also be provided for the remote and local operation of the circuit breaker. However, the remote operation shall only be by the System Control Centre in Curepipe and not from the local SCADA System of the PV Farm. Local operation of the breaker is from Local SCADA only. Push buttons shall be made available on the front fascia of the low voltage compartment for the opening and closing of the circuit breaker. In addition, the following test blocks shall be provided on the front fascia of the circuit breaker cubicle:

- One (1) voltage test block
- One (1) current test block
- One (1) trip test block

In addition, an interlocking system shall be provided to ensure that closing of this Circuit Breaker shall ONLY be allowed if 22 kV Circuit Breakers of Inverter Transformer’s side towards the Floating Solar Plant are in the open position. The opening of this 22kV Circuit Breaker shall inter trip Circuit breakers of Floating Solar PV Transformers.

Current Transformers

The current transformers shall comply with IEC 61869-2 and shall be of the dry type. The current transformers shall be provided for both protective relay and metering purposes (one core for the main meter and one core for the Protection). Toroidal current transformers will not be acceptable for metering purposes. Current transformers with split iron cores will also not be acceptable. The current transformers shall have dual primaries with current rating 100/200A or 200/400A. The secondary windings of each set of current transformers shall have a rating of 5 A and shall be earthed at one point only, through a bolted disconnecting link.

The maximum continuous rating of the current transformers shall not be less than 150% of the maximum continuous rating of the FPV Plant (2000KW AC). The current transformers including primary winding conductors shall be capable of withstanding without damage the peak and rated short-time currents of the associated equipment.

The contractor shall perform calculation for the burden, taking into consideration a spare capacity of 20%, to be submitted for approval prior to ordering.

The rated volt-amp output of the current transformers shall not be less than the connected burden as installed in service, the burden of cable connections being taken into account. The output of the current transformers shall be not less than 10 VA with an accuracy limit factor of not less than 20 and the Contractor shall ensure that the capacity of the current transformers provided is adequate for operation of the associated protective devices and instruments.

The current transformers provided for protective relay purposes shall be used for combined overcurrent and earth fault protection of the inverse time-overcurrent type and shall have Class 5P20. The current transformers shall have overcurrent and overcurrent limit factors not less than those corresponding to the design short circuit level of the system. The current transformers provided for metering and instrumentation purposes shall have class 0.2.

The current transformers shall be solidly fixed using appropriate support structures. When double-ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformers, indicating clearly the connections required for each tap. The connections and the ratio in use shall be indicated on all connection diagrams.

Magnetization and core loss curves and dc resistance values shall be submitted for each type and rating of current transformers. The metering CT shall be mounted so that P1 is located on CEB side direction and P2 on PV plant side.
In addition, the Contractor shall send the current transformers (including the spares) to CEB Meter Laboratory for necessary tests before commissioning. The Contractor shall bear the cost for the testing of the CTs.

Protection Relay

The protective relay shall be of approved numerical multi-function type and shall comply generally with the requirements of IEC 60255. The protection relay shall be of the latest technology available, at the time of implementation, incorporating a wide range of protection and control functions as well as comprehensive communication facilities. The system shall be IEC 61850 compatible.

The protection relays shall include full programmable scheme logic, self- diagnostics and time tagged event recording (at least 100 events) to indicate the pre-fault currents and voltages by phase and maximum recorded analogue quantities. The protection relay shall integrate a user-friendly interface for troubleshooting and local programming with password. The protective relay shall be suitable for flush mounting on the front fascia of the LV compartment.

The protective relay shall offer two (2) independent over-current stages for phase elements (I>, I>>) and for earth fault (Io>, Io>>). The I>/Io> elements shall operate when the power frequency component of the current exceeds the set threshold. The time/current characteristic associated with these elements must provide a selection of inverse definite minimum time (IDMT) curves or be settable to a fixed (definite) time delay. The relay shall be provided with a start function (and programmable relay output) that responds to the current exceeding either I> or Io> thresholds. In addition, the relay shall have Neutral Voltage Displacement protection functionality and directional functionalities for the overcurrent and earth fault protections.

The auxiliary power supply for protective relays shall be 110V dc. All protective relays supplied shall be tested on site. Proper facility shall be provided for the testing of protective relays and associated circuits. In case, injection test plugs are required for this purpose, the Contractor shall provide them.

The Contractor shall be responsible for providing to the Employer/Engineer relay setting details for relays along with the calculations which will be correctly coordinated with relays of other systems, wherever applicable.

A protective relay study completes with curves illustrating co-ordination between new and existing systems along with all calculations to determine relay settings and CT & VT requirements shall be submitted to the Engineer/ Employer for approval.

The Contractor shall provide the associated documentation, programming software and communication cables as part of his scope of supply. A communications menu system shall be provided in accordance with IEC 60870. A hard copy as well as a soft copy of the relay configuration, settings and manuals shall be submitted to the Engineer/ Employer before commissioning.

Voltage Presence Indicators

The switchgear cubicle shall be equipped with voltage presence indicators according to IEC 62271-206. The voltage presence indicators shall allow the visualization of voltage presence on each phase with LED indication.

6.3.4 Item 4 – Incoming from Inverter Transformer Cubicle

The 22 kV Incomer from Inverter duty transformer cubicle shall be of Single isolation and comprise of the following basic equipment: -

S.No	Description
1.	Three-phase 630 A busbar
2.	Triple pole Isolator
3.	SF6 Gas/Vacuum Circuit Breaker
4.	Motor operated spring charged operating mechanism for quick closing and opening both locally by push button and remotely.
5.	Tripping coil 110 V dc for emergency tripping
6.	Trip release device to work in conjunction with the relay
7.	Current Transformers.
8.	Voltage Terminal block.
9.	Current test terminal block.

10.	Tripping test terminal block
11.	Mechanical interlocking between earthing switch and triple pole Isolator
12.	Earthing switch located in a position to allow its contacts or position to be seen easily through the cubicle window
13.	Bottom plate with cable gland
14.	Neon lamp for live cable indication
15.	Built-in padlocking device for the cubicle door

<u>Three-Position Isolator/Disconnector:</u>

a. The 3-position disconnector shall be positioned between the circuit-breaker and busbars.
b. The disconnector can only be operated when the circuit breaker is maintained in open position.
c. The 3-position disconnector shall be integral with fault making earth switches and shall be in one of three positions: “closed”, “open” or “earthed”.
d. Mechanical indicators shall be provided for the switch position on the front fascia.
e. Auxiliary contacts shall be provided on the 3- position disconnector to indicate its status to the local SCADA system.

<u>Circuit Breaker of SF6 Type/ Vacuum Type:</u>

a. The circuit-breaker shall be of the SF6/Vacuum type and shall comply with IEC 62271-100. The circuit breaker mechanical and electrical endurances shall be chosen from IEC 62271-100 in accordance with their duty.
b. All circuit-breakers having the same rating shall be identical in arrangement and shall be interchangeable.
c. The rated current of the circuit breaker shall be defined by the bidder, taking into consideration the current rating of the dry type transformer for the ambient conditions specified.
d. The rated short circuit current AC and DC components of the circuit-breaker shall be chosen in accordance with the results of the short circuit calculation.
e. The minimum short circuit rating for MV switchgears shall be 16 kA, 1s & the minimum short circuit rating for LV switchgears shall be 50 kA, 1s.
f. The circuit breaker shall operate by means of a motor-operated spring-stored energy system, featuring a rapid acting mechanism, independent of the operator.
g. The motor shall be suitable for 110 Vdc.
h. Mechanical indicator for “charged- discharged” position shall be provided. In the absence of auxiliary power supply, the manual operation of the spring charging system shall be possible.
i. The circuit breaker shall also be equipped with opening, closing and tripping coils suitable for 110 Vdc.
j. Auxiliary contacts shall be provided on the circuit breaker to indicate its status to the local SCADA system. The circuit breaker shall be equipped with a SF6 pressure switch with two (2) levels of alarms for low pressure and very low pressure respectively.

k. Mechanical indicators of the circuit breaker position shall be provided on the front fascia.
l. A selector switch shall also be provided for the remote and local operation of the circuit breaker.
m. Push buttons shall be made available on the front fascia of the low voltage compartment for the opening and closing of the circuit breaker. In addition, the following test blocks shall be provided on the front fascia of the circuit breaker cubicle:
   One (1) voltage test block
   One (1) current test block
   One (1) trip test block

Current Transformers

a. The current transformers shall comply with IEC 61869-2 and shall be of the dry type. The current transformers shall be provided for both protective relay and metering purposes.
b. Toroidal current transformers will not be acceptable for metering purposes. Current transformers with split iron cores will also not be acceptable.
c. The current transformers shall have dual primaries with current rating 100/200A or 200/400 A.
d. The secondary windings of each set of current transformers shall have a rating of 5 A and shall be earthed at one point only, through a bolted disconnecting link.
e. The maximum continuous rating of the current transformers shall not be less than 150% of the maximum continuous rating of the associated dry type transformer.
f. The current transformers including primary winding conductors shall be capable of withstanding without damage the peak and rated short-time currents of the associated equipment.
g. The contractor shall perform calculation for the burden, taking into consideration a spare capacity of 20%, to be submitted for approval prior to ordering.
h. The rated volt-amp output of the current transformers shall not be less than the connected burden as installed in service, the burden of cable connections being taken into account.
i. The output of the current transformers shall be not less than 10 VA with an accuracy limit factor of not less than 20 and the Contractor shall ensure that the capacity of the current transformers provided is adequate for operation of the associated protective devices and instruments.
j. The current transformers provided for protective relay purposes shall be used for combined overcurrent and earth fault protection of the inverse time-overcurrent type and shall have Class 5P20.
k. The current transformers shall have overcurrent and overcurrent limit factors not less than those corresponding to the design short circuit level of the system. The current transformers provided for metering and instrumentation purposes shall have class 0.2.
l. The current transformers shall be solidly fixed using appropriate support structures. When double-ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformers, indicating clearly the connections required for each tap. The connections and the ratio in use shall be indicated on all connection diagrams.
m. Magnetization and core loss curves and dc resistance values shall be submitted for each type and rating of current transformers.

Earthing Switch for Cables

a. The earthing switch shall be mounted in the cable compartment for cable earthing and shall be of the fault making type.

b. Access to the cable compartment shall only be possible when the circuit is in earthed position.
c. The earthing switch shall be mechanically interlocked with the position of the disconnector.

Protection Relay

a. The protective relay shall be of approved numerical multi-function type and shall comply generally with the requirements of IEC 60255.
b. The protection relay shall be of the latest technology available, at the time of implementation, incorporating a wide range of protection and control functions as well as comprehensive communication facilities.
c. The system shall be IEC 61850 compatible.
d. The protection relays shall include full programmable scheme logic, self- diagnostics and time tagged event recording (at least 100 events) to indicate the pre-fault currents and voltages by phase and maximum recorded analogue quantities.
e. The protection relay shall integrate a user-friendly interface for troubleshooting and local programming with password.
f. The protective relay shall be suitable for flush mounting on the front fascia of the LV compartment.
g. The protective relay shall offer two (2) independent over-current stages for phase elements (I>, I>>) and for earth fault (Io>, Io>>).
h. The I>/Io> elements shall operate when the power frequency component of the current exceeds the set threshold. The time/current characteristic associated with these elements must provide a selection of inverse definite minimum time (IDMT) curves or be settable to a fixed (definite) time delay.
i. The relay shall be provided with a start function (and programmable relay output) that responds to the current exceeding either I> or Io> thresholds.
j. In addition, the relay shall have Neutral Voltage Displacement protection functionality and directional functionality for the overcurrent and earth fault protection.
k. The auxiliary power supply for protective relays shall be 110V dc.
l. All protective relays supplied shall be tested on site. Proper facility shall be provided for the testing of protective relays and associated circuits.
m. In case, injection test plugs are required for this purpose, the Contractor shall provide them.
n. The Contractor shall be responsible for providing to the Employer/Engineer relay setting details for relays along with the calculations which will be correctly coordinated with relays of other systems, wherever applicable.
o. A protective relay study completes with curves illustrating co-ordination between new and existing systems along with all calculations to determine relay settings and CT & VT requirements shall be submitted to the Engineer for approval.
p. The Contractor shall provide the associated documentation, programming software and communication cables as part of his scope of supply.
q. A communications menu system shall be provided in accordance with IEC 60870.

r. A hard copy as well as a soft copy of the relay configuration, settings and manuals shall be submitted to the Employer before commissioning.

Switch Disconnector:

a. The switch disconnector shall comply with IEC 62271-102 and should be fully insulated by SF6 gas.
b. The switch disconnector shall be triple pole with integral fault making earth switch.
c. The rated current of the switch disconnector shall be defined by the bidder, taking into consideration that the switch disconnector shall be able to carry and break the full rated current of the Floating Solar PV Farm.
d. The switch disconnector shall be capable of making on to a fault whose magnitude is equal to the specified short circuit level for 1 Second.
e. The switch disconnector shall operate by means of a motor-operated spring- stored energy system, featuring a rapid acting mechanism, independent of the operator.
f. The motor shall be suitable for 110 Vdc.
g. Mechanical indicator for "charged-discharged" position shall be provided. In the absence of auxiliary power supply, the manual operation of the spring charging system shall be possible. The switch disconnector shall also be equipped with closing and opening coils suitable for 110 Vdc.
h. Auxiliary contacts shall be provided on the switch disconnector to indicate its status to the local SCADA system. The switch disconnector shall be equipped with a SF6 pressure switch with two (2) levels of alarms for low pressure and very low pressure respectively.

   Mechanical indicators of the switch disconnector position shall be provided on the front fascia. A selector switch shall also be provided for the remote and local operation of the switch disconnector. Push buttons shall be made available on the front fascia of the low voltage compartment for the opening and closing of the switch disconnector.

6.4 Switchgear Installation

The switchgear installation shall, unless otherwise specified, be in accordance with the requirements of IEC 61936-1.

The layout of the switchgear shall take into consideration the access requirements for operation and maintenance of the substation. It shall be noted that locking of disconnector/earthing switch mechanisms is required as part of the Employer safety procedures.

Circuits shall be adequately labelled at the front and rear of the switchgear; these labels shall not be fitted on detachable doors or covers. A main label (identifying the switchboard designation) shall also be fitted in a prominent position.

Switchgear rating plates shall be provided with details engraved on a brushed stainless-steel label.

Circuit labels shall be engraved on stainless steel labels, preferably black lettering on brushed stainless-steel background.

Labels shall be provided to show the Employer designation of each switching device. The design of the substation installation shall comply with all relevant Health & Safety legislation applicable in Mauritius.

Switchgear shall be type tested in accordance with the requirements of the relevant IEC Standards. A summary of type tests shall be submitted with the tender. Copies of test certificates from an accredited short-circuit testing station covering the equipment offered shall be provided on request.

Routine tests (Factory Acceptance Tests) and tests after installation at site shall, as a minimum, be in accordance with the requirements of the relevant IEC Standards.

6.5 Test Certificates Prior to Commissioning

Employer/Engineer would require the following routine test certificates/documents before commissioning the HT switchgear panels:

(i) HT switchgear certificates.

(ii) CTs & PTs certificates.

(iii) Transformer routine tests.

(iv) Earth resistance test on site, including method used. The Client shall submit Earth Test report for the earthing system of the medium voltage equipment, duly signed by a Registered Professional Electrical Engineer of CRPE, and which include details such as weather conditions, equipment & methods used and the calibration certificate of equipment. The maximum acceptable earth resistance value during dry conditions shall be **5 ohms**.

(v) Protection relay tests on site.

(vi) HT cables Insulation & Pressure test certificate.

(vii) Proposed relay settings for Employer and Engineer approval.

(viii) Valid Calibration certificates of the test equipment being used for pressure and relay tests. Only calibrated equipment shall be used during pre-commissioning tests such as Power-Frequency Withstand Voltage Test & primary injection/relay tests.

(ix) Hard and soft copies of the switchgear internal wiring diagram and complete electrical layout of HT and LV systems, both signed by an appointed Client’s Registered Professional Electrical Engineer of CRPE.

(x) A commissioning certificate (as enclosed) duly filled and signed by an appointed Client’s Registered Professional Electrical Engineer of CRPE and witnessed by CEB representatives.

6.6 Additional Requirements

In addition, the following points should be strictly adhered by the Contractor for the MV switchgear Room:

- Laying of 2 PVC pipes 50 mm diameter for meter cables. These pipes shall be suitably clamped on the wall/ under the suspended beam from the switchgear panels to the meter with provision for bends at corners. In the switchgear room one pipe shall end in the Voltage Transformer panel and the other in the Circuit Breaker panel. In the meter room both pipes shall end near the terminals of the meter.
- Cable glands of diameter 22mm shall be installed on the bottom of the Voltage Transformer and Circuit Breaker panels for the laying of all supervisory cables.
- Provision of lighting system in the switchgear cabins. The lighting system will have to cater for emergency lighting in case of power cut.
- Lighting fixture to be installed in the LV chamber of the switchgear cabin. Same can be controlled by a water proof switch placed outside the cabin.
- Provision of a fire detection system in the switchgear room.
- Symbols and labels for Danger/Live shall be affixed on the Switchgear room doors.
- Fixing of rack for spare fuses in the switchgear room and appropriate stand for spare PTs and CTs.
- Fixing of HT switch handle support on wall in the switchgear room.
- Provision of padlock facility for switchgear room door. The padlocking facilities shall be installed prior to commissioning of supply.
- The door of the metering cabin will have a glass opening for meter reading purposes. The glass viewing panel for the meter cabin should be tinted using tinted film.
- PVC sleeves shall be placed at the corners of drawpits at deviation point of UG cables in order to allow for a larger bending radius whereas for straight running of UG cables, PVC sleeves should be placed at the centre.
- After completion of all cable works and before commissioning of HT Switchgears panels, safety covers shall be fixed at all cable entry points under each switchgear cubicle in order to avoid entrance of rats or any animals from cable ducts as this may cause damages to equipment. The covers will be fixed by means of bolts.
- The PTs and CTs including the spares will have to be tested at the CEB Meter Lab section prior to commissioning of the panel.
- Prior to sending the PTs and CTs (including their spares) to CEB Meter Lab section for testing, Contractor is requested to inform the General Planning section (via email or fax) details such as make, serial numbers, rating and other nameplate details of equipment to be tested and for which project they are meant for.

- Adequate air-conditioning in the HV switchgear room shall be provided on both demarcation sides . It must also be fitted with alarm/ monitoring device indicating any abnormal operation.
- The Contractor should provide a 22kV insulating mat to cover the whole length of the switchgear panels.
- The switchgear room as well as the meter cabin should be painted and epoxy paint of grey color should be used for floor finishing of the switchgear room.
- The Contractor should provide a means for fixing the system numbers onto the front panels of the switchgear modules. The system numbers (e.g., B5044) would be provided by CEB before commissioning. The labelling of the system numbers shall be in the form of white gravoply plates 80mm length x 30 mm height with black letters 15 mm high. The gravoply plates shall then be glued at appropriate locations on the panels.
- Provision of overhang or canopy and rooftop waterproofing should be carried out to prevent ingress of water into the switchgear room from the main doors and the roof respectively.
- Appropriate measures should be devised to prevent any water entry through the cable duct. For instance, all openings left at the CEB incoming PVC 160mm sleeves or Client outgoing sleeves should be sealed with Sika Boom.
- A step ladder should be provided inside the trench (below the checkered plates).
- Provision of cable tray from upper LV control compartment to the electrical panel.
- Provision of Lighting inside meter cabin with a waterproof switch located just outside the meter cabin door.
- Provision of an appropriate earthing and equipotential bonding system with visible earth bars and connection points provided in Cubicle.

6.7 Additional Protection and Safety Requirements

The protection requirements set forth in the previous sections are mandatory for the **22kV Medium Voltage switchgear.**

In addition to mandatory safety interlocks as per IEC 62271-200, for metal-enclosed MV switchgear, appropriate interlocking mechanism shall be incorporated at design and implementation stage, between the circuit breakers on the CEB and FSPV side as a measure of protection against an incorrect sequence of maneuvers by operating personnel.

This interlocking system shall be provided to ensure that closing of the CEB’s side 22kV Circuit Breaker, in i.e item-3, is ONLY allowed if ALL the FSPV SIDE 22 kV Circuit Breakers are in the open position. The opening of the CEB’s side 22kV Circuit Breaker shall inter trip ALL the FSPV side 22 kV Circuit Breakers.

During testing and commissioning, it shall be required to demonstrate the incorporation of the above safety interlocking mechanism both at design and implementation/commissioning stages.

Communication scheme shall be set as per Chapter 11.

7. CABLING

7.1 General

The Contract shall include for the supply, design, manufacture, delivery and off-loading on site of the power and auxiliary cables, earth conductors and electrodes, accessories and associated equipment, laying, construction of raceways including concrete encased duct bank pre-formed concrete trenches as required, erecting, fixing, jointing, bonding, termination, connecting up, testing on site, setting to work and maintenance in accordance with the Conditions of Contract The supply, fixing and painting where required of racks, cleats, steelwork,

7.2 Current Rating and Cable Sizing

The Contractor shall submit calculations for sizing of all cables to the Engineer/ Employer for approval.

Sizing shall take account of continuous current rating, method of installation, short-circuit rating under fault conditions and voltage drop under steady state and transient conditions.

Cable rating calculations shall be carried out by the Contractor in accordance with IEC 60287.

If a proprietary software program is to be used for sizing of the cables, same shall provide details of the software program in his Tender.

The Contractor may use the data set out in this tender document for preliminary calculations. However, the Contractor shall be responsible for determining the actual ground thermal resistance by measurement at locations dictated by ground variations and levels along the route.

7.3 Site Conditions

Attention is drawn to the fact that cables which are run in underground ducts or preformed concrete cable trenches may be subject to continuous immersion in water.

The following data may be used for preliminary calculation of cable current ratings:

- Ground temperature at one meter depth of cover: 30 ºC
- Average thermal resistivity of soil: 1.5 ºKm/W (to be confirmed by the Contractor)
- Highest maximum outdoor temperature 38 ºC
- Average daily maximum ambient temperature 28 ºC
- Maximum indoor average ambient air temperature: Contractor's design value.

7.4 Type Approval

Type test reports shall be submitted for approval during the engineering phase and cable design details and design drawings of each terminating accessory shall be included in the type test.

7.5 Cable Length

Cables shall be installed in the longest possible continuous lengths and straight through jointing between lengths will not be permitted unless otherwise approved by the Engineer/ Employer.

7.6 Cable Drums

Each cable drum shall bear a distinguishing number on the outside of one flange together with country of origin and year of manufacture. Particulars of the cable, i.e., voltage, conductor size and material, number of cores, type, length, gross and net weights shall also be clearly shown on one flange. The direction of rolling shall be indicated by arrows on both flanges.

7.7 Spare and Scrap Cable

All cable delivered to site shall become the Employer's property on completion of the Works.

Cut lengths of cable exceeding 10 meters in length shall be stored properly for future maintenance purposes.

All surplus cable lengths shall be individually tagged and labelled to include the cable type, size, length and voltage rating etc. All opened drums of cable and scrap cable shall be left in suitable storage location on site. The contractor shall ship any unopened drums of cable to his works.

7.8 22 kV Power Cables

Cables shall comply with the relevant sections of IEC 60502-2 (22kV). The technical requirements are as follows:

Table 6.1: Technical Specifications for HV Cables

Description	**Unit**	**22kV Cable**
Nominal System Voltage	kV	22
Highest System Voltage for Equipment (UM)	kV	24
Insulation Level	kV pk	125
Power transfer Capacity	MW	To be sized and approved by Engineer
3-phase short circuit fault	kA	16

The metal sheaths and armoring of each solidly bonded or cross-bonded cable circuit shall be rated to carry the maximum calculated earth fault current. If this is not practical, a separate suitably-rated earth conductor shall be installed in parallel to the associated power cable.

In the case of solidly earthed neutral systems, the design shall be such that in the case of an earth fault current of 16 kA for 1 second the final temperature shall not exceed 150 ºC.

Each cable conductor shall be sized to carry the maximum earth fault current equal to the design three phase fault level for one second, and in the case of an earth fault current of 16 kA for 1 second the final temperature shall not exceed 150 ºC.

7.9 Cable Construction and Manufacture

22kV Cables shall be of single core construction and be designed to meet the thermal, electrical and mechanical requirements of the CEB system.

The proposed cable construction shall be agreed prior to Contract award.

7.10 Conductor

Conductors shall be constructed of either compacted, plain annealed copper strands conforming to IEC 60228 (Class 2).

Conductor shall be sufficiently sized to carry the 3-phase short circuit fault current specified in Section 1.3 of this specification.

Conductors shall be longitudinally water blocked between all interstices of the conductor and shall satisfy to the water penetration test requirements specified in IEC 60502-2 / IEC 60840.

7.11 Semiconductor Screen

A conductor screen shall comprise an extruded layer of semi-conducting compound which continuously covers the surface of the conductor. The screen shall remain fully bonded to the insulation during installation and operation.

7.12 Insulation

The insulation shall be XLPE material with suitable nominal and minimum insulation thickness conforming to IEC 60502-2 / IEC 60840. The XLPE insulation shall be capable of continuous operation at 90ºC.

7.13 Insulation Screen

The insulation screen shall comprise an extruded layer of semi-conducting compound which continuously covers the surface of the insulation of each core.

The insulation screen shall be strippable and for 22kV cable shall meet the test requirement specified in IEC 60502-2 clause 19.23, although shall show no tendency in service to separate from the insulation due to the effects of installation or operation.

The semiconductor screen, insulation and insulation screen shall be free of water and triple extruded in a single operation with the semiconductor screen and insulation screen fully bonded to the insulation. Following vulcanization dry cooling is preferred.

7.14 Water Blocking Tape

Swelling tape shall be applied over the insulation screen to provide longitudinal water blocking.

7.15 Metallic Screen

The cable shall be provided with a continuous metallic screen composed of helically applied plain annealed copper wire which shall be rated to carry the phase to earth short circuit fault current specified in Table 6.1 of this specification.

7.16 Laminated Tape

An impermeable barrier to protect the cable from radial water ingress shall be provided over the metallic screen. Co-polymer laminated foil tapes for this purpose are acceptable.

7.17 Armour

On single core cables, the armour shall consist of either aluminium strip or other nonmagnetic armouring as approved by the Engineer.

Multicore cables shall have a single layer of galvanised steel wires and single core cables shall have a single layer of aluminium wires laid on an extruded inner covering.

7.18 Cable Accessories

This section specifies the technical requirements for HV cables and accessories including terminations and joints. Unless otherwise specified or agreed, they shall be made by the cable manufacturer to ensure compatibility, reliability and responsibility.

The designed life of all cable accessories shall not be less than the associated power cables. Preference is given to longer life designs and minimum maintenance requests.

7.18.1 Cable joints

In general, the joint design shall be suitable for XLPE insulated cables with conductor sizes selected for the application. In addition, following minimum technical requirements shall be met:

The joint shall provide a sufficiently rated current connection between conductors under both normal and fault conditions. It shall have a resistance not exceeding that of an equivalent length of conductor.

The joint insulation shall meet the same performance standard as the cable.

The joint shall provide a high current connection to permit the flow of short circuit current between the two cable sheaths or screen wires (if applicable).

A metallic joint shell or screen wire connection, electrically insulated from earth potential, shall be provided to match the insulation integrity of the cable oversheath.

The joint and cable insulation shall be protected against the ingress of water.

The joint metal work shall be protected against corrosion.

The joint design shall confirm to IEEE 404 and the test requirements specified in IEC 60502-4 / IEC 60840. Preference is given to prefabricated joints (either composite type or pre-moulded type) and heat/ cold shrink sleeve joints.

All joints shall have the conductor surfaces tinned to prevent oxidization and shall be riveted and soldered, or where specially approved, bolted and soldered or welded. Each joint shall be permanently clearly labelled detailing the Feeder Identification, Joint Number and Joint Phase colour.

The jointing kit shall include splicing instructions and all necessary materials such as consumable material and other components to complete the jointing work. All materials of cable joints and its associated consumable equipment shall be environmentally friendly and do not cause any hazard to the personnel who are carrying out the termination work.

7.18.2 Cable terminations

In general, the termination design shall be suitable for 22kV, insulated cables with an appropriate conductor size. In addition, following technical requirements shall be met as a minimum:

The termination shall provide a sufficiently rated current connection from the cable conductor to an external busbar or cable box interface.

Insulation shall be to the same performance standard as the cable.

The termination shall assist in supporting the cable.

The termination shall be able to withstand cable thermo-mechanical loads and external forces such as wind and busbar loading.

The termination must provide a high current connection to permit the flow of short circuit current from the cable metallic sheath or shield wires via a bonding lead to the system earth.

A connection to the cable metallic sheath or earth wires shall be provided which is electrically insulated from earth potential to match the insulating integrity of the cable over sheath.

The cable termination shall protect the cable insulation and sheath against the ingress of atmospheric water and, where applicable, the ingress of pressurized dielectric liquid or gas.

Both indoor and outdoor termination design shall confirm to the test requirements specified in IEC 60502-4 / IEC 60840. Preference is given to heat/ cold shrink sleeve terminations for connections to air insulated equipment and separable type terminations for connections to metal clad equipment (e.g., GIS) and transformers. The creepage distance across the weather shed of an external termination shall not less than 42 mm/kV based on the highest system line voltage.

Outdoor cable termination shall not be protected by arc gaps. If the cable is exposed to transient voltages, surge arresters shall protect the cable.

All terminations shall have suitable finishes, incl. metal coating, plastic coating, painting, inorganic treatment, etc., with high resistance to atmospheric conditions for metals liable to corrosion or rusting. Each termination shall be permanently clearly labelled detailing the Feeder Identification, Joint Number and Joint Phase color.

The termination kit shall include splicing instructions and all necessary materials such as consumable material and other components to complete the termination work. All material of cable terminations and its associated consumable equipment shall be environmental friendly and do not cause any hazard to the personnel who are carrying out the termination work.

7.19 Cable Installation

This section specifies the installation requirements for HV cables and accessories. The installation shall be complete in every respect to allow uninterrupted use of the equipment installed and to ensure security of electrical supplies. Every precaution shall be taken to ensure that cables and accessories are not installed in a manner or under conditions likely to cause electrolytic or other corrosive action or damage to or be detrimental to the performance of the cables and accessories during operation.

The installation shall be undertaken at all times by qualified staff and supplied with all the necessary plant, equipment and tools. The Contractor shall provide all the necessary material to complete the installation (incl. Site Acceptance Test). No welding, filling or plugging of defective parts during the installation shall be permitted without the approval from the Engineer.

7.20 Cable route

The Contractor shall be responsible for determining the cable route in agreement with the Employer/Engineer.

7.21 Cable installation methods

All power cables shall be installed in pressurised PVC pipes complete with all necessary accessories and fittings

Each trench shall have vertical sides that, where necessary, have been timbered or otherwise secured to avoid subsidence and damage. Trench backfilling shall not be commenced until the Engineer/ Employer has inspected and approved the installation.

Where cables are run in concrete cable ducts, all duct installations shall meet the mechanical requirements of the cable system. For road crossings, power cable shall be installed in ducts unless otherwise agreed. Following minimum technical requirements shall be met:

The internal bore and radius of any bends shall not be less than that specified by the cable manufacturer.

Non-magnetic duct materials shall be used for single core AC cable installations.

Duct joints, cable seals and duct mouth seals shall be designed to prevent the ingress of debris, other materials and vermin. No bentonite refilled is allowed.

Ducts shall have a smooth internal face and be brushed clean during installation.

Ducts must remain free of debris during and after cable installation.

A concrete duct bank may be considered where enhanced mechanical protection is required, e.g., road crossings with a minimum concrete strength grade C20/25, or to improve the cable rating. In case of stream crossing, the ducts must be pressurized PVC pipes along the structure for stream crossing. A proposed design shall be submitted to the Engineer/ Employer for approval.

During installation, a draw line, or pulling wire, shall be in installed. This draw line shall be made of a corrosion proof material and have a service live no less than the power cables. When the cable is not drawn in immediately, the ends of the duct shall be sealed. For trefoil formation, three single ducts shall be used. Power cable and associated pilot cables shall be in separate ducts.

Unless a concrete duct bank has been installed, all direct buried ducts shall be protected from external damage by cable protection covers, which shall follow the relevant requirements specified for direct buried cables.

For long duct runs where it may be necessary in the future to locate sheath faults, the installer shall demonstrate that a technique exists that would enable the location of a sheath fault to within a 6-meter length.

Provision of draw pits shall be made at regular intervals for ease of pulling of cables and replacement of same in the future. In addition, the contractor shall implement cable trenches under or next to the CMCS Building for cable entry. It is to be noted that the draw pits within the PV Farm shall have raised plinth with hinged galvanized heavy-duty steel cover. The layout of the draw pits and cable trenches shall be approved by the Engineer/ Employer prior to implementation.

7.22 Cable pulling and bending

A cable pulling calculation, conforming to AEIC CG5, shall be submitted to the Engineer/ Employer for approval before cable laying activity starts. During the laying, power cables shall be pulled over sufficient rollers and particular attention shall be given to the provision and placing of rollers at bends, to ensure that the minimum bending radius required by cable manufacturer is not exceeded.

The cable shall not rotate or twist during the laying in any circumstance, as a result of excessive pulling tension and/ or insufficient rollers. Except for short route lengths, the pulling tension shall not be borne by the cable conductor through the application of double-thimble stockings or pulling eyes wherever possible.

7.23 Cable supports

The Contractor shall supply and install all the supports, e.g., racks, trays, cleats, clamps, saddles, etc. required to carry and secure the cables, without risk or damage. The nominal support interval shall be, unless otherwise agreed, 1m for rigid fixing and 5m for flexible fixing.

The design of cable supports shall be suitable for either trefoil or flat cable formation and free of rough edges, burrs and sharp corners. No materials shall be supplied which will cause corrosive impact in contact. Cleats and/ or cable straps for single core cables shall be non-magnetic and be suitably spaced to withstand forces and prevent damage to the cable during normal and short circuit conditions.

The design of cable supports for in air installation shall consist of vertical steelwork at approved intervals and secured to walls, floors or ceilings, etc. The steelwork shall be designed to support a total weight no less than 125% of cables and metallic fixings combined, plus an additional 100kg load at the extremity. The steel used in construction of cable supports shall be galvanized.

Where cables are installed in cable galleries, consideration shall be given to the need to access this area without climbing on live cables. The Contractor shall propose a suitable design solution to meet this objective.

7.24 Cable bonding

Unless otherwise agreed, the cable system and metallic cable ways shall be fully bonded.

7.25 Short circuit current carrying capacity

The cable system design shall be such as to ensure that there is a continuous metallic return path of adequate cross section for the short circuit currents. Except for connections to SVLs (Sheath Voltage limiters) at unearthed positions, the link connections and bonding leads shall be capable of carrying the specified short circuit currents without sustaining any permanent damage.

7.26 Cable earthing

Cable earthing system design shall meet the following requirements:

- To ensure mechanical strength and corrosion resistance.
- To withstand the maximum potential fault current.
- To avoid damage to property and equipment.
- To ensure personal safety by limiting earth potentials.

Cable sheaths shall be bonded to the substation earthing system.

7.27 Inspection and Test

7.27.1 General

The cable and accessories shall be fully tested in compliance with IEC 60502-2/IEC 60502-4 / IEC 60840.

The Engineer shall retain the right to witness all relevant tests and a notice shall be given no less than 21 days prior to the test. A complete test programme shall be submitted no less than 14 days prior to the scheduled test. A report with all the results shall be submitted for review following each test.

All cable tests and measurement methods should conform to IEC 60502.

The cables shall comply to the following:

- Multi Strand, annealed high conductivity copper conductor
- XLPE extruded insulation
- Armored cable for underground laying
- All cables shall conform to IEC 60502, IEC 60364, IEC 60332-1-2
- The size of each type of cable shall be selected such that the maximum voltage drop is limited to 2%.

- Proper laying of cables has to be ensured in appropriate cable trays, pipes /trenches.
- A.C. supply cables shall be terminated at the AC Distribution Board.
- For termination of cables, latest IEC codes / standards must be followed.

Together with the type test certificates, evidence shall be submitted showing the type test has been executed at an internationally recognized testing station or in the Contractor's own facility, witnessed and certified by an international certification body.

The following additional tests are required on the cables:

- Fire resistance test, conforming to IEC 60331
- Low smoke test, conforming to IEC 61034
- Halogen content test, conforming to IEC 60754

7.27.2 Factory acceptance test (FAT)

The Factory Acceptance Test for 22kV cable shall consist of Routine tests and Sample test, conforming to IEC 60502-2 clauses 16 and 17 as the minimum requirement.

Factory Acceptance tests for accessories shall be in accordance with the requirements of IEC 60502-4 / IEC 60840.

Reports should be submitted to the Engineer/ Employer for review and approval within 14 days following the completion of routine testing and sample testing.

The sample test shall be carried out on one length from each manufacture batch of the same type and cross-section of cable, covering minimum 10% of the number of lengths in contract unless otherwise agreed. The test frequency and minimum requirements shall conform to section 17 of IEC 60502-2 / IEC 60840.

7.27.3 Site acceptance test (SAT)

After the completion of new cable installations, the Contractor shall perform testing in conformance with section 20 of IEC 60502-2 / IEC 60840.

Unless otherwise agreed, an AC power frequency test shall be performed for 15 minutes in accordance with IEC 60502-2 clause 20.3.1 option a) or IEC 60840 as appropriate. All test equipment and access arrangements shall be provided by the EPC Contractor.

Partial discharge shall be monitored during the a.c. power frequency test in accordance with IEC 60270 with background noise suppressed to a level as low as reasonably practicable.

7.27.4 Sealing and Drumming

Before dispatch, the Contractor shall cap the ends of all cable in order to form a seal to prevent the ingress of water during transportation and storage.

Where there is risk of stored charge building within the cables due to re-charging after factory acceptance test, conductive connections will be made between the metallic screen and the conductor underneath the seal.

The cable shall be supplied on steel drums, suitable for outdoor storage at the manufacturer location or the project site for a minimum period of two years.

Cable on drums shall be protected from damage with plastic wrapping and timber lagging/battening. Drum capacity shall be managed effectively and sufficient room shall be allowed for avoidance of timber lagging nails damaging the cables.

One length per drum is preferred for reasons of practicality and should an alternative arrangement be considered then this shall be agreed with the Engineer/ Employer.

Each drum shall bear the manufacturer's contact information and labelled with a unique distinguishing ID number on the outside of the flange and particulars of the cable, i.e. voltage, length, conductor size and cable type.

The drum weight and gross weight shall be shown and the direction for rolling shall be indicated by an arrow.

7.28 Documentation

Project documents as specified below shall be delivered as part of the Contract. The submission of documents specified here is a minimum requirement. CEB reserves the right to request additional documents where the information available does not give enough evidence to show the technical details, functions, interfaces, capabilities of the equipment. These documents shall be provided at no additional cost.

The following documents shall be submitted as a minimum requirement. The provision of these documents is to be covered by the contract price.

- With Tender (together with additional documents listed in Requirements for cable accessories and installation)
- Cable cross section drawing
- Cable technical schedule (as per format provided)
- Rating calculation under both continuous and fault conditions
- Test certificates
- Preliminary cable work programme
- Preliminary cable bonding diagram

After Contract Award (together with additional documents listed in Requirements for 22kV cable accessories and installation)

- Certification letter of compliance with the specification
- Manufacturing test programme
- Prequalification test report(s)
- Type test report(s)
- Factory acceptance test report(s)
- Cable/Accessory delivery programme
- Detailed cable work programme
- Detailed cable route drawing, including existing services along the route, locations of joints, link box chamber, communication chamber, major road crossings, crossing arrangement with other services, and future access points/ routes for maintenance and repairs
- Survey reports and drawings
- Detailed cable rating calculation as per requested (continuous, cyclic, emergency, fault) under proposed installation conditions.
- Bonding/ Earthing schematic drawing including phasing

All other information necessary for a full understanding and evaluation of the project shall be included.

The contractor shall comply with the following obligations in relation to the submission of any documents, including but not limited to correspondence, drawings, calculations, letters, method statements, and programmes:

- All Documents shall be submitted in both hard copy and electronic form;
- Three hard copies of all documents shall be submitted;
- Drawings for approval shall be submitted in one copy of paper prints and, after having been approved, the Tenderer shall supply any further copies required by the Engineer/ Employer, one copy at least on a digital media in AutoCAD format or other agreed 3D format.
- Only electronic copies shall be submitted to the project document management system.
- All drawings shall be to scale and fully detailed. All-important dimensions shall be given and the material of which each part is to be constructed shall be indicated.
- The drawings provided as input data for the substation civil design shall be provided as a 3D model suitable for use by internationally accepted and used 3D design software packages.

7.29 PV Plant LV Cables

The cables used in the PV plant must be able to stand, for the whole life cycle of the plant (i.e., 25 years), severe environmental conditions in terms of high temperatures, atmospheric precipitations and ultraviolet radiations. Cables specially designed for Solar PV installations shall be used and the cables shall be of armoured type.

The DC cables in a solar PV plant are used in the following areas

i. Interconnecting SPV modules
ii. From SPV Modules up to SMB
iii. From SMB (String Monitoring Box) up to the Inverter.

The cables on the DC side of the plant shall be single core and have double insulation (class II) so as to minimize the risk of earth faults or short circuits in accordance with IEC 60364-7-712.

7.29.1 DC Cables (Interconnecting SPV Modules and from SPV Modules TO SCB)

Cables used for inter-connecting SPV modules as well as Modules to SMU's shall conform to the requirements of **EN 50618:2014 and H1Z2Z2-K** applicable for DC cable for photovoltaic system.

These cables shall also meet the fire resistance requirement as per the above standard and shall be electron beam cured. All cables except module cable used for (+) ve and (–) ve shall have distinct color identification.

In addition to manufacturer's identification on cables as per **EN50618**, following marking shall also be provided over outer sheath.

a. Cable size and voltage grade
b. Word 'FRNC' (Flame Retardant Non-Corrosive) at every 5 meters
c. Sequential marking of length of the cable in meters at every one meter.

The Printing shall be progressive, automatic, in line and marking shall be legible and indelible.

Type test, routine, acceptance tests requirements for these cables shall be as per **EN50618:2014**. A maximum of 8 Cables (4 Circuits) shall be laid in one HDPE Pipe for DC Cable from Module to string monitoring box (if applicable). The fill factor of the pipe should not be more than 40%. However, in case of necessity to lay more than 8 cables (4 circuits) in one pipe, the same shall be allowed during detailed engineering and as per the derating factors recommended by the cable manufacturer. Fill factor criterion is still to be maintained.

Bidder to ensure that there is no gap and proper packing at the junction of two pipes, in which DC cable is laid, using proper method and accessories, like bell mouth.

7.29.2 DC Cables (String Combiner Box to Inverter)

Cables used between SCB's and Inverters shall be of min. 1.5 kV (DC) grade. In case bidder offers 1500V DC system 3.3 kV (E) grade cables shall be provided. These cables shall confirm to the requirements of the standards & codes specified at relevant Chapter

On floaters, the DC Cables shall be laid in UV Resistant HDPE pipes/covered cable trays. The material of the cable tray shall be corrosion resistant (Aluminium or FRP). Individual String DC Cables entering into covered cable trays/ UV Resistant HDPE pipes on floaters and cables exiting from covered cable trays/ UV Resistant HDPE pipes on floaters shall also be laid in suitable conduits.

Over-ground cables need to be properly routed and secured to the floater mounting structure using dedicated cable ladders (if applicable) and cable ties. Appropriate design and installation, subject to approval by the Engineer/ Employer, shall be done to allow DC cable crossing on road on the side of reservoir leading to switchgear control room, to allow ease of access to vehicles. Over-ground cables shall be enclosed in rodent proof covered heavy duty cable trays made of Fiber Reinforced Plastic (FRP)/ Galvanized Steel. All 90-degree bends shall be long sweeps installed in accordance with standard industry practices. Cables should be protected from direct sunshine, standing water and abrasion by the sharp edges of support structures. The selection and sizing of the cable should consider the maximum temperature (80^0C), maximum voltage of the PV strings or array, the maximum current (taking into consideration the various derating factors), maximum reverse current.

The use of specialized plug and socket connections on the modules are required so as to facilitate assembly. These plug connectors shall provide secure and touch-proof connections and are to be correctly rated (voltage and current), at least equal to those of the circuit they are installed on and IP 67. Connectors should carry appropriate safety signs that warn against disconnection under load.

The DC cables, steel wire armoured, should be sized so as to reduce losses and overall voltage drop between the PV array and the inverter to a minimum. Underground DC cables shall be run in pressurised PVC pipes. The LV cables shall have a separate routing from that of the 22kV power cables.

The AC cabling systems should be designed to provide a safe and cost-effective means of transmitting power from the inverters to the transformer(s) and beyond to the 22 kV switchgear panel. Cables should be properly rated for the correct voltage and have conductor sized, taking into consideration the operating currents, short circuits and losses within acceptable limits.

Where underground cables are allowed, it shall be mapped and identified along their entire run with hazard tape and warning slabs, 50 cm. above the cable elevation and 50 cm below finish grade elevation.

No underground cable splicing shall be acceptable under any circumstances.

Only multi-stranded copper wires with XLPE insulation, of appropriate size and of reputed make shall be used. Aluminium cables shall not be accepted for low voltage installations within the PV farm.

All connections are to be made through suitable cable lug or terminals; crimped properly & with use of cable glands.

7.30 Cable Marking

All cable/wires are to be marked in proper manner by good quality ferrule or by other means so that the cable can be easily identified. Any change in cabling schedule/sizes if desired by the Contractor need to be approved after citing appropriate reasons at design stage. All cable schedules/layout drawings have to be submitted to the Engineer/ Employer prior to installation.

7.31 Installation of Optic Fiber Cables

Optical fiber cable shall be of the single mode type equipped with at least 16 fibers, complying with CCITT recommendation G652. All fibers including spares shall be terminated and connected in patch panels and labelled accordingly at both ends.

Fiber optic cable shall be provided with steel armour, which shall in turn be protected by an extruded outer sheath. Fiber optic cable shall be suitable for direct buried. Such cables shall be tested in accordance with ITU-T G.652 and IEC 60793 as appropriate.

Prior to installation, the optic fiber cable shall be tested with an OTDR on each fiber to ensure that no physical damage has occurred to the fiber during delivery and shall be compared with the results prior to dispatch.

After installation, the above test shall be repeated to ensure that no damage has occurred to the fiber during installation.

An end-to-end attenuation measurement shall be taken in each direction on each fiber using an optical source and optical power meter. The overall attenuation of the installed cable shall not exceed that calculated using the attenuation and splice loss values specified by the fiber optic cable manufacturer at the bidding stage.

The communication system between the different components of the PV Farms and the local SCADA system shall be via fiber optic. A fiber optic network shall be established.

The optical fiber within the farm shall be installed undergrounded in PVC pipes.

8. AUXILIARY POWER SUPPLY SYSTEM

8.1 General

1.1 Auxiliary power supply arrangement shall be in line with tender SLD. The CMCS building shall have its own auxiliary power supply system comprising of AC distribution board (ACDB) which shall be fed from LV side of Inverter transformer through suitably rated auxiliary transformers. The ACDB shall have two incomers and a bus coupler (100% rated and interlocked and equipped with synchro-check) fed from two different sources. At CMCS, auxiliary transformer directly feed from 22kV switchgear are also acceptable (The requirement of ACDB having two (2) incomers shall be satisfied). Following consideration shall be taken while arriving kVA capacity of auxiliary transformer

1. 20% design margin.

2. The minimum kVA capacity of auxiliary transformer for Inverter Room/ Switchgear Room and CMCS requirement shall be 25kVA respectively.

1.2 All non-critical auxiliary loads shall be fed directly from ACDB. However, emergency and important load shall be fed from suitable sized redundant Uninterrupted Power Supply (UPS) or Battery Charged. Input AC supply for Uninterrupted Power Supply (UPS) and Battery Charger shall be fed from ACDB. Bidder shall consider the following one of the supply options for feeding different equipment loads:

1.3 UPS system shall comprise of 2 x 100% UPS. Each UPS shall consist of 1x100% charger and inverter, 1 x 100% Battery bank for providing 3 hours autonomy at full load. Bypass Line static switch, manual bypass switch, 1 x 100% UPSDB, and other necessary Protective devices and accessories. UPSDB shall have two incomers fed from two separate UPS as mention above. At a time one incomer shall be in service. Suitable auto changeover logic shall be provided. In place of UPS, bidder can provide DC supply system (2 x 100% Battery Charger) of 12V or above up to 110V DC if the auxiliary power supply requirement of loads are in DC. Rated AC output capacity shall be taken for UPS battery size calculation. However, the minimum UPS rating shall be 3 KVA and the battery sizing shall be calculated at full load for 3 hours autonomy. All UPS having rating 5KVA or more shall have three phase input.

1.4 The Bidder can provide alternate arrangement with suitable redundancies such as power pack with 3 hours autonomy at full load.

1.5 Each Battery charger system shall consist of 1 x 100% charger and1 x 100% Battery bank for min 3 hours autonomy at full load and 1 x 100% DCDB, and other necessary protective devices and accessories. DC supply system voltage shall be 12V or above up to 110V DC.

1.6 It is mandatory to use Battery charger system for control and protection supply of MV switchgear.

1.7 Bidder shall submit configuration diagram, power supply distribution scheme, single line diagram and data sheets, all calculations such as Rectifier Modules/UPS Charger/Inverter rating calculations, battery sizing calculation etc. for UPS, Battery Charger & Battery system during detailed engineering stage for Engineer's/ Employer's review and approval.

1.8 Size and rating of UPS, Battery Charger and Battery shall be finalized during details engineering stage, including sizing calculations to be submitted to Engineer/ Employer for approval.

8.2 Uninterruptible Power Supply (UPS) System

1.1 The minimum capacity of the UPS at load factor of 0.8 lagging inclusive of 10% design margin at 50 deg C. The UPS shall have an overload capacity of 125 % rated capacity for 10 minutes and 150 % rated capacity for 10 seconds. The overall efficiency of UPS shall be at least 80% on full load.

1.2 The UPS system shall be capable of operating without D.C. battery in circuit under all conditions of load and the performance of various components of UPS like inverter, charger, static switch etc. shall be guaranteed without the battery in circuit.

1.3 For UPS capacity 5 kVA or more, in addition to indications/display on UPS panel, important alarms along with important analog signal shall also be provided for use in SCADA. For UPS capacity less than 5 kVA bidder shall provide status, common alarm and trip DI (soft or hard) signal to SCADA

1.4 The UPS chargers shall be self-regulating, solid-state silicon controlled, full-wave rectifier type designed for single and parallel operation with battery and shall have automatic voltage regulators for close voltage stability even when AC supply voltage fluctuates. The charger should be capable to fully charge the required batteries as well as supply the full rated load through inverter. The charger shall be able to re-charge the fully discharge battery within 8 hours. The charger shall be design for input supply variation of ± 10% and frequency variation of ± 5%. Charger design shall ensure that there is no component failure due to fluctuations of input supply or loss of supply and restoration. The detailed specification for the battery charger for UPS rating of 5kVA and above has been mentioned in the battery charger section below in this specification.

1.5 The UPS inverter shall be of continuous duty, solid state type using proven Pulse Width Modulation (PWM)/Quasi square wave/step wave technique. Ferro-resonant types Inverters are not acceptable. The nominal voltage output shall be 230 Volts single phase ,50 Hz. The inverter equipment shall include all necessary circuitry and devices to conform to requirements like voltage regulation, current limiting, wave shaping, transient recovery, etc. The total harmonic content shall be 5% maximum and content of any single harmonic shall be 3% maximum.

1.6 The static switch shall be provided to perform the function of transferring UPS loads automatically without any break from faulty inverter to standby AC source. Manual bypass switch shall be employed for isolating the UPS during maintenance.

1.7 Contractor shall supply hermetic, maintenance-free stationary Nickel-Cadmium batteries. The detailed specification for the batteries has been mentioned in the battery and charger section below in this specification. Battery life shall be at least 7 years.

1.8 Equipment enclosures shall match and line up in assemblies of freestanding floor mounted cabinets designed for indoor service.

1.9 Individual enclosure shall be ventilated switchboard type fabricated from not less than 1.6-mm thick sheet steel. Enclosures shall be furnished with concealed hinges. Front and rear doors shall be designed to permit easy access to all components for maintenance or replacement. The enclosures shall be reinforced with formed steel members as required to form a rigid self-supporting structure. Doors shall have three-point latches.

1.10 Adequate ventilating louvers and enclosure top panels shall be included. All vent openings shall be covered with corrosion resistant fine screen coverings.

1.11 The cabinets shall be IP-42 protection class for indoor application and IP65 for outdoor application.

1.12 The temperature rise inside all the cabinets/enclosures shall not exceed 10 deg.C above ambient temperature.

1.13 The Contractor shall also carry out the site tests on UPS as required to be conducted as a standard practice of the UPS manufacture or deemed necessary by the Engineer/ Employer and mutually agreed between the Contractor and the Employer.

1.14 One set of tools shall be provided for maintenance and testing purposes.

8.3 Battery Charger

1.15 The chargers shall be self-regulating, solid-state silicon controlled, full-wave rectifier type designed for single and parallel operation with battery and shall have automatic voltage regulators for close voltage stability even when AC supply voltage fluctuates, effective current limiting features and filters to minimise harmonics. The charger should be capable to fully charge the required batteries as well as supply the full rated load. Furthermore, the charger should be able to re-charge the fully discharged battery within 8 hours. The charger shall be current limited for charger circuit protection and protection of battery from overcharge shall also be provided. The current limit shall be continuously adjustable. The chargers shall have a slow walk-in circuit. Charger design shall ensure that there is no component failure due to fluctuations of input supply or loss of supply and restoration. The charger shall be design for input supply voltage variation of ± 10% and frequency variation of ± 5%.

1.16 Battery Chargers shall have a selector switch for selecting the battery charging mode i.e., whether Trickle or Boost charging.

1.17 All Battery Chargers shall be provided with facility for both automatic and manual control of output voltage and current. A selector switch shall be provided for selecting the mode of output voltage/current control, whether automatic or manual. Means shall be provided to avoid current/voltage surges of harmful magnitude/nature which may arise during changeover from Auto to Manual mode or vice-versa under normal operating condition.

1.18 Soft start feature shall be provided to build up the voltage to the set value slowly. The chargers shall have load limiters which shall cause, when the voltage control is in automatic mode, a gradual lowering of the output voltage when the DC load current exceeds the load limiter setting of the Charger. The load limiter characteristic shall be such that any sustained overload or short circuit in DC system shall neither damage the Charger nor shall it cause blowing of any of the charger fuses. The Charger shall not trip on overload or external short circuit. After clearance of fault, the Charger voltage shall build up automatically when working in automatic mode.

1.19 When on automatic control mode during Trickle charging, the Charger output voltage shall remain within +/-1% of the set value for AC input voltage variation of +/-10%, frequency variation of +3/-5%, a combined voltage and frequency (absolute sum) variation of 10% and a continuous DC load variation from zero to full load. Uniform and step-less adjustments of voltage setting (in both manual and automatic modes) shall be provided on the front of the Charger panel covering the entire Trickle charging output range specified & shall be capable of matching the float voltage correction recommendations (w.r.t. temperature) as suggested by the respective battery manufacturer. Step-less adjustment of the load limiter setting shall also be possible from 80% to 100% of the rated output current for Trickle charging mode.

1.20 During Boost charging, the Battery Chargers shall operate on constant current mode (When automatic regulator is in service). It shall be possible to adjust the Boost charging current continuously over a range of 50 to 100% of the rated output current for Boost charging mode. The charger output voltage shall automatically go on rising, when it is operating on boost mode, as the battery charges up. For limiting the output voltage of the charger, a potentiometer shall be provided on the front of the panel, whereby it shall be possible to set the upper limit of this voltage anywhere in the output range specified for boost charging mode. All voltage and current setting potentiometers shall be vernier type.

1.21 Energizing the Charger with fully charged battery connected plus 10% load shall not result in output voltage greater than 110% of the voltage setting. Time taken to stabilize, to within the specified limits as mentioned elsewhere, shall be less than fifteen seconds.

1.22 Momentary output voltage of the Charger, without the Battery connected shall be within 94% to 106% of the voltage setting during sudden load Change from 100% to 20% of full load or vice-versa. Output voltage shall return to, and remain, within the limits specified as mentioned elsewhere in less than 2 seconds after the above-mentioned change.

1.23 Suitable filter circuits shall be provided in all the Chargers to limit the ripple content (peak to peak) in the output voltage to 1% irrespective of the DC load, even when they are not connected to a battery.

1.24 The DC System shall be ungrounded and float with respect to the ground potential when healthy. An earth fault relay shall be provided by the bidder in the DC distribution board for remote annunciation.

1.25 Digital Outputs shall be configured for connection to the SCADA for real-time charger status update. Outputs like charger output current, output voltage, float/boost mode, etc may be configured to provide the update to SCADA.

1.26 The Battery Chargers as well as their automatic regulators shall be of static type. The Chargers shall be designed to operate, as mentioned above, at an ambient air temperature of 50°C.

1.27 For Nickel-Cadmium battery: - Battery chargers shall be capable of continuous operation at the respective rated load in Trickle mode i.e., Trickle charging the associated DC Nickel-Cadmium Batteries while supplying the D.C. loads. The Batteries shall be Trickle charged at 1.4 to 1.42 Volts per cell. All chargers shall be capable of Boost Charging the associated D.C. Battery at 1.54 to 1.7 Volts per cell at the desired rate.

1.28 All Battery Chargers shall have an AC contactor on the input side. It shall be of air brake type and suitable for continuous duty. A thermal overload relay incorporating a distinct single phasing protection (using differential movement of bimetal strips) shall also be provided for the AC input. The relay shall trip the above contactor.

1.29 The rectifier assembly shall be full wave bridge type and designed to meet the duty as required by the respective Charger.

1.30 Digital or analog indicating instruments shall indicate DC current, DC voltage & AC voltage.

1.31 The Chargers shall be indoor, floor mounted, self-supporting sheet metal enclosed cubicle type. The Contractor shall supply all necessary base frames, anchor bolts and hardware. The Charger shall be fabricated using cold rolled sheet steel shall not be less than 1.6 mm and shall have folded type of construction. The panel frame shall be fabricated using cold rolled sheet steel of thickness not less than 2.0 mm. Removable undrilled gland plates of at least 3.0 mm sheet steel and lugs for all cables shall be supplied by the Contractor. The Charger shall be tropicalised and vermin proof. Ventilation louvers shall be backed with fine brass wire mesh. All doors and covers shall be fitted with synthetic rubber gaskets. The Chargers shall have hinged double leaf doors provided on front and/or backside for adequate access to the Charger internals. All the Charger cubicle doors shall be properly earthed.

1.32 Treatment as per IS: 6005. Two coats of lead oxide primer followed by powder painting with final shade of RAL9002 for complete panel except end covers & RAL 5012 for end covers.

1.33 All acceptance and routine tests as per the manufacture recommendations and relevant standards shall be carried out.

1.34 The cabinets shall be IP-42 protection class for indoor application and IP65 for outdoor application.

1.35 The Contractor shall also carry out the site tests on battery charger systems required to be conducted as a standard practice of the UPS manufacture or deemed necessary by the Engineer/ Employer and mutually agreed between the Contractor and the Employer.

8.4 Battery: Nickel-Cadmium Battery

1.36 **Battery Parameters**

Batteries should be suitable for continuous operation for the maximum ambient temperature as defined in technical parameters.

1.37 Codes and Standards

All standards, specifications and codes of practice referred to herein, shall be the latest editions including all applicable official amendments and revisions as on date of opening of techno-commercial bid. In case of conflict between this specification and those (latest British codes and Mauritius Standards or equivalents) referred to herein, the former shall prevail. All works shall be carried out as per the following standards and codes:

Equipment complying with other internationally accepted standards such as IEC., BS, VDE etc. will also be considered if they ensure performance and constructional features equivalent or superior to standards listed above. In such a case, the Bidder shall clearly indicate the standard(s) adopted, furnish a copy in English of the latest revision of the standards along with copies of all official amendments and revisions in force as on date of opening of techno-commercial bid and shall clearly bring out the salient features for comparison.

1.38 DC Batteries shall be stationary Nickel Cadmium Pocket plate type conforming to latest British codes and Mauritius Standards or equivalents. The batteries shall be high/medium discharge performance type suitable for the backup time as specified. For the purpose of design an ambient temperature of 50 degree centigrade and relative humidity of 85% shall be considered.

1.39 DC batteries shall be suitable for standby duty. The batteries shall normally be permanently connected to the load in parallel with a charger and shall supply the load during emergency conditions when AC supplies are lost. Batteries shall be suitable for a long life under continuous float operations and occasional discharges.

The batteries shall be boost charged at about 1.54 to 1.7 volts per cell maximum and float charged at about 1.42 V/cell.

1.40 **Construction Features**: -

a) **Containers**

Containers shall be made of polypropylene plastic material. Containers shall be robust, heat resistance, leak proof, non-absorbent, alkali resistant, non-bulging type and free from flaws, such as wrinkles, cracks, blisters, pin holes etc. Electrolyte level lines shall be marked on container in case of translucent containers.

b) **Vent Plugs**

Vent plugs shall be provided in each cell. They shall be anti-splash type, having more than one exit hole shall allow the gases to escape freely but shall prevent alkali from coming out. The design shall be such that the water loss due to evaporation is kept to minimum. In addition, the ventilator shall be easily removed for topping up the cells and of such dimensions that the syringe type hydrometer can be inserted into the vent to take electrolyte samples.

c) **Plates**

The plates shall be designed for maximum durability during all service conditions including high rate of discharge and rapid fluctuations of load. The construction of plates shall conform to latest revisions of IS:10918. The separators shall maintain the electrical insulation between the plates and shall allow the electrolyte to flow freely. Separators should be suitable for continuous immersion in the electrolyte without distortion.

The positive and negative terminal posts shall be clearly marked.

d) **Sediment Space**

Sufficient sediment space shall be provided so that cells will not have to be cleaned during normal life and prevent shorts within the cells.

e) **Electrolyte**

The electrolyte shall be prepared from battery grade potassium hydroxide conforming to IEC 60993. The cells can be shipped either in charged condition or in dry condition. Necessary electrolyte for make-up shall be supplied separately.

f) **Connectors and Fasteners**

Nickel plated copper connectors shall be used for connecting adjacent cells and PVC insulated flexible copper cables shall be used for inter-row / inter-tier / inter-bank connections. Bolts, nuts and washers shall be Stainless Steel / Nickel coated steel to prevent corrosion. The thickness of Nickel coating of connectors should be not less than 0.02 mm. All the terminals and cells inter-connectors shall be fully insulated or have insulation shrouds.

g) **Battery racks**

Mild steel racks for all the batteries shall be provided. They shall be free standing type mounted on porcelain/hard rubber/PVC pads insulators/High impact plastic insulators. Batteries shall preferably be located in the single tier arrangement. However, batteries having a complete cell weight of lower than 50 Kg could be located in the double tier arrangement. The batteries racks and supports for cable termination shall be coated with three (3) coats of anti-alkali paint of approved shade. Name plates, resistant to alkali, for each cell shall be attached on to the necessary racks. The bottom tier of the stand shall not be less than 150 mm above the floor.

h) **Test**

The Contractor shall submit for Owner's approval the reports of all the type tests carried out as per latest IEC applicable standards. The complete type test reports shall be for any rating of battery in a particular group, based on plate dimensions being manufactured by supplier. Routine and Acceptance tests shall be as per Quality Assurance & Inspection table of battery.

8.5 Auxiliary Equipments

Manual discharge resistance bank suitable for each type of battery bank of UPS/Battery Charger has to be provided by contractor.

8.6 Criteria

Following shall be taken as minimum load value for sizing calculation of UPS/Battery Charger/Battery system. However, Bidder needs to provide the details auxiliary power rating of each individual equipment. & any other load apart from below required for completion of the system is also in the scope of the bidder.

8.7 Site Tests

The contractor shall carry out the following site tests as applicable on UPS, Battery Charger and Battery system. However, any other site test is required to be conducted as a standard practice of the OEM or deemed necessary by the Engineer/ Employer and mutually agreed between the contractor and the employer, the same shall also be carried out.

Light Load Test

This test is carried out to verify that the UPS/Battery Charger is correctly connected and all functions operate properly. The load applied is limited to some percent of rated value. The following points should be checked:

a) Output voltage, frequency and the correct operation of meters;

b) Operation of all control switches and other means to put units into operation.
c) Functioning of protective and warning devices.

A. C. Input Failure Test

The test is performed in UPS/Battery Charger with a fully charged battery and is carried out by tripping input supply feeder or may be simulated by switching off all rectifiers and bypass feeder as at the same time. Output voltage variations are to be checked for specified limits with an oscilloscope/Recorder.

A. C Input Return Test

AC input return test is performed in UPS/Battery Charger by closing AC input supply feeder, or is simulated by energizing rectifiers. Proper operation of rectifier starting and voltage and frequency variations are to be observed. This test is normally performed with a fully or partially charged battery.

Auto changeover Test

This test shall be carried out in UPS ACDB fed from two separate UPS system. Auto changeover of one UPS source to standby UPS to be check by tripping the active UPS manually or by simulation condition. This test shall be check as per approved auto changeover logic.

Transfer Test (for UPS)

This test is applicable for UPS with bypass, particularly in the case of an electronic bypass switch. Transients shall be measured during load transfer to bypass caused by a simulated fault and load retransfer after clearing of the fault.

Full load test

Load tests are performed by connecting the actual load to the UPS/Charger output. Load tests are necessary for testing output voltage and frequency, rated stored energy, recharge time, ventilation, and temperature.

Rated Stored Energy Time (Battery test)

This test is a load test to prove the actual possible time of battery operation. If rated load is not available in the case of large UPS/Battery charger, it is possible to apply a partial load to check the actual battery discharge characteristics and compare these with characteristics specified by the battery manufacturer. Discharge time with rated load shall then be calculated. The test shall be performed with a fully charged battery and also may be done under other battery conditions to be specified, if so agreed. Active power output of the UPS/Battery Charger and the battery voltage shall be recorded during the test. Since new batteries often do not provide full capacity during a starting up period, the discharge test may be repeated after a reasonable recharge time if the original test has failed.

Rated Restored Energy Time

Restored energy depends on the charging capacity of the rectifiers and the battery characteristics. If a certain recharging rate is specified, it shall be provided by repeating the discharge test after the specified charging period.

Battery Ripple Current

If battery ripple currents are specified, then the ripple current which depends on UPS operation shall be checked under normal operating conditions. Rough measuring methods are sufficient.

9. SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

9.1 General

1.1 Contractor shall provide complete SCADA system and at least three workstations (two at TFR and one at the 8MW PV Project for remote monitoring of Floating solar PV system) in the control room of the PV plant with all accessories, auxiliaries and associated equipment and cables for the safe, efficient and reliable operation of entire solar plant and its auxiliary systems.

1.2 Provision shall be made for controlling and monitoring the PV farm at Tamarind Falls Reservoir from the control room at 8 MW Henrietta Phase II Solar PV farm.

1.3 One mobile workstation with all appropriate hardware, firmware, and permanent licenced software shall also be provided for the on-site and remote monitoring, operation, troubleshooting and maintenance of the PV farm.

1.4 The SCADA system shall compose of an integrated operator human-machine interface (HMI), input/output (I/O) modules, Laser printer, Gateway, Networking equipment along with associated cable and appropriate hardware, firmware, and software etc., needed for the completeness even if the same are not specifically appearing in these specifications.

1.5 Plant controller devices designed to industry standards shall provide for remote monitoring, alarm management, control and historical trending of the monitored equipment. For the control and monitoring of the PV farm via the local SCADA system, a ring optic fiber communication network shall be installed to connect all inverters and measurement devices amongst others

1.6 SCADA System shall monitor and display the following information:

i. The overall electrical schematic diagram of the electrical system with status of all equipment.
ii. Represent the farm geographically complete with monitoring parameters
iii. Measurement & continuous acquisition of ambient air temperatures and solar irradiations PV module temperature representative for each string.

iv. Measurement and/or recording of instantaneous power and energy parameters for each set of individual strings
v. Individual string current, inverter input voltage and current, inverter output voltage and current, output frequency and total harmonic distortion.
vi. Generation of yield reports detailing individual string performance and flagging those which are under-performing.
vii. Operating state monitoring and failure indication.
viii. Representation of monitored data's in graphics mode or in tabulation mode.
ix. Monitor and store data from the Project Site meters on an interval from between five (5) to twenty (20) seconds
x. Real-time acquisition and display of data, status, alarms and trends
xi. Power and energy to and from CEB grid
xii. Control of switchgears and Inverters
xiii. Display and storage of measured values
xiv. Display and storage of derived/calculated/integrated values
xv. Display and Storage of Alarm, Event and Trends
xvi. Generate, store and retrieve user configurable Sequence of Event (SOE) Reports
xvii. Generate, store and retrieve user configurable periodic reports. SCADA shall have facility to generate report in MS Excel file type.
xviii. Remote monitoring of essential parameters on the web authorized with user id and password using standard modem (Internet connection for transferring data to web shall be taken by Contractor in the name of Employer Site for O & M period).
xix. System self-supervision.

1.7 The following will make up the SCADA Calculated Values List:

Model vs Actual Performance in kW and kWh

Day's energy in kWh

Month's energy in kWh

Year-to-date energy in kWh

Total lifetime energy in kWh

Performance Ratios

Facility Performance Ratio, current value

Facility Performance Ratio, day's average

Facility Performance Ratio, month's average

Facility Performance Ratio, year-to-date average

Facility Performance Ratio, average since commissioning.

1.8 SCADA shall have provision to control (Switch On/Switch Off) all the MV Breakers and Inverters either in hard or soft signal and shall have facility to control Inverter active and reactive power as per requirement mentioned in respective chapter. SCADA shall also be able to acquire real time Data, Status and Alarm from following equipment included but not limited to as required or offered under the scope of this specification:

I. All the MV Switchgear Equipment (Isolators and Earth Switch/Breakers)
II. Main Incomer and Bus Coupler breaker of LT Panel
III. , DC supply status and alarms as approved in detail Engineering
IV. Weather Monitoring Equipment
V. Multi-function meter
VI. Numerical Relay
VII. Fire Alarm Panel
VIII. Tariff Energy Meter if applicable
IX. Monitoring of inverter's each DC input (current, voltage, power etc.).
X. GPS Time Synchronization unit
XI. SCADA Hardware, Accessories and Communication link
XII. Transformer
XIII. Power conditioning unit (PCU)/inverter
XIV. Any other equipment required as per specification

Type of signal from equipment (Hard wired or Soft) shall be as per specification of the equipment mentioned in the respective chapter and

approved during detail engineering.

SCADA shall provide real time performance monitoring according to IEC 61724 standard.

1.9 In the CMCS room, it shall be possible to remove/replace online various modules (like any I/O module, interface module, etc.) from its slot for maintenance purpose without switching off power supply to the corresponding rack. System design shall ensure that while doing so, undefined signaling and releases do not occur and controller operation in any way is not affected (including controller trip to manual, etc) except that information related to removed module is not available to controller. Further, it shall also be possible to remove/replace any of the redundant controller module without switching off the power to the corresponding rack and this will not result in system disturbance or loss of any controller functions for the other controller. The on-line removal/insertion of controller, I/O modules shall in no way affect the safety of plant and personnel.

1.10 The control system shall provide safe operation under all plant disturbances and on component failure so that under no condition the safety of plant, personnel or equipment is affected. Control system shall be designed to prevent abnormal swings due to loss of Control System power supply, failure of any Control System component, open circuit/short circuit. On any of these failures the controlled equipment/parameter shall either remain in last position before failure or shall come to fully open/close or on/off state as required for the safety of plant/personnel/equipment and as finalized during detailed engineering. System shall be designed such that there will be no upset when Power is restored. This operation shall be demonstrated by vendor during Factory Accepted Test (FAT) in the presence of Employers Representative.

1.11 The Control system shall be designed to operate in non-air conditioned area. However contractor shall provide a Package/Split AC of suitable capacity decided by load requirement in SCADA room. All the power supply module, Ethernet switches and network accessories for non-air conditioned area shall be suitable for operating in ambient temperature of 50 Deg C Minimum.

9.2 Human Machine Interface System (HMIS)

HMIS configured around latest state-of-the art servers/Workstations with open architecture supporting OPC /TCP/IP protocols, etc.

Graphical Interface Unit (GIU) / Operator workstation (OWS) shall perform control, monitoring and operation of all devices interacting with the Scada system. Contractor shall provide engineering workstation (EWS) as programming station of SCADA. It shall be possible to use same EWS as programming station and the Human Machine Interface System. SCADA System shall be provided with redundant OWS. Contractor/Bidder shall make provision for two identical workstations in the control room of the Floating Solar PV Plant, where all functions and controls can be performed on the other OWS in case of failure (act as backup to the main OWS).Operator shall be able to access all control/information related data under all operating conditions including a single processor and computer failure/hardware failure at CMCS in the HMIS. In addition to a desktop based EWS, vendor shall also provide dedicated portable (laptop) based EWS. All frequently called important functions including major displays shall be assigned to dedicated function keys on a soft keyboard for the convenience of the operator for quick access to displays & other operator functions.

The SCADA System shall have ability to perform operator functions for each OWS / GIU as a minimum, include Control System operation (A/M selection, raise/lower, set point/bias change, on/off, open/close operation, mode/device selection, bypassing criteria, sequence auto, start/stop selection, drive auto selection, local-remote/other multi-position selection etc.); alarm acknowledge; call all kind of displays, logs, summaries, calculation results, etc.; printing of logs & reports; retrieval of historical data; and any other functions required for smooth operation, control & management of information as finalized during detailed engineering.

The display selection process shall be optimized so that the desired display can be selected with the minimum no. of operations. Navigation from one display to any other should be possible efficiently through paging soft keys as well as through targets defined on the displays. There should be no limitation on number of such targets.

The system shall have built-in safety features that will allow/disallow certain functions and entry fields within a function to be under password control to protect against inadvertent and unauthorized use of these functions. Assignment of allowable functions and entry fields shall be on the basis of user profile. The system security shall contain various user levels with specific rights as finalized by the Engineer/ Employer during detailed engineering. However, no. of user levels, no. of users in a level and rights for each level shall be changeable by the programmer (Administrator).

Wherever Graphical Interface Unit is envisaged, it shall meet the minimum functional requirements of monitoring, operating & controlling the process and displaying information related to process locally. GIU shall be provided with TFT active matrix or LED display and keypad for operation. GIU shall be ruggedly designed to withstand hard environments like high temperature, shock and vibration.

Remote monitoring of essential parameters on the World Wide Web using standard modem and Popular Browser such Chrome/Internet Explorer shall be provided by the vendor.(Internet connection for transferring data to web shall be taken by Contractor in the name of Employers Site for O & M period).

Bidder has to provide suitable hardware DMZ network firewall to restrict unauthorized access to HMI/ SCADA system.

SCADA shall have facility to provide real time reporting of alarms and statistical data through SMS and e-mails.

9.3 Software Requirement

All necessary software required for implementation of control logic, operator station displays / logs, storage & retrieval and other functional requirement shall be provided. The programs shall include high level languages as far as possible. The contractor shall provide sufficient documentation and program listing so that it is possible for the Employer to carry out modification at a later date.

The Contractor shall provide all software required by the system for meeting the intent and functional/parametric requirements of the specification.

Industry standard operating system like WINDOWS (latest version) etc. to ensure openness and connectivity with other system in industry.

SCADA system shall include the following standard protocols as a minimum.

a) Modbus (TCP/IP, RTU, ASCII)
b) Sub Station Protocol (IEC-61850 and IEC 60870 -5-101/104)

Any other protocol on which the offered equipment (by Contractor) will communicate with SCADA

The system shall have user friendly programming language & graphic user interface.

All system related software including Real Time Operating System, File management software, screen editor, database management software, On line diagnostics/debug software, peripheral drivers software and latest versions of standard PC-based software, Antivirus software and latest WINDOWS based packages (MS Word, Excel and PowerPoint) etc. and any other standard language offered shall be furnished as a minimum.

All application software for SCADA system functioning like input scanning, acquisition, conditioning processing, control and communication and software for operator interface of monitors, displays, trends, curves, bar charts etc. Historical storage and retrieval utility, and alarm functions shall be provided.

The Contractor shall provide software locks and passwords to Employer's engineers at site for all operating & application software so that Employer's engineers can take backup of these software and are able to do modifications at site.

9.4 Parametric Requirements

The control system shall be designed such that under worst case loading conditions the response time shall not be worse than the following:-		
On/Off Command	-	The response time for screen update after the execution of the control command from the time the command is issued shall be one second (excluding the drive actuation time).
Adjustment Command	-	0.5 to 1 second.
On screen Updating	-	1 second.
All Control related displays	-	1 second.
Bar Chart displays	-	1 to 2 seconds.
Plant Mimic displays	-	1 to 2 seconds.
Group review displays	-	1 to 2 seconds.
X-T Plot Displays	-	1 to 2 seconds.
Plant Summary Displays	-	1 to 2 seconds.

All the Analog data shall be scanned at the resolution of 1(one) second and refreshed on screen however, recording of data shall be finalised during detail engineering.

9.5 Input/Output Modules

Input Output modules, as required in the Control System for all type of field input signals (4-20 mA, non-changeover/change over type of contact inputs etc.) and outputs from the control system (non changeover/change over type of contact, output signals for energizing interface relays at suitable DC voltage as decided during detail engineering, 4-20 mA output etc.) are to be provided by the Contractor

Electrical isolation of 1.5kV with optical couplers between the plant input/output and controller shall be provided on the I/O cards. The isolation shall ensure that any inadvertent voltage or voltage spikes (as may be encountered in a plant of this nature) shall not damage or mal-operate the internal processing equipment.

The Input/output system shall facilitate modular expansion in fixed stages. The individual input/output cards shall incorporate indications on the module front panels for displaying individual signal status.

Individually fused output circuits with the blower fuse indicator shall be provided. All input/output points shall be provided with status indicator. Input circuits shall be provided with fuses preferably for each input, alternatively suitable combination of inputs shall be done and provided with fuses such that for any fault, fuse failure shall affect the particular drive/equipment system only without affecting other systems. switching of power supply.

The I/O Module shall have the following features:

a	Power supply monitoring.
b	Contact bounce filtering.
c	Optical isolation between input and output signals with the internal circuits
d	In case of power supply failure or hardware fault, the critical outputs shall be automatically switched to the fail-safe mode. The fail-safe mode shall be finalized during detailed engineering.

Binary Output modules shall be rated to switch ON/OFF coupling relays of approx. 3 VA. Analog output modules shall be able to drive a load impedance of 500 Ohms minimum.

Output module shall be capable of switching ON/OFF inductive loads like solenoid valves, auxiliary relays etc. without any extra hardware.

All input field interrogation voltage shall be finalized during detail engineering

In case of loss of I/O communication link with the main processing unit, the I/O shall be able to go to predetermined fail safe mode (to be finalized during detailed engineering) with proper annunciation.

The single (i.e. non-redundant) binary & analog signal required for control purposes shall be wired as follows:

All single analog & binary inputs including the limit switches of SWGR check-backs of all drives & information related signals shall be wired to single (i.e. non-redundant) input modules.

Inputs and Outputs related to each of the redundant drives / equipment shall be wired to separate input and output modules.

Requirement of Nos. of channel in each type of Module (Analog Input, Analog Output, Binary Input, Binary Output, RTD) and Modbus link at Inverter and main control room shall be calculated based on the Input/output signal list to be submitted by the contractor for approval during detail engineering.

9.6 Data Communication System (DCS)

The Data Communication System shall include a redundant Main System Bus with hot back-up. Other applicable bus systems like cubicle bus, local bus, I/O bus etc shall be redundant except for backplane buses which can be non-redundant.

The DCS shall have the following minimum features :

a. Redundant communication controllers shall be provided to handle the communication between I/O Modules (including remote I/O) and PLCs and between PLCs and operator work station.

b The design shall be such as to minimize interruption of signals. It shall ensure that a single failure anywhere in the media shall cause no more than a single message to be disrupted and that message shall automatically be retransmitted. Any failure or physical removal of any station/module connected to the system bus shall not result in loss of any communication function to and from any other station/module.

c If the system bus requires a master bus controller philosophy, it shall employ redundant master bus controller with automatic switchover facility.

d Built-in diagnostics shall be provided for easy fault detection. Communication error detection and correction facility (ECC) shall be provided at all levels of communication. Failure of one bus and changeover to the standby system bus shall be automatic and completely bump less and the same shall be suitably alarmed/logged.

e The design and installation of the system bus shall take care of the environmental conditions as applicable.

f Data transmitting speed shall be sufficient to meet the responses of the system in terms of displays, control etc. plus 25% spare capacity shall be available for future expansion.

g Cat 6 UTP or fiber optic cables shall be employed.

The Contractor shall furnish details regarding the communication system like communication protocol, bus utilization calculations etc.

Contractor shall setup Gigabit Ethernet based Plant Local Area Netowrk (LAN) to connect to different communication nodes at Inverter /Switchgear location etc. with redundant backbone using ring or better topology. Each Modbus cable shall be provided with Surge protection device at SCADA Panel End. Specification of OFC and Modbus cable has been given elsewhere in this specification

9.6 Operator Interface Displays/Logs/Reports

Suitable Operator Interface Displays/Logs/Reports for control operation & monitoring shall be provided. The details shall be finalized during detailed Engineering stage.

Minimum quantities shall be as follows:-

Various displays on the OWS shall as a minimum include P&ID displays or mimic, bar chart displays, X-Y & X-T plot (trend) displays, operator guidance message displays, group displays, plant start-up/shutdown message displays, system status displays etc. Number of displays and the exact functionality shall be on as required basis and as finalized during detailed engineering subject to the minimum quantities as given in subsequent clauses. For X-T & X-Y plots, the facility of providing a background grid on operator request shall be variable with adequate no. of divisions in both co-ordinates

The minimum quantity of major types of displays per unit shall be as follows:

Sl	Display	Minimum Qty for Plant capacity

a)	Control displays (group/sub-group/ sequence/loop)	(On as reqd. basis subject to 100 minimum)
b)	P&ID/ mimic display	25
c)	X-Y Plot (with superimposed operating curves + using user selectable stored data)	25+25
d)	Group displays	30
e)	Operator guidance message	20
f)	System status & other diagnostic display	on as required basis

The assignment for the above will be done by the contractor as per the requirement of operation of contractor's system as well as for maintenance. The balance displays shall be left as spare for future modification/addition

9.7 Historical Storage and Retrieval System (HSRS)

The HSRS shall collect, store and process system data from MMIPIS data base. The data shall be saved online on hard disk and automatically transferred to erasable long term storage media once in every 30 Days periodically for long term storage. Provision shall be made to notify the operator when hard disk is certain percentage full. The disk capacity shall be sufficient to store at least seven days data.

The data to be stored in the above system shall include alarm and event list, periodic plant data, selected logs/reports. The data/information to be stored & frequency of storage and retrieval shall be as finalized during detailed engineering. The system shall provide user-friendly operator functions to retrieve the data from historical storage. It shall be possible to retrieve the selected data on OWS or printer in form of trend/report by specifying date, time & period. Further, suitable index files/directories shall also be provided to facilitate the same. The logs/reports for at least last ninety (90) days shall be available on the disk.

In addition to above, the system shall also have facility to store & retrieve important plant data for a very long duration (plant life) on portable long term storage media). These data will include any data from the database as well as processed/computed data based a various calculations/transformation. The retrieved data from long term storage media should be possible to be presented in form of alarms, logs, reports, etc.

SCADA shall have facility to store long term data, days wise/ weekly/ monthly/yearly for 25 years for analysis and analytical reports to analyze the plant performance (PR) at various levels i.e, SMB, Inverter, Plant. For faster retrieval of long-term aforementioned performance data, contractor shall offer time series data historian of 400 tags minimum. However actual nos. of tags shall be determined based on the tag calculation.

Following plant performance (PR) long term data as a minimum with time

stamping and interval as indicated in below table but not limited to shall be stored daily on historian for analysis and analytic report.

Important plant data for a very long duration (plant life) Storage

Sl.	Parameter	Time Interval
1	Weather Monitoring Stations data: Global Horizontal Irradiance, Global Inclined Irradiance and Diffuse Horizontal Irradiance, Ambient Temp, Wind Speed, Wind Direction, Rain Fall and Relative Humidity.	1 (One) Minute

2	Calculated Daily Global Horizontal Insolation, Global Inclined Insolation and Diffuse Horizontal Insolation.	24 (Twenty-Four) Hours
3	Power Conditioning Unit (PCUs):- DC Voltage, DC Power, DC Current, SMB/SMU Current (PCU end), AC Active & Reactive Power, Power factor, AC Current & Voltage, Energy, Inverter room temp, Inverter Cabinet temp and Modules Temp	1 (One) Minute
6	MFM, Energy meter and Numerical Relay data:- Active & Reactive Power, Energy (day), Current and Voltage	1 (One) Minute
7	Export feeder/s Energy Meter Data:- Active & Reactive Power, Energy import and export, Current and Voltage and Grid Frequency.	1 (One) Minute
8	Daily energy export from each Inverter	24 (Twenty-Four) Hours
9	Total sum of daily energy export from all Inverter	24 (Twenty-Four) Hours

Contractor shall provide separate/stand-alone historian server as per specification mentioned in respective clause

9.8 Control & Power Supply Scheme

Contractor shall provide the DC Power supply of suitable rating to cater all the load requirements of SCADA system and its auxiliaries. The details of UPS and its batteries are mentioned in the respective clause of this specification. The power backup duration for the entire system should be as mentioned in UPS specification. SCADA system shall have two UPS input power supply and one raw power supply. Power supply module used to convert DC power to AC power shall be redundant. it shall be ensured that SCADA system remain in service in case of single UPS power supply failure/power supply module failure. Suitable alarm shall be generated in case of any power supply failure.

9.9 Cabinets

The cabinets shall be IP-22 protection class. The Contractor shall ensure that the packaging density of equipment in these cabinets is not excessive and abnormal temperature rise, above the cabinet temperature during normal operation or air-conditioning failure, is prevented by careful design. This shall be demonstrated to the Employer during the factory testing of the system. The Contractor shall ensure that the temperature rise is limited to 10 deg. C above ambient and is well within the safe limits for system components even under the worst condition and specification requirements. Ventilation blowers shall be furnished as required by the equipment design and shall be sound proof to the maximum feasible extent. If blowers are required for satisfactory system operation, dual blowers with blower failure alarm shall be provided in each cabinet with proper enclosure and details shall be furnished with proposal. Suitable louvers with wire mesh shall be provided on the cabinet.

The cabinets shall be designed for front access to system modules and rear access to wiring and shall be designed for bottom entry of the cables for Main control room.

The cabinets shall be totally enclosed, free standing type and shall be constructed with minimum 2 mm thick steel plate frame and 1.6 mm thick CRCA steel sheet or as per supplier's standard practice for similar applications, preferred height of the cabinet shall not higher than 2200 mm. The cabinets shall be equipped with full height front and rear doors. The floor mounting arrangement for other cabinets shall be as required by the Employer and shall be furnished by the Contractor during detailed engineering. Wall mounted cabinet is acceptable for Inverter room/ switchgear.

Cabinet doors shall be hinged and shall have turned back edges and additional braking where required ensuring rigidity. Hinges shall be of concealed type. Door latches shall be of three-point type to assure tight closing. Detachable lifting eyes or angles shall be furnished at the top of each separately shipped section and all necessary provisions shall be made to facilitate handling without damage. Front and rear doors shall be provided with locking arrangements with a master key for all cabinets. If width of a cabinet is more than 800 mm, double doors shall be provided.

Two spray coats of inhibitive epoxy primer-surface shall be applied to all exterior and interior surfaces. A minimum of 2 spray coats of final finish colour shall be applied to all surfaces. The final finished thickness of paint film on steel shall not be less than 65-75 micron for sheet thickness of 2 mm and 50 microns for sheet thickness of 1.6 mm. The Preferable finish colors for exterior and interior surfaces shall conform to following shades:

a. Exterior:- As per RAL 9002 (End panel sides RAL 5012),
b. Interior:- Same as above.

Paint films which show sags, checks or other imperfections shall not be acceptable.

As an alternative, single coat of anodic dipcoat primer along with single textured powder coating with epoxy polyester meeting the thickness requirement is also acceptable.

The mimic shall be configured on the HMI and it shall be possible to control, monitor and operate the plant from the same.

9.10 Control Desk

Control desk shall be free standing table top type with doors at the back and shall be constructed of 2 mm thick CRCA steel plates. A 19 mm thick wooden top shall be provided on the desk to keep the TFT monitors at top and computers inside. Control desk shall consist of vertical, horizontal and base supports with their coverings for work surface, keyboard trays, mouse pads, monitor shelf and concealed cable and wire way management, perforated trays with covers in both horizontal and vertical directions. Telephone sets, very few PB stations and lamps shall be mounted on the control desk on mosaic grid structure and same shall be decided during detailed engineering. ASCII Keyboard shall be capable of being pulled out through a tray.

Each Control Desk shall have two UPS input power supply and one raw power supply. It shall be ensured that Workstation remain in service in case of single UPS power supply failure.

The cabling / wiring between OWS & CPU'S, power supply cables etc. shall be aesthetically routed and concealed from view.

9.11 Furniture

Chairs – Industry standard revolving chairs with wheels and with provision for adjustment of height (hydraulically/gas lift) shall be provided for the operators, unit-in-charge & other personnel in control room area. These shall be designed for sitting for long duration such that these are comfortable for the back. Arm-rests in one piece shall be of poly-urethane and twin wheel castor of glass filled nylon.

Two Office Tables with Drawers and Fully Enclosed Cabinets for Workstation

One Printer Table with Drawers made of Laminated Wood or Heavy Duty MDF shall be provided for printer. All the furniture shall be of reputed make.

One Full Height File Cabinet

Heavy Duty Racks for the Store Room

9.12 Software Documentation and Software Listings

All technical manuals, reference manuals, user’s guide etc., in English required for modification/editing/addition/deletion of features in the software shall be furnished. The Contractor shall furnish a comprehensive list of all system/application software documentation after system organization for Engineer’s/ Employer’s review and approval.

All The software listings for application software, Project data files etc. shall be submitted by the Contractor.

All the SCADA Software with license Key shall be handed over to Employer on the DVD/CD media. All the hardware and software shall be licensed to CEB.

9.13 Software Licenses

The Contractor shall provide software license for all software being used in Contractor’s System. The software licenses shall be provided for the project (e.g. organization or site license) and shall not be hardware/machine-specific. That is, if any hardware/machine is upgraded or changed, the same license shall hold good and it shall not be necessary for Employer to seek a new license/renew license due to up gradation/change of hardware/machine in Contractor’s System at site. All licenses shall be valid for the continuous service life of the plant.

Contractor shall provide licenses as per Cl. 2.0 of Chapter A-2 for remote monitoring of the essential parameters of solar plant on the web using popular web browser without requirement of additional software. User ID and password for remote view can only be changed by SCADA Administrator.

9.14 HMIPIS Hardware

The Human Machine Interface and Plant Information System (HMIPIS) as specified shall be based on latest state of the art Workstations and Servers and technology suitable for industrial application & power plant environment.

The Workstation/Servers employed for HMIPIS implementation shall be redundant based on industry standard hardware and software which will ensure easy connectivity with other systems and portability of Employer developed and third-party software.

Redundant sets of communication controllers shall be provided to handle all the communication between the HMIPIS and redundant system bus and to ensure specified system response time and parametric requirements. Each communication controller shall have message checking facility.

Power Fail Auto Restart (PFAR) facility with automatic time update shall be provided.

All the peripherals shall conform to the following minimum requirement but the exact make & model shall be as approved by Engineer/ Employer during detailed engineering. The LAN to be provided under HMIPIS shall support TCP/IP protocol (Ethernet connectivity) and shall have data communication speed of min. 100 MBPS. All network components of LAN and Workstations shall be compatible to the LAN, without degrading its performance.

Operator Workstations/Historian/Portable EWS

SI No.	Features	Industrial Grade Operator workstations/ Other workstations/ Documentation station (in case not part of prog. Stn.)
1.	Processor	64 bit(i5 or Equivalent)
2.	Memory	8 GB RAM upgradable to 16 GB
3.	Hard Disk	500 GB ultra wide RAID1 for OWS/ 500 GB for Portable EWS 1 TB ultra wide RAID1 for Historian
4.	Monitor (color)	Min 22” TFT Flat Monitor with non-interfaced refresh rate min. 75 Hz. **Communication port:-** 2 Serial bus , one parallel Dual 10/100/1000 Mbps. Ethernet Graphic Memory = 16 MB Expansion slot=3
5.	Removable bulk storage drive (DVD / DAT)	6 GB (minimum)
6	Network Connectivity	4 Nos. Built-in Ethernet Network Port
7.	DVD R/W	16x or higher

8.	Keyboard	ASCII
9.	Pointing Device	Mouse
10.	Additional general purpose software (for using over network by servers/workstations/PCs)	Comprehensive disk maintenance utility for disk clean sweep/ crash guard/antivirus, etc.
11.	Software	MS. Windows latest, MS Office Editor (EXCEL,WORD, POWER POINT), Adobe Acrobat, Anti Virus, Network Security, Etc.

Engineering Cum Operator Workstations

SI No.	Features	Industrial Server Grade Engineering cum Operator workstations
1.	Processor	64 bit Server Grade (Xeon or Equivalent), Octacore minimum
2.	Memory	16 GB RAM upgradable to 24 GB
3.	Hard Disk	1 TB RAID1
4.	Monitor (color)	Min 22" TFT Flat Monitor with non-interfaced refresh rate min. 75 Hz. **Communication port:-** 2 Serial bus , one parallel Dual 10/100/1000 Mbps. Ethernet Graphic Memory = 16 MB, Expansion slot=3
5	Network Connectivity	2 Nos. Built-in Ethernet Network Port
6.	Removable bulk storage drive (DVD / DAT)	6 GB (minimum)
7.	Portable Bulk Storage Media	2 TB (2 nos.)

8.	DVD R/W	16x or higher
9.	Keyboard	ASCII
10.	Pointing Device	Mouse
12.	Additional general purpose software (for using over network by servers/workstations/PCs)	Comprehensive disk maintenance utility for disk clean sweep/ crash guard/antivirus, etc.
13.	Software	MS Windows latest, MS Office, Adobe PDF Reader, Anti Virus, Network Security Etc.

Printer

Sr	Features	Networked Color Laser Printer
1	Paper Size	A3
2	Printing Speed (min.)- in normal mode for A4 size paper	6 ppm (Color)
		24 ppm (B&W)
3	Type	Heavy duty, at least 50000 pages/month
4	Resolution (black) (min.)	600 dpi
5	First page out time (with full graphic display)	=<1 min for color,
		<45 sec for BW
6	Paper input capacity (min.)	500 sheets
7	Additional features	Automatic Duplex Printing
8	Paper sheets (1 ream = 500 sheets) with printer (To be supplied with printer)	10 reams (A3)
		21 eams (A4)

9.15 Factory Acceptance Test (FAT)

FAT procedure shall be submitted by bidder for Engineer's/ Employer's approval and after approval of FAT procedure, FAT will be witnessed by Engineer or authorized representative of Employer. The SCADA shall be able to communicate with all third party devices which are part of Solar Plant and the same shall be demonstrated during the FAT.

9.16 Additional Clause

Please refer to the Chapter A-2 for additional clause related to this section of specification.

9.17 Time Synchronisation Equipment

Time Synchronization equipments shall be provided and shall be located in the Control Room. It shall receive Coordinated Universal Time (UTC) transmitted through Geo Positioning Satellite (GPS) for time synchronization of all components of the SCADA.

It shall be complete in all respects including antenna, all cables, processing equipment, etc.

All auxiliary systems and special cables required for synchronization of the equipment shall be supplied and commissioned by the Contractor.

It shall work from DC supplies only and the Contractor to clarify if any built-in battery backup is provided, in which case, same shall be of long life lithium batteries.

It shall be immune to hostile electrical environment. Suitable protections are to be provided against lightning surges and over-voltages in power supply systems and antenna feeders.

The system shall be fully tested to the relevant international standards such as IEC: 801 and IEC: 255.

All components of the SCADA, including power plant Controllers, Workstations, and all numeric protection relays as per requirement under this scope of technical specification or offered by bidder shall be synchronized with an accuracy of 1ms.

The GPS shall be synchronized with the SCADA system to be supplied under this contract and all devices which are communicating with Solar SCADA shall be synchronized with GPS. Necessary software and Hardware (including laying of communication cable) required for time synchronization with SCADA and all other devises shall be in scope of contractor.

The system should be able to track more than 1 satellite at a time to ensure no interruptions of synchronization signals.

The system shall have provisions for combination of any of the following output signals:

- NTP (network time protocol) 100Mbits Ethernet port
- IRIG-B00x (TTL, pulse width modulated signal)
- 2 x Pulse per half-hour/ Pulse per minute/ Pulse per second outputs via potential free contacts
- Any other output port as may be required for the offered system.
- Alarm status contact indicating healthy status of system

These output ports shall be compatible with the requirement of the equipment to be synchronized. The master clock in control room shall also be synchronized with the time synchronization system. The actual port requirements (no./type) in line with the system offered shall be finalized during detailed engineering.

The equipment should have a periodic time correction facility of one-sec. periodicity. The equipment shall also have real time display in hour, minute, second (24-hour mode) and have a separate time display, having display size of approx. 144mm height.

9.18 Technical Specification for Network Firewall

Offered firewall shall include but not limited to the following features-

Technical Requirements for Network Firewall		
S No	Feature	Required parameter
A	General	
A1	Common Criteria Certification.	The offered product series or its operating system series must have achieved EAL (Evaluation Assurance Level) Certification of EAL4 or higher in the Common Criteria for Information Technology Security Evaluation (ISO/IEC 15408) for computer security certification.
A2	Architecture	The firewall should be a purpose built hardware appliance based next generation firewall (NGFW) solution having application awareness & Intrusion prevention function.

A3	End of sale	OEM End-of-sale declaration shall not have been released for the offered model at the time of the bid submission.
B.	Hardware Specifications & Performance Parameters	
B1	Firewall Interfaces	Minimum Four or AS REQUIRED Nos of gigabit 10/100 base T Ethernet ports to be provided.
		Provision of addition of at least Two Nos of gigabit Fiber SFP ports shall be available.
		Each Port must be configurable flexibly in any security zone as per the requirement without any fixed zone assignments.
		All the above specified interfaces shall be firewall interfaces. Internal Switch interfaces shall not be considered.
		The Firewall shall NOT have any wireless interfaces.
	Security Zones	At least four Security zones must be supported.
C	Firewall Inspection	
C1	Application Support for Inspection	Should support standard protocols
		Internet based applications like Telnet, FTP, SMTP, http, DNS, ICMP etc. should be supported for filtering
		Internet web 2.0 applications & widgets.
C2	NAT & PAT	Dynamic NAT as well as one to one NAT
		Port / IP Address Forwarding
		PAT
C3	Resistance to Evasion	The firewall shall be able to detect and block evasion techniques including SYN flood, Address spoofing and TCP split handshake etc.
D	Application awareness	
D1	Application intelligence and	Firewall should support detection of application regardless of port, protocol etc.

	control	firewall must identify and control applications sharing the same session
		The firewall should allow creation of securities policies to identify, allow, block or limit an application regardless of port, protocol etc.
E	Intrusion Prevention System (Integrated with firewall)	
E1	General	The IPS must provide intrusion prevention functionality out of the box.
		The IPS should be capable of accurately detecting intrusion attempts and discern between the various types and risk levels, including unauthorized access attempts, pre-attack probes, suspicious activity, vulnerability exploitation etc
		The IPS should provide protection from Advanced Botnets, inbound and outbound.
		The IPS should use stateful detection and prevention techniques and provide zero-day protection against worms, Trojans, spyware, keyloggers, and other malware from penetrating the network.
E2	Detection Methods	The offered solution should use the following methods for detection of malicious traffic:
		(a) Signature based detection
		(b) Statistical Anomaly based detection
E3	Threat Intelligence and signature Updates	The IPS OEM should have a 24x7 security service update and should support real time signature update of the system as soon as updates are released.
E4	Exception List	The IPS should support the creation of Access Control Lists to bypass the inspection of any specific flow.
E5	DoS/ DDoS protections	The offered solution should be capable of preventing Denial of Service and Distributed denial of service attacks.
E6	Threat control features	The offered solution should provide the following Security features:

		a) Detection and blocking malicious web traffic on any port.
		c) Capability of detecting attacks within protocols independent of port used
		d) IPS Sensor should allow the admin to create IPS policies on the basis of IP addresses and range.
E7	Signature Tuning	The offered solution should allow enabling/disabling of each individual signature. Each signature should allow granular tuning to suit user requirement.

9.19 Remote Control and Monitoring

The Contractor shall describe and provide external communications link to provide the Employer access to all data acquisition and real time performance monitoring. The microprocessor control unit shall have the provision for installation of Ethernet communication link so as to enable remote control and monitoring capability via a personal computer and mobile phones. All parameters, status and indicators and targets accessible through the local operator interface may be accessed remotely through these ports.

10. EQUIPMENT PROTECTIONS

The electrical design shall include the design of equipment earthing (grounding) and lightning and surge protection for the entire PV Plant site. The detailed equipment protections are described below:

10.1 Lightning Protection

The Contractor shall design, supply, install, test and commission a lightning protection system, materials and components fully in compliance with IEC 62305 or NFC 17-102. The Contractor shall use the services of a lightning protection company to design the lightning protection system. The Tenderer shall provide details of his proposed solution in his Tender.

The Contractor shall provide air terminals, bonding plates, conductors, connectors, conductor straps, fasteners grounding rods, and rod clamps and other components required for a complete system that meets the requirements of IEC 62305 or NFC 17-102. Lightning protection shall be designed and provided in accordance with Protection Class level III (minimum) for the entire Solar PV system.

Ground rods shall be 20 mm minimum diameter by 3 meters long, copper clad steel, molecular bonded with minimum 27 percent of the rod weight in the copper cladding.

Conductors shall be installed with a direct path from air terminals to the ground connection avoiding sharp bends and narrow loops.

The Contractor shall use approved C-clamps for all conductor splices and for all connections between conductors and other components.

The control system DC supply shall be protected via appropriate lightning and surge arrester modules.

Adequacy of the lightning protection system coverage shall be demonstrated by the rolling sphere method using a proprietary software package. Lighting protection study reports shall be submitted for review and approval by the Engineer/ Employer.

At least two (2) earth connections shall be provided for the PV metal frames, each bonded to earth electrodes.

Lighting Protection System for Solar Array

Complete Solar Array with associated structure shall be protected from Direct Lightning Stroke. Lightning Protection for solar array shall be achieved with any or both of the following two systems as per specification provided below

Single Rod Air Terminal (Faraday Rods)

Early Streamer Emission (ESE) Air Terminal

Suitable earthling and equipotential bonding shall be ensured for the lightning protection Air Terminal as per applicable standard/Equipment manufacturer guidelines.

Current carrying parts and accessories such as clamps, fasteners, down conductor, Test links and earth termination etc. shall be preferably procured from OEM of Air Terminals if it is supplied by them as part of lighting protection system.

Lightning Protection System for Solar Array with E.S.E air terminal

Solar array shall be protected from direct lightning stroke with Early Streamer Emission air terminal in accordance to NF C 17-102.

Location and layout of ESE terminal shall be in such a manner that it cast no shadow on the PV Modules during 08:30 AM to 04:30 PM. Number and location of ESE air terminal shall be decided during detail engineering. For this purpose, design calculation considering protection level III (minimum) and Autocad drawing of the layout of ESE terminal shall be submitted to Engineer/ Employer for approval.

ESE air terminal shall be type tested as per Annexure- C of NF C 17-102 (Latest Revision) in the manner as mentioned in the standard.

ESE Air terminal shall be supplied with test link, counter, down-conductor, Tripod Earthing, support mast and accessories required for completeness for ESE Lightning protection system.

Owner shall test ESE terminal (Each terminal/Sample basis) before installation with suitable instrument for functionality of terminal. Vendor shall replace the terminal free of cost if found defective.

Support mast for ESE Air terminal shall be heavy duty hot dip galvanized material and shall be suitable to withstand dynamic and static forces acting on it without failure. Foundation for the mast shall be M20 Grade concrete or better with minimum depth of 1200 MM.

10.2 Surge Protection

Internal surge protection shall consist of three surge-arrestors connected from positive and negative terminals to earth (via Y arrangement).

10.3 Earthing Protection

The Contractor shall design and install an earthing system in accordance with the latest edition of IEEE 80 to achieve touch and step potentials within safe limits.

The continuity of the earthing grid shall accommodate the thermal and mechanical stresses caused by any fault current which may arise.

The earth grid shall consist of a combination of bare copper conductors and driven earth rods. Earth rods shall be driven into the ground for a depth of no less than 3 m and shall be at least 12 mm diameter and may be of either copper or copper clad steel. The main grid conductor shall be bare copper conductor, having a cross section area calculated for the maximum earth fault current for 1 sec. and a final conductor temperature not exceeding 150°C.

Interconnection of all equipment and main earth bars shall be by means of PVC insulated copper conductor of cross-sectional area sufficient to carry the prospective fault current for 1 second with due allowance for specified future extensions.

Earth bars shall be provided in the switchgear rooms for connecting MV and LV switchgear to earth. In addition, an earth bar shall be provided adjacent to the surge arresters and all transformers for connection of these items to earth.

All major items of electrical equipment under this contract shall be bonded to the earth bar at no less than two locations. Such major items of equipment are PV modules, switchgear, transformers and inverters.

All earth bars shall be connected to the main earth system at two points.

Where parallel earth conductors are provided to accommodate the full earth fault rating of the circuit, fault current sharing shall be based on no greater than 60% of the rating of the individual conductor.

Conductors for bonding of cable tray shall be bare. Continuity shall be ensured by means of a continuous length of conductor for each run of ladder or tray or by means of flexible straps at joints between sections.

Pipework, other than PVC, supplied under this Contract shall also be bonded in an approved manner.

Earth connection to surge arresters, transformer neutral points shall be made direct to the nearest group of earth rods and interconnected to the remainder of the earth system, using conductors of adequate current carrying capacity.

Connections between equipment and earth bar shall be made by means of lugs compressed onto the copper strands, using the appropriate materials. Connections which depend upon solder shall not be used.

The contractor shall be responsible for the bonding to the main earthing system of all electrical equipment supplied under this contract. The metal sheath and armour, if any, of all cables shall be connected to the main earthing system via a copper conductor.

Unless otherwise approved, the metallic sheath and/or armouring of single-core power cables laid in trefoil formation shall be bonded together and efficiently earthed where the trefoil breaks at each end of the run, and elsewhere as instructed by the Engineer/ Employer. The sectional area and contact of the bond shall be sufficient to carry normal currents and also the maximum fault current without undue heating of the bond.

All metal parts other than those forming part of an electrical circuit shall be connected in an approved manner to separate copper earth bars running along the bottom of boards and desks.

The dimensions of these earth bars shall be not less than 70 mm2 for control boards and desks and 150 mm2 for switchboards. The Contractor shall submit detailed calculation for the sizing of the earth bars for approval by the Engineer/ Employer prior to ordering.

The metal cases of all instruments, relays and the like shall be connected to the copper earth bars by conductors of not less than 2.5 mm2 or by other approved means.

Earthing connections shall not depend on welded or bolted joints between the enclosures of panels or cubicles. Copper earth bars shall be provided in every case.

The use of electronic equipment and in particular solid-state controllers and programmable controllers, demands that special attention be paid to the cabling requirements and supplies to the equipment.

The recommendations of the suppliers of the equipment must be rigidly adhered to. In general, the considerations relate to the following areas:

1). Earth faults on the power system must not result in excessive voltages on the electronic equipment.

2). System disturbances (switching surges etc.) must be isolated from the electronic equipment.

3). Signal cables shall be routed and screened to avoid induced signal noise, and the screens connected at the control panel end only, to avoid current loops.

4). The use of galvanic or optical isolation may be necessary to avoid 'noise'.

5). The circuit or 'electronic' earth shall be brought separately to the nearest main earthing point (substations typically) and shall not be connected to the equipment enclosures earth or the protective earth conductor for the equipment.

Tests shall be carried out on site to confirm that, when it is isolated from the existing earth system the resistance of the earth grid to the general mass of earth, is no greater than 1 Ohm.

Tests shall also be carried out on site to confirm that the overall interconnected grid resistance to the general mass of earth shall not exceed 0.5 ohms.

The Contractor shall measure and record the conductivity and continuity of all grid connectors prior to back filling.

10.3.1 Earthing Requirement for Equipment on Floater

Aforementioned requirement of the earthing are applicable earth surfaces. For Floater area, contractor shall lay 25X6 GI Flat all along the periphery of the floater area. This periphery GI Flat shall be connected at suitable location by laying minimum 2 Nos. of 25X6 GI flat equi-spaced (Location to be decided during detail engineering) along East-West and North-South direction making a grid 25X6 GI Flat on the floater.

All the equipment/devices, module metallic frame & structure on the floater shall be connected with 25X6 GI Flat.

The earthing system of Floater shall be connected with earthing system of ground at each location of Inverter transformer with 2 (two) nos. of 120Sqmm copper earthing cable.

10.3.2 Earthing Requirement for Other Equipment

Contractor shall ensure there at least two earth pits each dedicated for earthing of each Transformer, HT/LT Switchgear panel, transformer neutral, Battery Charger/UPS/Control

Panel etc. shall be provided. Earth electrode shall be located near to the equipment and all earth electrodes shall be interconnected with parallel conductor buried in earth surrounding the equipment.

Earthing system of different locations such as Inverter room/MV and LV Switchgear//Inverter etc. shall be interconnected in single network with buried copper conductor laid at minimum 600 mm depth. Contractor shall submit the calculation based on the system of earth conductor and electrode connected in single network. Location and manner of interconnection shall be approved during detail engineering.

For functional earthing of electronic component such as SCADA, contractor shall provide 1 no. (Min) isolated earth electrode near to the equipment connected with 2 run of copper cable of size not less than 25 sq-mm. Contractor shall comply to the recommendation of OEM (Original Equipment Manufacturer) for electronic earthing and electrode can be connected with other earth electrode as per recommendation of OEM.

Each inverter duty transformer having shield between HV and LV winding shall be provided with 2 nos. Isolated earth electrode connected with each other for functional earthing of transformer shield. Each electrode shall be connected with transformer shield with separate 25X6 Cu flat.

11. COMMUNICATION SYSTEM

The CEB has a ring optical fibre network that span over the island to connect all major substations, including Henrietta Substation. The CEB’s communication in Henrietta Substation is made up of RTU Micom C264, Multiplexer DXC500 and patch panels as shown in Figure 11.1 below. The SCADA system at the national System Control Centre at Curepipe is of ALSTOM EMS.

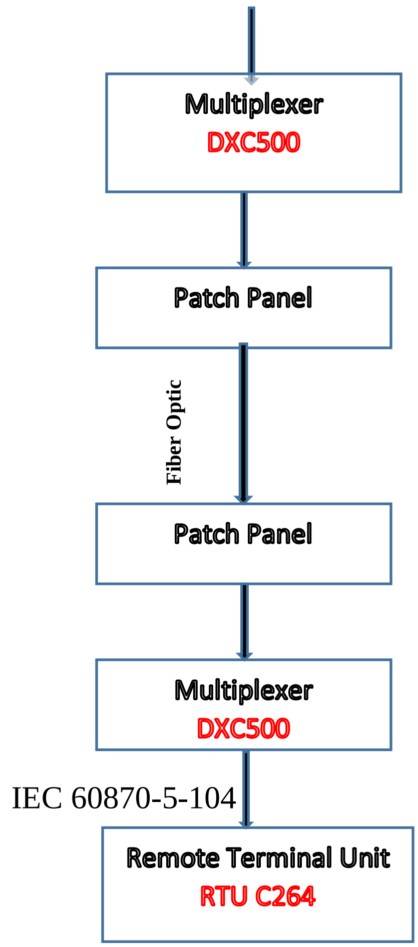

Figure 11.1 Communication System

11.1 Requirements

All alarms and signals shall be transmitted under the IEC-104 protocol with compatibility with the existing eterra-platform at the national control center in Curepipe to the existing Multiplexer panel of Henrietta substation. These data will then be transmitted for communication to the national control centre in Curepipe via the fibre optic.

All equipment required for the 22kV switchgear communication, control and data acquisition shall be part of the Contractor’s scope of supply unless stated otherwise. The system shall comply with the requirements in this Specification as indicated.

11.2 Communication Requirements

A communication system is required for secured transfer of operating data, protection and control signals via fiber optics cable from the TFR to the 8 MW Henrietta Phase II Solar PV Farm and then transfer these information to the System Control Centre via the Remote Terminal Unit (RTU) in Henrietta Substation.

The communication requirements are as follows:

- A fibre-optic link facility will be installed by the CEB from Tamarind Falls Reservoir (TFR) control room to the 8MW Henrietta Phase II Solar PV Farm to allow for data transmission and communication from the TFR to 8 MW Henrietta Phase II Solar PV Farm and CEB System Control Centre via Henrietta Substation.
- The Fibre Optics shall be terminated by the Contractor at both ends i.e. in patch panels (at TFR and 8 MW Henrietta Phase II Solar PV Farm) and also design, procure, install, test and commission all the necessary interface equipment (Switches, Patch Panels, Media Converters, Data Cabinets, Secured Power Connections, or any other equipment as may be required) at both ends of the fibre optics.
- The Contractor shall ensure that all newly installed communication equipment is compatible with the existing communication system at the 8 MW Henrietta Phase II Solar PV Farm and RTU at Henrietta substation.
- The Contractor shall be responsible for the testing and commissioning of the complete communication system from the TFR (Control Room) to the 8 MW Henrietta Phase II Solar PV Farm and up to the System Control Centre.

1. Communication system shall be established from the FSPV farm Facility to the System Control Centre through 8MW Henrietta Phase II Solar PV Farm for the following purposes:
   - Controlling of 22KV CEB side Circuit breaker
   - Status of all feeders of 22kV switchgear at TFR (Open/Close)
   - All isolators, Load break Switch Status Open and Closed status separately
   - All Circuit Breaker Status Open and Closed individually for each breaker
   - Protection Relay Operated
   - Protection Relay health status
   - SF6 Alarm (if available)
   - UPS Alarms
   - Door Alarm (Switchgear room door on CEB side of the Interconnection Facility)
   - Communication equipment faulty
   - Other Alarms (grouped)
   - Main LV circuit Breakers
   - MW, MVAr, power factor, voltage level and frequency

2. Remote control facilities of the FSPV farm Facility from the 8MW Henrietta Phase II Solar PV Farm and the System Control Centre:

   - Load Break Switch OPEN CTRL command for All Incomers including status.
   - Load Break Switch CLOSED CTRL command for all Incomers including status.
   - All Circuit Breaker OPEN CTRL command including status.
   - All Circuit Breaker CLOSED CTRL command including status.

3. Communication from the FSPV farm Facility to 8 MW Henrietta Phase II Solar PV Farm and the System Control Centre for Active-Power Control

Curtailment Facility:

- Curtailment facility status indication (ON/OFF). This controllable point is set ON or OFF by the System Control Centre,
- Curtailment in progress digital feedback
- Facility MW curtailment set-point value (MW Feedback)

It is important to note that system priorities shall be developed and installed for the above between the 8 MW Henrietta Phase II Solar PV and the System Control Centre.

The Signals set forth under Availability Estimates and Curtailment Facility shall be updated at the following rates:

(a) Analogue Signals – 2 Seconds
(b) Digital Signals – 1 Second

Remote monitoring of all the equipment status of TFR as listed above shall be provided at the 8 MW Henrietta Phase II Solar PV Farm.

Controlling of the 22KV Circuit breaker (FSPV side) shall be from the local as well as from remote i.e from the 8MW Henrietta Phase II Solar PV Farm.

A simplified diagram showing the communication system is given below.

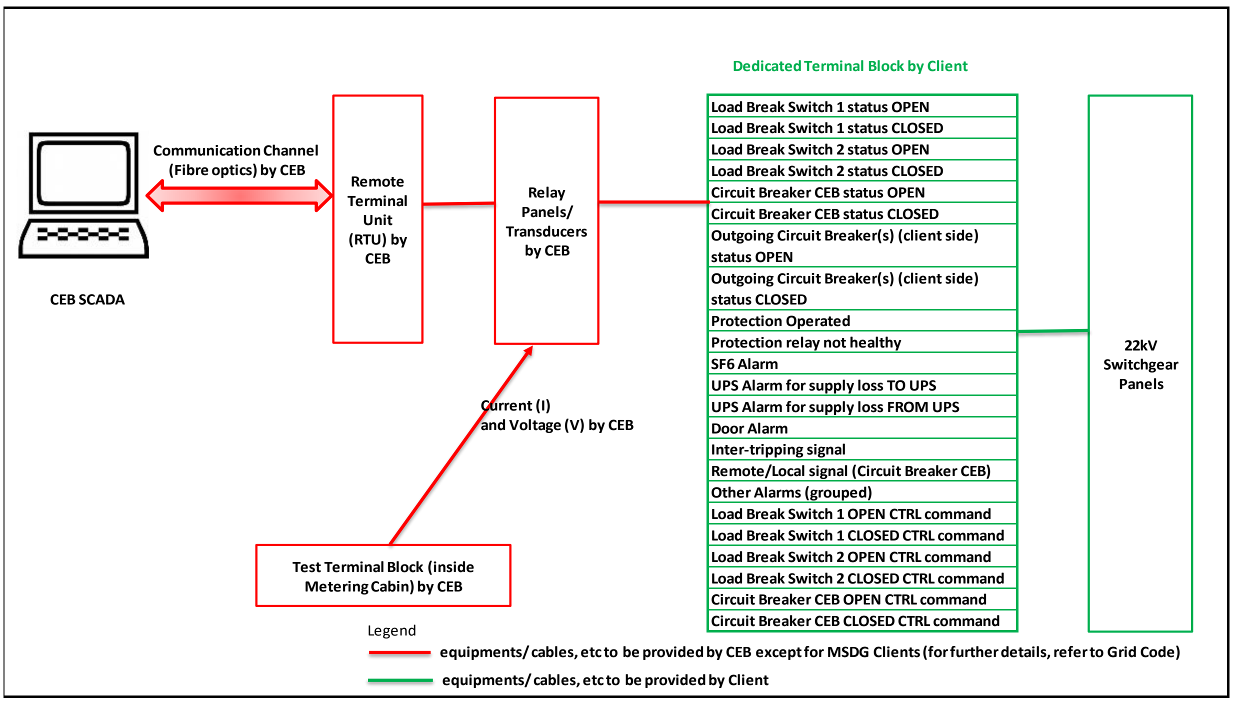

Figure 11.2: Simplified block diagram showing the communication system

11.3 Reactive Power Capability

The PV plant shall be equipped with reactive power control functions capable of controlling the reactive power supplied by the PV plant at the point of delivery (POD, Tamarind Falls Reservoir switchgear) with CEB's network. The reactive power control functions shall be mutually exclusive, which means that only one of the two functions mentioned below can be activated at a time:

- Power Factor Control
- Reactive Power Control

If previously agreed with the CEB on a case-by-case basis, a Voltage Control mode may also be required.

The actual operating modes, as listed above, as well as the operating point shall be determined by the CEB. The functional mode and set point of the PV plant shall not be changed unless instructed by CEB.

The PV plant shall supply rated power (MW) for power factors ranging between 0.95 lagging and 0.95 leading, available from 20% of rated power measured.

11.4 Human Machine Interface (HMI)

The HMI at the control room of the PV plant shall consist of a video display unit with a keyboard and mouse, and shall be based on a single computer system with automatic fail change-over. The computer shall be continuously updated with real-time operational data and events. It shall only be possible to perform one control command at a time.

11.5 Test Requirements

Factory testing and witnessed Acceptance tests to demonstrate compliance with required functionality shall be performed on the Integrated Control system before shipment to site. A programme of site commissioning tests shall be prepared by the supplier for approval prior to commissioning.

11.6 Cyber Security

Cyber security is a recognised issue that requires positive steps to prevent unauthorized access of one kind or another, be it malicious or nuisance.

Connections to the public telephone system represent a cyber security risk.

Also, cyber security risks can be present within an organisation e.g., unauthorised access by employees etc. Such risks have to be covered adequately.

NERC CIP requirements for cyber security are the baseline reference requirements for utility companies. They are now mandatory for utility companies in the USA.

NERC is the 'North American Electric Reliability Corporation'.

CIP is 'Critical Infrastructure Protection'.

The substation controller shall comply with NERC CIP requirements.

12. GUARANTEE OPERATING CHARACTERISTICS OF PV PLANT

12.1 General

Bidders are required to ensure that all equipment proposed have the capabilities to implement all the requirements of the MSDG Grid Codes, especially requirements stipulated in this chapter.

12.2 Fault Ride through Requirements

The PV plant shall remain connected to the distribution system for system voltage dips on any or all phases, where the system voltage measured at the point of common coupling to the CEB network remains above the green line in the voltage duration profile of the Figure 12.1 below.

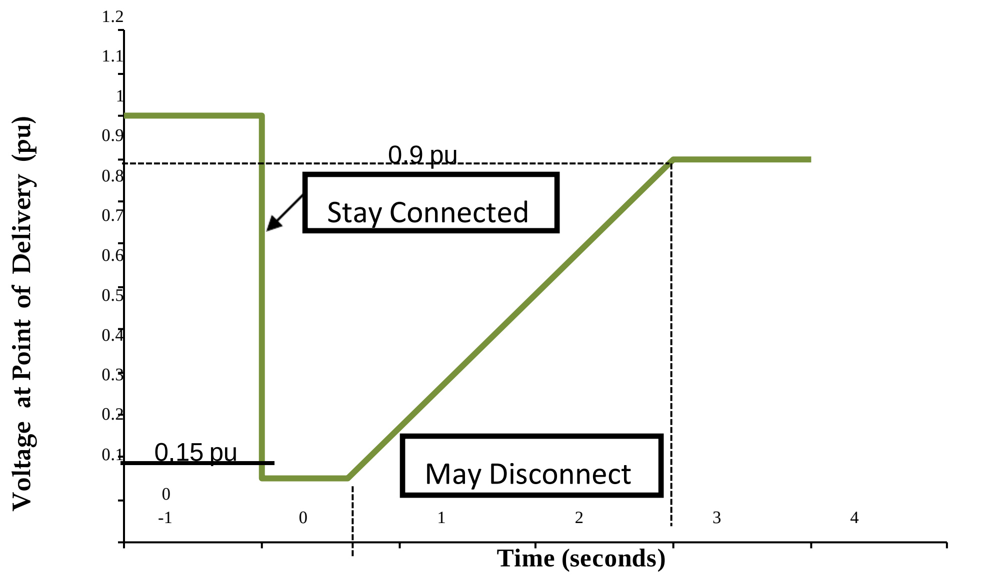

Figure 12.1: Fault Ride Through Requirement

In addition to remaining connected to the distribution System of CEB, the PV plant shall have the technical capability to provide the following:

During the voltage dip in the CEB network being connected to floating solar PV plant, the PV plant shall provide active power in proportion to retained voltage and maximise reactive current to the distribution system, within the technological and design limitations of the PV plant facility and without exceeding its design limits. The maximisation of reactive current shall continue for at the least 3 seconds or until the distribution System Voltage recovers to within the normal operational range of the distribution System whichever is the sooner.

Due to the dynamic nature of the CEB network, higher or lower fault clearance time and the LVRT voltage curve for the Solar Farm may be required, which shall then be discussed with the CEB.

The above LVRT curve shall be coordinated with the under-voltage protection settings to ensure grid support during fault conditions

12.3 Frequency Response

In case of frequency deviations in the CEB network, the PV plant shall be designed to be capable to provide power-frequency response in order to contribute to the stabilization of the grid frequency. Under normal system frequency ranges, the PV plant should operate with an active power output as set in Figure 12.2 below exceeding its design limits.

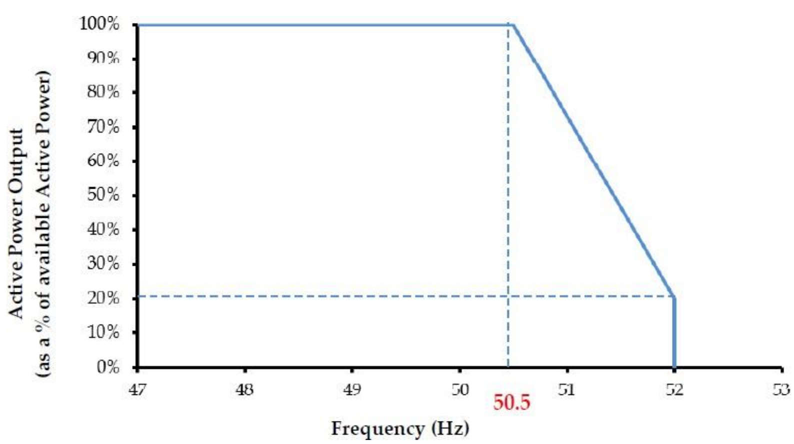

Figure 12.2: Frequency Response Requirements

The PV plant shall have to reduce the power output about a system frequency above 50.5Hz. The power has to be reduced with a gradient of 40% per Hz of the instantaneously available power. The output power is only allowed to increase again as soon as the frequency is only 50.05Hz. Above 52Hz and below 47Hz the plant has to disconnect from the grid.

12.4 Power Quality

The PV plant and equipment shall not cause excessive voltage excursions nor cause the voltage to drop below or rise above the range maintained by CEB. The PV plant and equipment shall not introduce excessive distortion to the sinusoidal voltage or current waves.

12.5 Limitation of voltage flicker induced by the MSDG

The installation shall not cause abnormal flicker beyond the limits defined in IEEE 519.

12.6 Harmonics

The total harmonic distortion will depend on the injected harmonic current and the system impedance seen from the PCC.

The PV plant output should have low current-distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system. The PV system electrical output at the POD/PCC should comply with IEEE Std. 519 and should be used to define the acceptable distortion levels for PV systems connected to a utility. The IEEE 519 recommendation is to be applied at the PCC, not to downstream equipment.

The table below applies to voltage harmonics whose frequencies are integer multiples of the power frequency

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV < $V \leq$ 69 kV	3.0	5.0

At the PCC, the harmonic currents limits are as follows:

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
< 20[c]	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L

where

I_{sc} = maximum short-circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

12.7 Voltage step change

The process of starting the PV plant can sometimes cause step changes in voltage levels in the distribution network. These step changes are caused by inrush currents, which may occur when transformers or induction generators are energised from the network. Step voltage changes will also occur whenever a loaded generator is suddenly disconnected from the network due to faults or other occurrences.

Step voltage changes caused by the connection and disconnection of generating plants at the CEB grid level should not exceed +/- 3% for infrequent planned switching events or outages and +/-6% of the nominal voltage of 22 kV for unplanned outages such as faults.

Surge Withstand Capability The interconnection system shall have a surge withstand capability, both oscillatory and fast transient, in accordance with IEC 62305-3. The design of control systems shall meet or exceed the surge withstand capability requirements of IEEE C37.90

12.8 Voltage Unbalance

The contribution to the level of unbalance of the voltage at the POD of any installation with generation should be less than or equal to 1.3%.

12.9 Ramp Rate Limits

The ramp up in normal conditions, positive ramp rate only during start-up and negative ramp rate during shut down of the PV Farm shall be settable from the SCADA system.

The following ramp rate is being proposed:

- 10-minute maximum ramp rate: PV installed capacity (MW) divided by 1.5; and
- 1-minute maximum ramp rate: PV installed capacity (MW) divided by 5.

The ramp rate averaged over one minute should not exceed 3 times the average ramp rate over 10 minutes.

The ramp rate settings provided in the SCADA, shall be approved by CEB prior to testing and commissioning of the system on the network.

12.10 Active Power Constraints / Curtailment

For system security reasons, it may be necessary for CEB System Control Center (SCC) to issue Curtail Instruction to the Solar Facility for the curtailment of active power output at the Point of Delivery.

The Solar Facility shall be capable of:

- Operating at a reduced level if a Curtail Instruction has been issued by the SCC.
- Commencing the reduction of the output power within 2 seconds of receiving the curtailment signal and complete the reduction not later than 30 seconds.

The accuracy of the set-point shall not deviate by more than ± 2% of the set point value.

13. ELECTRICAL BUILDING SERVICES

13.1 Luminaries and External Lighting

13.1.1 Lighting Design

The contractor shall design, provide and install a complete lighting installation system for building services, comprising mainly of HT switchgear room and LT switchgear including inverter room and transformer area, Battery room, SCADA Room, Stores, Toilets, outdoor lighting and any other areas. The design and installation shall be as per the tender requirements and in compliance with MS 63 or equivalent.

Drawings including location, type and number of lighting to be used (schedule of lighting) shall be submitted for approval to the Engineer/ Employer prior to order. The Contractor shall review architectural drawings to verify that the types of lighting fixture he has chosen for the ceiling types, modules and suspension systems are appropriate and meeting the lux level requirements.

For lighting system, CIBSE Lighting codes and European Standards shall be applicable.

The illumination levels for the various areas involved shall be as per Table 13.1 below. The design, together with accompanying calculations clearly showing the horizontal and/or vertical illuminance values corresponding to each feature being lit, shall be submitted to the Engineer/ Employer prior to order.

The Design shall consider the following to minimise energy consumption:

- Use of LED light fittings complete with LED Driver.
- Warranty shall be minimum of 5 years
- The balance between task and building illuminance.
- Availability of daylight lighting.
- Provision of switching controls to enable electric lighting to respond to daylight variations.
- Efficient exterior lighting.
- Occupancy Sensors in offices and store areas.
- Required Illuminance Level at 750mm above floor level.

- All Luminaries shall be rated 230V±6% and 50Hz.

Minimum size of cable shall be 1.5 mm2 for lighting circuits. All lighting wiring shall be terminated directly at each end with other lighting terminal block. Connectors in between lighting shall not be used.

Fuses for systems at low voltage are not acceptable. Moulded case circuit breakers and where appropriate, miniature circuit breakers shall be used.

13.1.2 Luminaries

LED lighting is the preferred light source unless approved otherwise. The contractor shall provide the type of light fittings and include the supplier's details. Samples of all lighting shall be submitted to the Engineer/ Employer for approval, prior to any order.

LED luminaires shall be provided complete with LED driver, LED controller, connectors and lamps. The metal work of all luminaires and equipment shall be effectively earthed to the installation.

Luminaires and lamp type shall be selected as appropriate for the area to be served. Luminaires shall be selected for ease of lamp changing and cleaning and have adequate mechanical and electrical features to ensure durability and resistance to Deterioration.

13.1.3 Fixtures

Areas within the building shall also be illuminated using LED light fittings. Luminaires shall be selected to provide the lighting level as set out in Table 12.1. External areas shall be illuminated using outdoor fittings suitable for the application with protective enclosures to IP66. All fixtures that shall be fixed in hazardous areas such as stores, electrical room, Battery room, Inverter and Transformer room and etc. shall be of explosion proof type,

Fixtures shall also be factory assembled complete with all fittings and delivered in factory fabricated containers or wrappings.

Metal parts shall be grounded. The rated voltage shall be 230Vac, 50Hz, single phase and neutral. The Contractor shall ensure safe handling and installation of the fixtures. The Contractor shall replace damaged units or components with new ones.

13.1.4 Luminaries Installation

Luminaires shall be installed complete with control gear, lamps, louvers or diffusers where specified, including any necessary fixings and steel supports. Where detailed specifically elsewhere the luminaire bodies to be installed in suspended ceilings.

Luminaires shall be suspended from, or fitted to, a small conduit box, unless otherwise agreed. Luminaires mounted in suspended ceilings shall be provided to suit the ceiling and with brackets suitable for mounting the luminaire from the top of the ceiling grid.

Conduit or chain suspensions shall be provided for all pendant luminaires. The stems of conduit suspension shall be screwed to ball and socket type dome lids with positive earth connection.

Luminaires shall be cleaned prior to final handover, if necessary, with an anti-static cleaning agent, to provide clean, dust free lighting.

13.1.5 Luminaire wiring

Luminaires, except continuous type, recessed into suspended ceilings shall be connected using flexible cables from plug-in type ceiling roses. Flexible cables shall be of a minimum length to facilitate disconnection of the luminaire. It shall be between 2m and 4m long with a minimum conductor size of 1.5mm^2.

Circuit cables shall not be routed through bulkhead or other fittings where the cables would be liable to undue temperature rise. They shall terminate in a fixed base connector in a conduit box mounted behind or adjacent to the fitting. Final connection to each fitting shall be carried out with silicone rubber insulated cable.

Luminaire internal wiring shall be arranged such that it is not visible when lamps/reflectors/louvres are in place.

13.1.6 Exterior Installations and General Flood Lighting

The scope of work will also cover external electrification around the following facilities:

- Under Canopy and adjacent to Doors for all External Doors of Buildings.
- Along Roadway near the Control room, flood lights shall be used.
- Along boundary wall, fencing and Main Gate.
- Walkways to Floaters and along floating PV Farm (solar powered lighting are also acceptable)

All exterior lighting shall be automatically switched by predefined timers located out of range of artificial light sources. Manual override switches shall be provided on a Light control panel in control room.

Luminaires shall be protected as follows:

- Index of protection minimum of IP65 unless otherwise specified in drawings or schedules.

- Luminaire bodies shall be manufactured in Aluminium, Epoxy Powder coated, moulded Polyester, any clips shall be Stainless steel or suitable plastic. Steel only to be used if galvanised.
- Diffusers shall be vandal resistant and UV stabilised.
- Shall not have the external case penetrated by the fixing screws of any internal component.

13.1.7 Emergency Lighting

Emergency lighting shall be provided in all the rooms of the control building.

- Efficient lighting shall be ensured so as to allow technical team to cease operations safely and applied emergency procedures.
- Such lighting shall be adequate to enable technical team to visually check switchgear displays and control panel displays and enable personnel to carry out switching operations in safety.
- Indicate clearly the escape routes.
- Ensure that fire alarm call points and firefighting equipment provided along the escape routes can be readily located.
- All other internal areas shall be provided with emergency lighting to illumination levels set in BS 5266.
- Emergency lighting shall be powered from self-contained battery sources and shall comply with BS 5266 and designed and manufactured as per BS EN 60598-2-22.
- The type, number and location of emergency luminaries shall be according to BS5266.
- Self-contained exit signs shall be provided at each exit from buildings. These shall be self-maintained emergency units. A minimum of 5 Lux illuminated exit signs shall be provided.
- Wiring systems of the emergency units shall be separate from the main supply.
- Self-Contained Emergency luminaries shall be carefully designed to achieve a 4-year battery design life.
- The Response time for high risk areas like Control Room and other switchgear room shall have a quick response time of 0.5s through the emergency duration.
- The minimum emergency duration (autonomy) shall be 3 hours.
- Where conversion packs are provided, they shall be incorporated into the spine of the luminaire they serve. Where this is not practical, they shall be enclosed within a compact metal box and installed within 1 metre of the luminaire in a

concealed but accessible position. The remote conversion packs shall be independently supported of the ceiling installation and shall be fitted with safety chains to prevent injury.

- Emergency luminaires shall be connected direct to the mains supply. In the event of mains failure the unit shall automatically connect to the battery. On restoration of the permanent supply the unit shall revert to mains operation. Internal wiring and connections shall be carried out in silicone rubber covered cable. A green LED indicator shall be visible through the diffuser or louvre of the fitting to indicate when the batteries are on charge.

13.1.8 Ceiling roses

Ceiling roses shall be manufactured of white plastic, complying with BS 67. They shall be overlapping or fitted with break joint ring when used on recessed BS conduit boxes.

They shall be two plate types with additional loop-in earthing and strainer terminals where necessary. They shall be plugged in type where mounted in ceiling voids or as specified in drawings.

13.1.9 Lighting Control Switches

All lighting switches shall be fixed at a level of 1350mm above finished floor level and are general purpose rocker type switches. The number of gangs shall be as per approval of the Engineer/ Employer prior to ordering. They shall comply with BS 3676 and BSEN 60669. Concealed Switch boxes shall be galvanised steel and switches for external use shall be weatherproof type to IP 66.

Lateral positions of the switched with respect to door jambs and corner walls shall be discussed and agreed with the Engineer/ Employer.

Switches shall be of the slow break, AC only pattern in which the successful operation of the switch does not wholly depend upon the action of a spring. The operating mechanism shall be insulated from all live parts. Switches shall have a minimum rating of 10amps and be suitable for inductive operation at their rated capacity.

All boxes used for fixing switches shall be supplied with an earth terminal or screw in the base of the box.

Any switch controlling equipment not visible from the switch point shall be engraved with a label identifying the final circuit it controls. Unless otherwise indicated, it shall be fitted with a 0.5-watt neon indicating lamp.

Switches shall be rocker type mounted on an all insulated front plate. The front plate shall overlap the box on all sides.

The switches shall be mounted on boxes not less than 25mm deep of metal or white PVC depending on the type of construction. They shall have cable or conduit entries. PVC boxes shall have accessory fixing lugs or columns with brass fixing screw inserts.

Table 13.1: Lux Level

Location	**Average Illumination Level (Lux)**	**Type of Fixture**
Control /SCADA Room	300	LED Luminaries
Storeroom and Toilets	200	LED Luminaries
Switchgear Room	150	LED Luminaries
Inverter Room	150	LED Luminaries
Street lighting-Roads, Outdoors,walkways along site roads and any other areas to be accessed during plant operation, maintenance or repair.	60	LED Luminaries

13.2 LV AC Distribution

13.2.1 General

Distribution boards shall be provided as required for local 400/230 Vac distribution of lighting and small power (sockets). The lighting and small power circuits may use a common distribution board.

They shall be fitted with the appropriate number and rating of circuit breakers, RCD's, distribution blocks, earth bars, neutral bars, etc. Electrical drawings shall be submitted for the LV Distribution board to the Engineer/Employer, prior to ordering of panel and equipment.

Each low voltage switchboard shall be of the single-busbar, built assembly type, in accordance with IEC 60439 and IEC 61439.

Install anti-condensation heaters inside MV cubicles and let them run continuously, i.e. without automatic or manual control.

13.2.2 Enclosures

The Main switchboard shall be of the freestanding floor mounted type and suitable for continuous operation in the environment specified. Provision shall be made for extension of the switchboard at both sides.

Other Distribution Board may be wall mounted.

They shall be unit or cubicle type construction from the same manufacturer as the switchgear.

They shall be protected to not less than IP31 for indoor use and shall be weatherproofed IP65 for exterior use.

The maximum height shall not exceed 2.30 m.

The switchgear shall be capable of withstanding the thermal, dielectric and dynamic stresses resulting from the maximum prospective short circuit currents without injury to personnel or damage to material.

The distribution switchboards shall include for the provision of the required number of circuit breakers plus at least two spare breaker and 30% spare space shall be provided.

The door or cover can be locked in the closed position. A lock and 3 keys shall be provided for each distribution board.

Distribution boards shall be capable of with-standing without injury the mechanical and electrical stresses set up by the prospective fault current for twice the period required to disconnect such fault on any circuit.

Distribution boards shall be provided with removable top and bottom un-drilled gland plates equipped with knock-outs for the outgoing cables corresponding to the circuit capacity of the distribution board and a suitable brass earthing stud.

Distribution boards shall be of sheet steel with either a galvanised or enameled finish. The finish colour of all indoor distribution boards shall be chosen to match the adjacent switchboards.

The panels shall be fitted with flush mounted indicating lamps to indicate presence of voltage.

Neutral bars shall be drilled for an appropriate number of ways relative to the size of the board.

Enclosures shall be so designed and constructed as to protect all live parts to IP2X including live parts behind locked doors, removable panels, and particularly on the back of opening doors. So, designed and constructed as to provide test facilities via 3mm holes in protection to IP2X as necessary for fault finding purposes.

Enclosures shall not be located such that it can be affected by the normal operation, maintenance or failure of mechanical services installations, including drainage.

The metal surface adjacent to any live part and all spaces between phases shall be protected by barriers or fireproof insulation material.

Engraved nameplates shall be fitted to the front cover of each distribution board giving the distribution panel board reference of each panel board. A circuit list shall be typed or printed stating the location of the equipment served, rating of the protective unit and the circuit loading. The lists shall be mounted on the inside of the cover door and shall be protected by an acrylic sheet slid into a frame over the circuit list, the list and cover to be easily removable to permit circuit modifications. Allocation of circuits shall be in accordance with MS 63.

13.2.3 LV Distribution

The current rating of the busbars in each distribution board shall not be less than the sum of maximum current rating of all outgoing circuits. The neutral connection for each circuit is to be direct to the neutral busbar.

All distribution boards shall incorporate a main MCCB which shall isolate the incoming supply to the distribution board.

Socket outlets for working maintenance areas shall have Residual Current Circuit Breakers (RCCBs) comprising circuit breakers with integral ground leakage trip circuits.

The distribution boards shall be either single pole or triple pole and neutral types and shall be equipped with means to provide overcurrent protection to each circuit. This protection shall be a miniature circuit breaker, which shall be removable without exposing live connections.

Each sub distribution board supplied from main circuit breaker shall have an incoming Circuit breaker as part of the board. The rated current of the circuit breaker shall be not less than the total capacity of the distribution board unless otherwise specified.

Single Phase socket shall be incorporated within Main and Sub distribution board.

Each circuit in every distribution board shall be numbered and identified by means of an approved label and a schedule attached to the interior of the door or cover of the board. The schedules shall be legible and durable to the Engineer's approval.

All distribution boards and protective devices to be from a single manufacturer to ensure proper discrimination between the protective devices.

13.2.4 LV AC wiring

All LV wiring within polyethylene concealed conduits shall generally be PVC insulated single core copper conductor cables. Minimum size of cable shall be 1.5 mm2 for lighting circuits and 2.5 mm2 for socket circuits. Wiring cables shall be provided with copper conductors, with PVC insulation 450/750 volt grade, to BS 6004.

Cables sizes for other circuits shall be as specified on a one-line diagram of the relevant distribution or sub-distribution boards. Circuits' schematics from relevant distribution board shall be submitted for approval from the Employer/Engineer prior to implementation.

All cables supplied shall meet the approval of the Mauritius Standards Bureau and shall also comply with the relevant European Standards.

All LV Circuits for sockets and lighting shall be run inside appropriately sized PVC trunking. Necessary separation of voltages shall be ensured.

13.2.5 Plastic conduit and trunking

All plastic conduits shall be LSF to BS 4607 and BS EN 50086 as applicable. They shall be heavy gauge, high impact, smooth inside and outside, free from imperfection, of minimum diameter 20mm.They shall be protected from weather and all mechanical damage during installation or whilst stored at site. They shall be reamed to remove all sharp edges and burrs and shall be cleaned of all debris.

Conduits shall be to BS 4607 as applicable where they are to be cast in concrete.

They shall be installed in accordance with the manufacturer's recommendations. They shall have bends and sets formed with the aid of helical spring fitted internally, with the conduit warmed sufficiently for it to move without deformation of the bore, and with minimum wall thinning on the outside of the bend.

Plastic trunking shall be LSF in accordance with BS 4678 Part IV extruded unplasticised PVC compound. They shall be smooth inside and outside and free from imperfections. They shall be of the high impact resisting heavy gauge type fitted with drip proof lids.

13.2.6 Miniature Circuit Breakers and Moulded Case Circuit Breakers

All moulded case circuit breakers (MCCBs) shall be of the high-speed fault limiting thermal/magnetic type to IEC 60947.

MCBs may be used subject to the protection grading satisfactorily with other circuit breakers

MCBs shall be equipped with quick make and quick break trip free mechanisms which prevent the breaker being held in against overloads or faults.

Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Proper grading for the MCB shall be provided.

Circuit breakers shall be of the high-speed fault limiting, thermal/magnetic type with quick make and quick break trip free mechanisms which prevent the breaker being held in against overloads or faults.

13.2.7 Residual current devices (RCD’s) and RCBO

RCD’s and RCBO shall be provided to IEC 61008 and shall be rated as per the schematic or shall be 30 mA for all outlets. Unless otherwise specified, RCD/RCBO shall be of the one pole and Neutral or three pole and Neutral type. The Neutral shall open in event of tripping of the device. All outgoing circuits shall be equipped with RCDs as a means of protection.

13.2.8 Busbars and connections

Busbars shall be of constant cross section copper throughout. The copper conductors shall be tinned. Busbars shall be air insulated except where solid insulation is a design feature. They shall be connected to outgoing switches with solid copper connections. The connections to be as short and direct as possible.

Busbars shall be rigidly clamped and secured to prevent undue movement under fault conditions or displacement as a result of the installation of cabling and provided, where necessary, with insulated phase or circuit barriers. All clamping and supporting bolts, nuts and screws to be plated brass or steel.

Busbars shall be separate for individual supply systems. Two systems shall not occupy the same busbar chamber unless they are segregated and separated by earthed metal and warning notices fixed.

13.3 Power Sockets

Socket outlets shall be mounted 450 mm above finished floor level.

Socket outlets shall be to BS 1363. They shall be flush pattern where used with concealed systems, surface pattern elsewhere. They shall be switched type and shall be capable of switching full rated inductive or resistive load.

All sockets shall be supplied with 13 amp plugs complete with appropriate fuse to BS 1362 for equipment connected to socket outlets as specified in drawings.

Sockets shall be supplied with fixing flanges and fitted into plasterboard partitioning.

The position and quantity of general 13 A socket outlets in rooms shall be in accordance with MS 63. Twin Sockets shall be installed as per the following locations:

Table 13.2: Number of Sockets

Item No	Area	Sockets
1	Each Offices	3
2	HT Switchgear Room	4
3	Control/SCADA Room	Minimum of 4
4	Stores	3
5	Inverter and Transformer area	2

Three phase and neutral, and single-phase and neutral industrial socket outlets shall be provided in the workshop. Socket outlets shall consist of the following:

- 400 V ac, 32 A, three phase and earth, semi flush mounted, corrosion-protected, selfclosing cover.
- 230 V ac, 16 A, single phase, neutral and earth, corrosion-protected, self-closing cover.

MCCB or MCB shall be provided to protect the incoming circuit and feeder circuit to each socket outlet. Power supply cables shall be sized in accordance with the requirements of MS 63.

Industrial sockets shall be single phase and three phase types. The sockets shall be heavy duty and at least IP44.

13.4 Testing

The whole of the equipment provided shall be subject to inspection and witnessing of tests by the Employer and/or Engineer. The procedure shall include the testing of all equipment in accordance with the IEE Wiring Regulations. The Contractor shall submit a programme of testing for the Engineer's approval.

13.5 Insulation Tests

Tests shall also be made on complete circuits for lighting, socket outlets, etc. between poles and to ground and shall include associated switches and distribution switch.

The procedure shall include for the rectification of faults or the renewal of any part of the installation which fails or breaks down a result of the insulation tests.

13.6 Continuity Tests

Ground continuity tests shall be made for each item of electrical equipment, lighting fittings, switch and socket outlets to the main grounding connections for the installation. This shall be the point where the main bonding conductor to the ground electrode system is connected to the main grounding terminal on the main switchboard.

13.7 Ground Loop Impedance Tests

Ground loop impedance tests shall be made for all socket outlets in the installation and shall show the complete ground loop impedance from the socket outlet. Records of these tests shall be handed over to the Engineer or Employer.

13.8 Phase Rotation Tests

The phase rotation at each three-phase socket outlet shall be checked and verified to be standard anticlockwise phase rotation and sequence L1, L2, L3.

13.9 RCD Operation Tests

Residual current devices test at a test current of 50%, 100% and 500% of the rated tripping current.

13.10 Testing Equipment

Shall be correctly calibrated and certified for the limits of accuracy necessary and identified by serial number on each test sheet. If an instrument used is considered suspect it shall be tested by an authorised standard testing laboratory. All equipment shall meet the requirements of BS EN 61557 Equipment for testing up to 1000V.a.c to ensure safety of the operator. Calibration certificate which has been issued maximum one month prior to the testing sessions shall be produced to the Engineer before any test is carried out.

Tests instruments shall be provided with insulated and shrouded probe.

13.11 FIRE ALARM SYSTEM

13.11.1 General

The system shall employ a microprocessor-based analogue addressable Fire Alarm Control Panel (FAP).

Manual call points, heat detectors and smoke detectors shall be sited in accordance with the minimum distances specified in BS 5839 as a minimum standard of installation but shall be increased in number as necessary to provide a full and effective system.

Areas to be covered shall be as follows:

- Control room
- 22kV MV Switchgear (substation) Room
- Store
- Inverter and Transformer area
- Any other area where protection is required.

The Following documents shall be submitted to the Engineer/ Employer prior to any order:

- Submit manufacturer’s technical product data, including specifications and installation instructions, for each type of fire alarm system equipment.
- Include standard or typical riser and wiring diagrams, and operation and maintenance instructions for inclusion in maintenance manuals.
- Provide drawings showing equipment/device locations and connecting wiring of entire fire alarm system.
- Building plan showing zoning and location of fire controller, detectors, call points, sounder and other devices.

The components of the system shall be manufactured by companies regularly engaged in manufacture of fire alarm systems of types, sizes, and electrical characteristic required, and whose products have been in satisfactory use in similar service for not less than 5 years.

The system shall be installed by a company with at least 5 years of successful installation experience on projects with fire alarm systems work similar to that required for this project. The company shall have a factory authorised service organisation and spare parts stock.

Comply with BS EN 54 and the applicable requirements of NEC standards pertaining to fire alarm systems.

The Fire alarm system shall be installed, completed, tested and commissioned in presence of the Engineer/ Employer.

The main control panel shall be placed in the control room and repeater panel if any shall be installed in easily accessible location and shall be approved by Engineer/Employer.

13.11.2 Control Panel

The control panel shall be complete with power supply unit, batteries, integral charger, all control, indicators and any other equipment. The control panel shall be designed and manufactured according to NFPA and European Standards.

The panel shall be surface mounted and the front fascia shall have a lockable door.

The Features of the Fire alarm panel shall be as follows:

- A well labelled front fascia with instructions how to use the panel and testing instructions to be affixed next to the panel.
- When a fire alarm is manually or automatically raised, the zone shall be identified on the panel with annunciators. A back lit lamp annunciator shall be provided, with two lamp.
- All zone devices shall be monitored for open and short circuit faults and indicated by appropriate zone fault indicator and internal buzzer.
- Internal sounder: Pulses during mains failure or if battery disconnected and sounds continuously for other faults.
- The internal battery system shall be provided for at least 24 hours standby operation. It shall further be capable of withstanding full alarm load for at least 5 minutes.
- Provide control panel for operation on 230 volts AC supply with integral battery stand by power source.
- All Fire Alarm signals shall be sent to the SCADA system in the local control room and shall be recorded.

13.11.3 Conduit and Wiring

PVC concealed conduit/trunking and wiring shall be carried out using fire retardant low smoke material. Cables shall be shielded type. Call points shall have a minimum conductor size of 1.5mm2 and Sounders wiring shall have a minimum of 2.5mm2. Joints in the cables shall be avoided. If joints are necessary, this should be done in junction boxes which are clearly labelled FIRE ALARM. Conduit systems used for fire alarm wiring shall not be utilized for any other service.

The contractor may be requested to provide certificates for ensuring that the cables and conduits used are fire resistant and suitable for use in fire alarm installations.

Connections shall be made at terminal strips in cabinets or at equipment terminals.

Run cables in recessed conduit for drops to units in areas requiring flush installations.

13.11.4 Fire Alarm Detectors

The Fire Alarm detectors shall have the following features:

- All detectors shall be of the analogue addressable type.
- These shall be identifiable by a light emitting diode provided on the detector casing.
- The detector bases shall be suitable for interchanging with same of different types of detectors.
- Detectors shall provide separate fire and fault signals.
- Addressable Ionization Smoke Detectors shall be used and shall connect with two wires to the fire alarm control panel.
- The detectors shall use the dual-chamber ionization principal to measure products of combustion.
- The detectors shall capable of operation on either 2-wire or 4-wire loops. A 57 °C fixed temperature heat detector shall be provided in each base.
- Heat Detectors shall be automatic addressable detectors.
- The detectors shall provide an alarm and power LED. The LED shall flash under normal conditions. The LED is placed into steady illumination by the control panel, indicating that an alarm condition has been detected.
- The detectors shall provide a test means whereby they will simulate an alarm condition and report that condition to the control panel. Such a test may be initiated at the detector itself, by activating a switch, or may be activated remotely on command from the control panel.

13.11.5 Manual Call Points

Manual Call points shall have the following features:

- shall have LED indication

- Shall be surface mounting type with red enclosure and break glass operation
- Shall be to IP 54 with weather resistant gasket

A 200 x 200 mm sign, “FIRE ALARM BOX”, shall be provided over each fire alarm pull station and mounted perpendicular to the wall, red with 60 mm high white letters.

13.11.6 Sounders

Both outdoor and indoor sounders shall be installed, so that it is clearly audible all over the PV farm site and inside building. The manufacturer’s standard fire alarm sounders shall be provided, surface mounted and with double projection.

The specifications are as follows:

- The electronic sounders shall operate on 230V AC.
- Shall be vandal proof.
- The outdoor electronic sounders shall be to IP66
- Shall have a sound level of at least 5 dB above the normal noise in the premises.

13.11.7 Alarm Lights

Alarm lights with flashing red lenses shall be provided, plain or lettered white “FIRE”.

13.11.8 Field Quality Control

Submit shop drawings for function and operation only, pre-approved by authority having local jurisdiction.

Submit copy of test results in duplicate signed by Employer’s Representative to Engineer, Employer, Employer’s Insurance Company and local Fire Protection Authority.

13.12 Closed Circuit Television (CCTV) Systems

13.13.1 General

An IP based closed circuit television (CCTV) surveillance system along with network switches, database servers, video management software, keyboards, monitors, interconnecting shall be provided for monitoring of specific areas of the Plant like the Dam boundaries focusing on the floating structures and the CMCS building. Wireless communication for CCTV system is also acceptable.

Monitors shall be located in the control room. The CCTV system shall enable digital video record of all events for a period of at least four weeks. Records shall be logged in a dedicated server/control system by the bidder and print out of the logged events shall be possible on demand at any time.

The video cameras shall be:

- Weather resistant (box, windscreen wiper, etc.) and adapted to site ambient Site Conditions,
- Able to operate at night, taking into account the ambient lighting of the Plant,
- Color type, auto-focus and auto-iris type,
- With pan/tilt and zoom capabilities (360°)

The IP CCTV system shall consist of IP CCTV cameras that allow the transmission of CCTV images over local network using IP addressable cameras/video servers. All CCTV equipment shall be rack mounted. Camera certification has to be CE/FCC/UL or equivalent.

Cameras: All the cameras shall be color, suitable for day and night surveillance and network compatible. There will be two types of cameras viz. PTZ & Fixed. PTZ cameras shall be high speed integrated dome type.

Detailed technical specification cameras (High Definition (HD) is given below.

Image Device: 1/2.8-1/3” Progressive scan CMOS

Lens for PTZ cameras: 4.45-4.7 /89-94.0 mm focal length

For Fixed Cameras: Varifocal Lens f=8-50 mm, CS-Mount

Optical Zoom/ Digital Zoom for PTZ cameras: 20x or better/12x or better

Number of Pixels/Effective resolution: 1920X1080 (Full HD)/2 MP at 25/30 IPS

Electronic Shutter 1/50 to 1/10000 Auto

S/N Ratio: >50dB

Alarm Input/output For PTZ cameras: Minimum 2 Alarm I/Ps & 1 alarm output

For Fixed Cameras: Minimum One Alarm I/P & One Alarm O/P

Pan, Tilt for PTZ cameras 360 Deg Continuous ,90 deg

IP cameras shall be connected to nearest data cabinet and contractor shall ensure routine of cable from camera to data cabinet shall not exceed 90m.Data cabinet shall be provided by contractor supplying and installing structured cabling system.

Cables shall run generally in ELV cable tray if False Ceiling are used, else the cables shall be run through trunking.

In the administration building, the Cameras shall be supplied by 230Vac through the AC distribution board inside the switchgear room.

Surveillance CCTV System shall operate on 230 V, 50 Hz single -phase power supply. Power for all the equipment will be conditioned using on-line UPS with minimum 30 minutes or more back up. If any equipment operates on any voltage other than the supply voltage and supply frequency, necessary conversion/correction device for supply shall be supplied along with the equipment.

The final position, height lens selection, etc. shall be subject to the Security Specialists recommendations to suit the equipment performance and selected to provide good target height, visibility and coverage.

System shall provide sufficient storage of all the camera recordings for a period of 90 days having good quality using necessary compression techniques for all cameras

All cameras installed externally and all those installed in the vehicle entrance, service yard/area shall be mounted within weather/vandal resistant enclosures and withstand the environmental conditions particularly during cyclones. All cameras installed internally shall be mounted within a `smoked' dome enclosure. Accessibility of cameras shall cater for act of vandalism.

IP video management server shall have ability to retain control parameters following mains failure and to reinstate parameters on resumption of mains supply.

External camera and lens assemblies shall be mounted securely in a weatherproof enclosure to IP65 standards. The housing shall be of a rugged construction, resistant to corrosion and generally vandal resistant. The aperture window shall be fitted with toughened glass. The housing shall be fitted with a sun visor and a self-parking wiper. Tentative list of cameras and the location are as follows:

Sl No	Location	Number of Cameras
01	LT Switchgear and Inverter Room	02
02	Store	01
03	Transformer Room	01
04	Control Room	01
05	MV Switchgear Room	01
06	Entrance	01
07	Battery Room	01
08	Boundary of the facility* which includes the location from where the PV farm on the reservoir can be monitored	04 Fixes or 02 PTZ (Towards the reservoir side) + 02 (Towards the CMCS Building).

*Note: Need to be designed by the Bidder and submitted to the Engineer/ Employer for review and approval.

The CCTV system shall comply with BS EN 50132-7, and those standards listed elsewhere in this Specification.

The whole system shall be tested and commissioned in presence of the Employer/Engineer.

13.14.1 General Type and Capacity

The Contractor shall supply, install, type and split type air conditioning units using DC inverter technology/centralized ac technology shall be installed in the local SCADA control and MV switchgear room on both demarcated sides separately.

The Contractor shall carry out all relevant civil works and shall calculate the proper sizing in terms of BTU rating for each room.

Air Conditioner Characteristics:

- Indoor Unit:

  - Wall mounted/ cassette type
  - horizontal / vertical air flow
  - low noise level at high speed
  (less than 52 dBA at 1 m from the unit)
  - automatic air deflection
  - variable fan speed and temperature control
  - wireless remote control with LCD temperature display and holder
- Presence sensors

  - one touch air filter (down to 0.01 micron)
  - Slim, compact and of elegant design
  - LED display
- Outdoor Unit:

  - shall be suitable for tropical climates
  - shall be weatherproof, cyclone proof
  - rotary type compressor

  The location of the indoor units shall be agreed with the Employer/Engineer prior to installation.

  The guarantee for the air conditioners complete system shall be at least 3 years.

- All split type/centralised air conditioners shall be equipped with remote controls by means of which the air conditioners may be switched on and off, the temperature and fan speed may be controlled and from which one may read the room/office temperature via an LCD display.

- Any supports, mounting brackets etc. (to be hot dipped galvanized) shall be supplied and installed by the successful bidder.

- The outdoor units shall be fixed on galvanised brackets on the wall of the building or on concrete base on the roof of the building. Rubber mounting pads shall be provided in between to limit vibration in the equipment.

- All piping (refrigerant and drain) shall be enclosed within white PVC trunking of suitable dimensions indoors and outdoors. Note that the cover of same shall be securely fixed as not to be blown away by cyclonic gusts. Moreover, all joints shall be suitably sealed by means of silicon rubber.
- Air Conditioners shall be supplied by 230V/415V ac from the LV Distribution Board. The AC units shall be controlled by double pole switches with red LED indicator that are properly rated. The successful bidder shall undertake the electrical installation from the air conditioners to the switches. The electrical installation from the switches to the air conditioners shall have to be concealed in conduits of sufficient size. The cable from indoor units to outdoor units shall pass through trunking/conduits of appropriate size.
- The bidder shall test and commission the Air conditioning units in presence of the Engineer/ Employer.
- Redundant air conditioning system shall be implemented in the MV Switchgear room.
- The air conditioning system shall not cause accumulation of dust.

14. CIVIL ENGINEERING WORKS

The design calculations and drawings for RCC structure, Steel structure, foundation system, road work, drainage, etc. shall be submitted for prior approval of Engineer/ Employer before commencement of construction. The construction methodology for road works, drains shall also be submitted for Engineer/ Employer approval before start of works.

The Contractor shall design, detail, procure, supervise and commission the required civil and building works associated with the project. The Contractor shall also undertake all studies and investigations (such as geotechnical investigations and topographical survey) necessary for the design and construction of the civil and building works. The Contractor shall carry out all enabling works (diversion of services, provision of site offices, temporary access, storage and welfare facilities etc.) that are required for the completion of the civil and building works. The Contractor shall provide a Registered Professional Civil Engineer to supervise and approve the civil engineering works during the construction works.

The civil engineering works shall include the design and construction, among others, of the following:

- Leveling of ground at the site;
- Develop access roads to the site from the existing approach roads (Compaction tests shall be carried out at every (Max) 300 mm thick layer, where there would be vehicular traffic)
- Arrange for proper water drainage system;
- Cable Trenches/ducts (Compaction tests shall be carried out at every (Max) 300 mm thick layer)
- The CMCS building has an approximate surface area of 300 sq. m. (Indicative Layout Drawing attached). Provision of the Architectural Design for a single-storey RCC building of an approximate surface area of at least 300 m² to include the following:

CMCS shall consists of:

- Air-conditioned SCADA room: Air Conditioner shall be of non-ozone depleting type.
- Air-conditioned 22 KV MV Switchgear Room. Air-conditioning shall be of non-ozone depleting type.

- Inverter Duty Transformers
- Inverters
- Storeroom
- Lobby
- Toilet and Urinal
- Battery and UPS Room
- ACDB/LDB/MLDB etc.

Inverter(s), battery room, ACDB and 22 KV Switchgear room shall be based on manufacturer recommendation, easy passage of O&M persons and cable trench/ducts layout required. The CMCS shall be RCC framed structure with bricks/concrete blocks masonry walls.

The minimum size & requirements of the CMCS Building & all items shall be as per drawing No.:A-005 Layout of Central Monitoring and Control Station.

Note:

1) The above-mentioned surface areas are only indicative. The Architect should allocate the spaces as he/she deems fit.
2) The building shall consist of one RCC staircase.
3) The roof terrace shall be secured by a low-level parapet wall, along the whole perimeter of the roof, of an approximate height of 1200mm.

- Submission of Architectural drawings signed by a Professional Registered Architect.
- Structural Design of the Single-storey building.
- Submission of calculations and drawings for the structural design, signed by a Professional Registered Engineer (Civil) with the Council of Registered Professional Engineers of Mauritius. The structure shall resist wind speeds of 280 km/h for 3 secs and the structure shall be designed as frame structure.
- Construction of the single-storey building complete with all openings and finishes along with plinth protection and garland drain all around the building.
- Provision of manholes, septic tank and absorption pits.
- Implement necessary measures to control surface drainage from cuts and fills and prevent erosion and sedimentation.
- Provision of asphalted driveway from the gate to the building.
- Provision of Cable Duct Ways and Trenches.
- Provision of the necessary rainwater pipes, catch pits, soak away, concrete kerbs, proper landscaping inclusive of flower boxes near the buildings.

The Contractor shall make its own estimate of the types and of the extent of the various materials to be required to accomplish the above works. Approval shall be sought for the dimensions as well as the layout and outlook of the buildings to be constructed, during the design stage.

Specification for RCC Building for CMCS.

The CMCS building shall be made of RCC framed structure with concrete blocks. The thickness of outer masonry walls shall be minimum 200mm thick in case of concrete blocks. The following detailed specification shall also be followed for RCC works:

Floor Finishes

Switchgear/Inverter/ Transformer rooms	Hi build epoxy paint
SCADA room	: Heavy duty homogeneous antiskid ceramic tiles at least 9 mm thick.
Battery room	: Acid Alkali resistance tile flooring or acid alkali resistant epoxy coating over concrete flooring with ironite hardener

Flooring for air-conditioned areas area shall be provided with homogeneous antiskid ceramic tiles of size 600X 600 mm (or as approved) of min 9 mm thickness, laid with 3 mm ground joints as per approved pattern. Cement concrete flooring shall conform to Latest British codes and Mauritius Standards or Equivalents.

The floor finish for toilet shall be homogeneous ceramic anti-skid tiles and Dado glaze ceramic tiles up to 2.1m shall be used. The normal size of Ceramic tiles shall be 300 mm X 300 mm X 9 mm and shall comply Latest British codes and Mauritius Standards or Equivalents.

Finish floor level of all building shall be minimum 600 mm above from Finish graded (ground) level.

Plinth Protection

500 wide plinth protection minimum 75 mm thick of cement concrete 1:3:6 (1 cement: 3 coarse sand : 6 graded stone aggregate 20 mm nominal size) over 75 mm bed of dry brick ballast 40 mm nominal size well rammed and consolidated and grouted with fine sand including finishing the top smooth, shall be provided around the Pre-Engineered Building.

False Celling

The SCADA room shall be provided with false ceiling of 15 mm thick mineral fiber board, in tile form of size 600mm x 600mm, along with galvanized light gauge rolled form supporting system in double web construction pre painted with steel capping, of approved shade and color, to give grid of maximum size of 600x600 mm as per manufacturers details including supporting grid system, expansion fasteners for suspension arrangement from RCC, providing openings for AC ducts(if required), return air grills(if required), light fixtures, etc., all complete.

Roof Finishes

Roof of the Building shall consist of Cast-in-situ RCC slab with decking sheet (RCC slab with permanent formwork) The slab formwork decking sheet shall be permanently colour coated profile sheet with minimum 0.6mm thickness of grade SS255 as per ASTM A653M / grade G250 as per AS 1397 coated with zinc of class designation Z275 or aluminium zinc alloy of class designation AZ150 or similar. The decking sheet shall meet the strength, deflection and other functional requirements.

Bidder can also provide Roof of the building as Cast-in-situ RCC slab conforming to British/applicable international code.

The roof of the building shall be waterproofed with polyurethane membrane type waterproofing as per Latest British codes and Mauritius Standards or Equivalents. The roof shall be designed for minimum superimposed load to 150 kg/m2. A warranty certificate of 10 years for roof waterproofing shall be provided upon completion of works.

For efficient disposal of rainwater, the run off gradient for the roof shall not be less than 1:100 and the roof shall be provided with PVC/RCC water gutter, wherever required. Gutter shall be made water tight using suitable watertight treatment. This gradient can be provided either in structure or subsequently by screed concrete 1:2:4 (using 12.5 mm coarse aggregate) and/or cement mortar (1:4). However, minimum 25 mm thick cement mortar (1:4) shall be provided on top to achieve smooth surface. The roof of all building shall be projecting out by at least 450 mm all around the building for its external walls protection from rain water and parapet wall above the roof beam. Height of parapet wall shall be minimum 1.2 meter above top of finished roof level.

The bidder shall also provide rain water harvesting system consisting of ground water tanks for recharge for CMCS building roof.

View point

RCC terrace of CMCS building shall also work as view point. View point shall be used for security purposes and viewing gallery. Suitable RCC half landing staircase shall be provided for access to roof of the RCC CMCS building. A parapet wall of at least 1.2 meter high shall be erected along the perimeter of the building for safety purposes. For RCC Staircase, a minimum vertical headroom of 2200mm shall be ensured.

Windows, Doors, Ventilators and Rolling Shutters

Doors, windows and ventilators of air-conditioned areas, entrance lobby of all buildings, and all windows and ventilators of CMCS building shall have, powder coated (minimum thickness of powder coating 60 micron) aluminum framework at least 1.5mm with laminated glazing at least 6mm thick. Window shall be provided with suitable aluminum grill / burglar bar.

Doors of toilet areas shall be of steel framed solid core flush shutter as per latest British codes and Mauritius Standards or equivalents. Minimum size of door provided shall be 2.1 m high and 1.2 m wide. However, for toilets minimum width shall be 0.85 m and office areas minimum width shall be 1.20 m.

The Bidder can also propose uPVC extruded casement/ sliding windows and doors with complete fitting and accessories as per latest British codes and Mauritius Standards or equivalents.

All external door of CMCS shall be provided with Collapsible metal grille with locking system.

Doors and windows on external walls of the buildings (other than areas provided, with insulated metal claddings) shall be provided with RCC sunshade over the openings with 300 mm projection on both side of the openings. Projection of sunshade from the wall shall be minimum 450 mm over window openings and 450 mm over door openings except for main entrance door to the control room where the projection shall be 1500 mm. All external openings shall be designed to resist a wind load of 280 km/h. ***Design calculations, signed by a registered Engineer and shop drawings shall be provided for all openings.***

Rolling shutter (Mechanical gear operated). Rolling shutters shall be fabricated from 18-gauge steel and machine rolled with 75 mm rolling centers with effective bridge depth of 12 mm lath sections, interlocked with each other and ends locked with malleable cast iron clips to Latest British codes and Mauritius Standards or Equivalents. and shall be designed to withstand a wind load of 280 Km/h without excessive deflection. Metal rolling shutters and rolling grills as Latest British codes and Mauritius Standards or Equivalents. Design calculations, signed by a registered Engineer and shop drawings shall be provided.

Glazing

All accessible ventilators and windows of all buildings shall be provided with min. 6mm thick laminated glass, tinted for preventing solar radiations, unless otherwise specified. The glazing thickness shall be determined in the design calculations.

For single glazed aluminum partitions and doors, toughened float glass of 10 mm thickness shall be used. All glazing work shall conform to Latest British codes and Mauritius Standards or Equivalents.

The glass to used should be from reputed brand / manufacturer and as approved by Engineer/ Employer. The glass should be free from distortion and thermal stress.

Paintings of wall and ceilings

Internal wall surfaces:	
SCADA room	- Copolymer Acrylic Paint
All other rooms in plant buildings	- Copolymer Acrylic Paint
External faces of walls:	- 100 % Copolymer based paint
Walls of battery room	-Acid alkali resistant paint, an exposed wall above Dado -2100 mm high Dado of acid alkali resistant tiling.
All Ceiling	- Copolymer Acrylic Paint

The paint shall be anti-fungal quality of reputed brand suitable for masonry. All painting on masonry or concrete surface shall preferably be applied by roller. If applied by brush, then same shall be finished off with roller. For painting on concrete, masonry and plastered surface, Latest British codes and Mauritius Standards or Equivalents shall be followed. Minimum 2 finishing coats of paint shall be applied over a coat of primer. Painting shall be done to the satisfaction of the Engineer/ Employer.

For painting on steel work and ferrous metals, BS: 5493 and Latest British codes and Mauritius Standards or Equivalents shall be followed. The type of surface preparation, thickness and type of primer, intermediate and finishing paint shall be according to the painting system adopted.

Ceiling of all rooms except Battery room shall be white washed. The ceiling of Battery room (if provided) shall be acid/alkali resistant paint. CMCS building outside colors of paining shall be similar to PEB painting colors.

A standard color scheme for the different buildings/structures shall be prepared by the Contractor and the approval of the Owner shall be obtained, before commencement of work. Sample paints shall be provided on building walls on site for approval.

Plumbing and sanitary

Wash basin provision for hand wash shall also be provided in battery room. The wash hand basin (Lab sink) shall be acid resistant and the tap shall have a long handle (approval shall be sought to CEB prior to procurement). The wash hand basin shall be incorporated in a table made of metal sections and covered with granite if required.

All fittings, fastener, grating shall be brass with chromium plated (country of origin Italy) as per relevant Latest British codes and Mauritius Standards or Equivalents. Necessary plumbing lines shall be provided for CMCS room building.

The bidder shall design & provide packaged sewerage treatment plant/septic with soak pit, inclusive of manholes and absorption pits for CMCS assuming that a total of 15 people shall use the facility. The waste water/effluents from the sewerage plants/septic tank shall meet the state pollution board requirement.

Water Supply

The distribution networks shall be made with good quality ('PN 25') PVC pressure pipes and brass fittings (country of origin Italy).

Brass fittings shall be provided as and where required and directed.

Approval should be sought for all pipes and fittings prior to fixing.

A stop valve shall be provided at the entrance to the building, similarly, an isolation tap shall be provided to each sanitary fixture.

In general, the various works, connections and fittings used and their method of installation shall comply with the standards in force.

The whole of the water installations must be tested by the Contractor and any defective work or part to be made good or replaced immediately and shall be re-tested until found satisfactory.

Pipes conforming to Latest British codes and Mauritius Standards or Equivalents shall be used for all portable hot and cold water distribution supply and plumbing works.

The Polyethylene water storage tank conforming to Latest British codes and Mauritius Standards or Equivalents shall be provided over the roof of the CMCS with adequate capacity for 10 No person and 24 hr requirement, complete with all fitting including float valve, stop cock etc. The capacity of the tank shall be minimum 2000 liters.

Plastering

All external surfaces shall have 18 mm cement plaster in two coats, under layer 12 mm thick cement plaster 1:5 and finished with a top layer 6 mm thick cement plaster 1:6 Latest British codes and Mauritius Standards or Equivalents.

White cement primer shall be used as per manufacturer's recommendation.

At least one coat of plaster shall be applied to interior walls by hand or mechanically, to a total thickness of 12 mm using 1:6, 1 cement and 6 sand. Plastering shall comply to Latest British codes and Mauritius Standards or Equivalents. Oil bound washable distemper on smooth surface applied with minimum 2 mm thick Plaster of Paris putty for control room. Plaster of Paris (Gypsum Anhydrous) conforming to Latest British codes and Mauritius Standards or Equivalents shall be used for plaster of paris punning.

Masonry Work

Brick works shall be using at least class designation 7.5 of approved quality as per Latest British codes and Mauritius Standards or Equivalents. Concrete blocks shall be of minimum compressive strength of 7.5 N/mm2. Stone masonry work with hard stone in building works, foundation, plinth and drains shall be Coursed Rubble or Random Rubble masonry work with stone of good quality and durability. The masonry surface shall be plastered with minimum 18mm plaster in case of CMCS walls. The stone masonry work shall be in line with Latest British codes and Mauritius Standards or Equivalents.

The cement mortar for all kind of masonry work shall be in the ratio 1 cement and 6 sand by weight.

Bricks/blocks required for masonry work shall be thoroughly soaked in clean water tank for approximately two hours. Brick shall be laid in English bond style. Green masonry work shall be protected from rain. All masonry work shall be kept moist on all the faces for a period of seven days.

Bricks of class designation 50 and 35 may be permitted to have slight distorted & rounded edges provided no difficulty shall arise on this account in laying of uniform courses in non-load bearing structures and shall be subjected to approval of Engineer/ Employer. Tolerances on dimensions up to +/- 8% shall be permitted. Dimension test to be carried out as per latest British codes and Mauritius Standards or equivalents.

The external wall for the building shall be 230 mm thick walls and internal wall 230/115 thick as per requirements. The internal wall of CMCS facing the transformer area shall be as per Latest British codes and Mauritius Standards or Equivalents - Code of practice for fire safety of buildings (general): electrical installations.

Suitable damp proof course shall be provided the proportion of cement, sand & aggregate shall be 1:2:4 using 6 mm down stone chips with a water proofing admixtures. The thickness of damp-proof course shall be minimum 40 mm.

Tanking membrane shall be provided below ground level along the external surface of the blockwall perimeter. Data sheets shall be provided for approval.

Reinforced Concrete Structure, Allied Works and Foundation

All RCC works shall be design mix as per BS: 8110. For structural concrete items, Ordinary Portland cement (43 Grade) and Fly ash-based Portland pozzolana cement conforming to Latest British codes and Mauritius Standards or Equivalents shall be used for superstructure. Type of cement for sub-structures shall be decided based on the final Soil Investigation report.

Coarse aggregate for concrete shall be crushed stones chemically inert, hard, strong, durable against weathering of limited porosity and free from deleterious materials. It shall be properly graded.

Sand shall be hard, durable, clean and free from adherent coatings of organic matter and clay balls or pellets. Sand, when used as fine aggregate in concrete, plaster and Masonry work shall conform to Latest British codes and Mauritius Standards or Equivalents.

Reinforcement steel shall be of high strength deformed TMT steel bars with corrosion inhibitors, Corrosion Resistant Steel (CRS) re-bars, Fusion Bonded Epoxy Coated (FBEC) re-bars or Zinc Coasted re-bars of grade minimum Fe-500 and shall conform to Latest British codes and Mauritius Standards or Equivalents. Ductile detailing in accordance with Latest British codes and Mauritius Standards or Equivalents. shall be adopted for superstructure and substructure of all RCC buildings / structures

The following minimum grades of concrete for design mix and nominal mix shall be adopted for the type of structures noted against each unless not specified elsewhere.

M 30 - All RCC structural elements above and below ground level, precast concrete, MMS foundation, cable trench, oil pit, Grade Slab, Paving, culverts & road, base slab of drains.

M-15 (Equivalent Nominal Mix of 1:2:4) - Plain Concrete Cement.

The bidder shall carry out the design mix of M-30 grade concrete on priority. The design mix shall be approved from Employers before start of work. Sample test cube result shall be provided at 7 and 28 days.

In case Geotechnical investigations requires any special kind of cement or higher grade of concrete, the same shall be provided.

The foundation system shall be made which transfer loads safely to the soil for the structures, depending on soil conditions, geographical condition, regional wind speed, bearing capacity, slope stability etc. All foundation system and foundation depth shall be decided based on the approved geotechnical investigation report. No foundation allowed on back filled soil and the foundation depth to reach upto NGL.

All loads shall be considered in line with Latest British codes and Mauritius Standards or Equivalents. Seismic loads for design shall be in accordance with BS:8110 and relevant Standards.

Bending and Fixing of Bars for concrete Reinforcement and Reinforcement detailing must be complied Latest British codes and Mauritius Standards or Equivalents.

A minimum 75 mm thick PCC shall be provided below RCC wherever RCC is laid over the ground. Proper and sufficient formwork/shuttering shall be provided for the required period as per Latest British codes and Mauritius Standards or Equivalents.

A. Structural Steel

All structural steel design shall be carried out as per BS 5950 Structural steel, Pipe, Chequered plates and Hollow steel sections shall conform to the Latest British codes and Mauritius Standards or Equivalents.

B. Structural Steel/Steel Sheet Painting

All non-hot dip galvanised structural steel (excluding Module Mounting & SCB structure)/ Outdoor metal containers/ Enclosure/ Rolling shutter items shall be provided with paint designed for a minimum maintenance-free life of fifteen (15) years (high durability) as per Latest British codes and Mauritius Standards or Equivalents. For finishing coat suitable colour pigment shall be added. All paints including primer shall be of the reputed brand/manufacturer and as approved by the Engineer-In-charge. The method of application shall be as per the recommendations of the manufacturer.

Grouting

Cement mortar (1:2) grout with non-shrink additives shall be used for grouting below base plate of column. The grout shall be high strength grout having a minimum characteristic compressive strength of min 30 N/mm2 at 28 days. Nominal thickness of grout shall be at least 50mm for building columns and pedestals. For secondary posts, ladder base and staircase, grouting shall not be less than 25mm thick.

Transformer - Civil Works

Transformer and equipment's foundations shall be founded on piles/isolated spread footings depending on the final geotechnical investigation report. Metering yard equipment's structures shall be designed as per Latest British codes and Mauritius Standards or Equivalents.

Pipe /Cable Racks & Trenches

Trenches shall be constructed in reinforced cement concrete of M-30 grade of wall thickness min 150 mm. The top of trenches shall be kept at least 100 mm above the gravel level so that rain water does not enter the trench. Trench walls shall not foul with the foundations.

Indoor Cable Trenches: RCC indoor cable trenches shall be provided with 50X50X4 mm angles grouted on the top edge of the trench wall for holding minimum 6 mm thick mild steel galvanized checkered plate covers (600-1200 mm in length except at ends & bends) conform to Latest British codes and Mauritius Standards or Equivalents with lifting arrangement. Angle or channels shall also be grouted at distances of 600 mm across the indoor cable trenches to support the checkered plates.

Trench Drainage: The trench bed shall have a slope of approx. 1/500 along the run & 1/250 perpendicular to the run. In case straight length exceeds 30 m, suitable expansion joint shall be provided at appropriate distances. The expansion joint shall run through vertical wall and base of trench. All expansion joints shall be provided with approved quality PVC water stops. Suitable drainage at lowest point of the trench shall be provided.

Road and Pathway

The different types of roads are enlisted below:

- Pathways all around the building and its component for accessing the building.

  These pathways shall be permeable to rain.

  The Contractor shall propose an appropriate pathway and shall design same accordingly as approved.

- Access road from existing road to the CMCS Building. This road shall be an asphalted one of a width of at least 6m. The road will lead up to the building premises, driveway and all around the building.

  Kerbs (with proper haunching) shall be provided on the two sides of the road.

Drainage System

Surface drainage system shall be designed considering “maximum hourly rainfall intensity” at the site area considering latest 25 years return period however the minimum value of “maximum hourly rainfall intensity” shall be maintained as 60 mm in the drainage system design. The minimum value of surface run off coefficient shall be considered as 0.6 in the design of drainage system. The drainage system shall be designed as per the Latest British codes and Mauritius Standards or Equivalents and prevailing industry practices. The drainage scheme shall be designed considering the bidder’s plot area and nearby catchment area contributing to the plot drains. Drainage scheme with detention ponds which allows for groundwater recharge & maintains the existing drainage pattern as far as possible is desired. A network of open drains shall be designed & provided to carry surface run off. The drains shall be trapezoidal or rectangle section lined with concrete slabs/brick masonry/stone masonry/stone slabs. The minimum thickness of these lining shall be 115mm for brick masonry, 75mm thick for concrete slab, 150mm thick for stone masonry and 40mm thick for stone slab.

Grade level shall be fixed with due reference to highest high flood level of the receiving body of water. Laying of Hume pipe shall be in line with Latest British codes and Mauritius Standards or Equivalents.

Electrification of Building

Electrification of all building shall be carried out as per Latest British codes and Mauritius Standards or Equivalents and other relevant standards.

14.1 Geotechnical investigations and Bathymetry

Geotechnical investigation report is available for a Ground Mounted Solar Project at 500m away from the proposed CMCS building. Topographical survey has been carried out at proposed project location. Further, Bathymetry report in form of Google KMZ file is also available. All these documents/results are attached in the Tender documents. **However, Detailed investigations like Geotechnical investigations, topographical Survey and bathymetry shall be carried out by the successful Bidder during Detailed Engineering.**

The Bidder may base his tender on the data made available by the Engineer/ Employer to be cross checked from his own inspection and examination, all as aforementioned.

The Bidder must ensure himself whether any soil improvement will be required on site prior to the start of the construction works. All expenses required for soil improvement survey and soil improvement works must be included in the bid price.

Site Levelling and Grading:

Site levelling works involves the following works:

- All works related to site clearance including removal of bushes, trees, levelling, grading, finishing and other additional works shall be carried out by the Contractor. Mandatory permission/ licenses/ statutory clearances from Competent Authorities for site levelling activities like removal of tree and bushes, undertaking blasting related works, disposal of cutting material etc. shall be carried out by the contractor.
- Site grading level shall be fixed with due reference to site drainage of the whole area, existing drainage pattern, maximum flood level and system requirements.
- Site levelling works/scheme shall match with the specific functional requirement of Solar PV optimum generation considering the full utilization of the plot area for the desired capacity.
- Consideration from the boundary and fencing requirements.
- Based on the spot level, contour survey done and meeting above requirements, bidder can propose different site grade levels. The site levelling may be carried in patches/blocks. Bidder may also propose the site leveling and grading matching with the natural topography of the land considering the optimized use of the land, however bidder shall ensure to meet the desired power generation capacity in the allotted plot area. Bidder shall also ensure that no water ponding and flooding occurs in the low

lying areas & effective drainage is provided in the whole plot area, in all kind of site levelling and grading or plant at natural topography schemes, bidders has to ensure to provide proper and effective drainage system in line with “Drainage System” chapter. After performing the optimization of levels from the detailed site survey by the Contractor, the final formation level of the plot in various areas shall be finalized. The area shall be suitably cut and filled to suit the layout requirement. The site levelling and grading scheme incorporating the above aspects shall be submitted to Engineer/ Employer for approval.

- Fill shall normally be made up of Cohesive Non swelling material capable of being compacted upto 95% Modified Proctor density. In case earth has to be borrowed, the same shall be arranged by the Contractor himself. The slope at the edge of graded areas shall not be flatter than 1:1.5 (1 vertical to 1.5 horizontal) in cutting and 1:2 in filling. In case of fill by rock material, the same shall be done in line with relevant Latest British codes and Mauritius Standards or Equivalents.
- All buildings shall be constructed in levelled area. No foundation shall be allowed on back filled soil and in that case the depth of foundations shall reach up to NGL. Final Level will be approved in detail engineering.
- The slope protection measure shall be provided in case inter levelled patches level difference is more than 2.0m. Random rubble/boulder/stone pitching/concrete blocks etc. shall be provided for the slope protection for road side slope, storm water ditches/drainage, embankment slopes, inter levelled patches slopes etc. as per design requirements.
- Suitable sand erosion control measure shall be provided in case any sand dune falls inside the plot area. The same may be made with Random rubble/boulder/stone pitching/concrete blocks etc. Bidder shall also provide sufficient grass/buses/trees covers on these dune.

14.2 Architectural Design

The Architect shall design the following:

14.2.1 Building Works

Construction of a new single-storey RCC building to include Air-conditioned SCADA room and 22 KV MV Switchgear, Inverter Duty Transformer, Inverters, Storeroom, Lobby, Toilet and Urinal, Battery and UPS Room, ACDB/LDB/MLDB etc. of an approximate total surface area of 300 m².
Certification from certified civil/structural engineer that the structures will withstand cyclonic winds of 280 kmph, 3s gust, 50 years return period shall be submitted to the Employer.

14.2.2 Site Works

- Sewer system inclusive of manholes, septic tank and absorption pit
- Access roads and their drainage system within the site and all around the building and site
- Access roads and their drainage system to provide access to the site.
- Refurbishment of the existing fencing as required.
- Cable trenches and ducts
- Any other associated ancillary building and site works

14.2.3 Schedule of Architectural Services

- Design the buildings (aesthetically) and provide drawings for the buildings and the site works
- Provision of signature to the Construction Contract drawings.
- The Architect shall be required to issue to the Employer signed and stamped drawings in both hard copy (three sets for application of building permit and two sets of tender drawings) and soft copy.
- The Architect shall also issue any other drawings that may be required e.g. Site plan, Elevations and Cross sections etc.
- The Architect should also cater for the following:
- Schedule of finishes
- Schedule of openings
- Site works to include drainage system, access roads, among others.
- Specifications of materials for the execution of works
- The Architect shall visit the site at intervals appropriate to the stage of construction to inspect the progress, workmanship and quality of the works and materials to determine that works are being executed as per drawings and specifications submitted to the Employer.
- The Architect shall provide information required for statutory applications under planning and building acts and any other statutory requirements under building acts, regulations or other statutory requirements.

14.3 Civil Works Structural Design

Structural Design shall be carried out in accordance with the relevant British Codes of Practice and Mauritius Standards, which apart from those mentioned above, shall include the following, viz:-

- BS8110 – Reinforced Concrete
- BS5950 –Structural Steelwork
- BS8007 – Water Retaining Structures
- MS10 – Reinforcement

Note:

- All foundations shall be laid on firm soil.
- The buildings shall be designed as frame structures.
- The buildings and openings shall be designed to resist wind speed of 280 km/h.
  - Concrete grade 30 shall be used for all concrete structures

For all concrete works:

- Cover against earth surface – 75mm
- Cover against formwork or blinding in concrete bases – 50mm
- Cover against formwork for other concrete structures – 35 mm
- Cover against formwork in building slabs – 30mm
- For any concrete casting, 6 nos. cubes shall be taken and cube tests results at 7 and 28 days shall be provided. The tests shall be carried out by an independent institution.

14.4 Design and Construction

A Professional Registered Engineer with the Council of Registered Professional Engineers of Mauritius (with an experience of at least 10 years) of the contractor shall design the works. The design calculations and the execution drawings shall be signed by the Engineer and submitted to the CEB for approval before execution of the works. Approval from the CEB does not relieve the Contractor from his obligation to have the appropriate design and to ensure that the works and equipment meet CEB's requirements. The works have been described in as much details as possible. The Contractor shall rely on his professional competence to cater for any omission. In no case shall he be able to claim additional payment based on omissions.

14.5 Materials for the Works

All materials supplied by the Contractor shall comply with the appropriate standard specification unless otherwise required hereinafter.

Application of compounds shall be carried out strictly in accordance with Manufacturer's specifications.

All safety measures with respect of storage and application in accordance with the Manufacturer's specifications shall be exercised.

14.6 Disposal of Material Off-Site

Where any material arising from civil works undertaken, the Contractor shall consult with the Employer on whether such materials are to be disposed of or retained by the Employer. Where the Employer designates that the materials are to be disposed of, all such materials will be disposed of by the Contractor at a suitable location off site. The Contractor shall be responsible for obtaining all necessary permissions and licenses for the disposal of such materials. Where hazardous waste is required to be disposed of, the Contractor shall take adequate measures to safeguard human health and the environment. The Contractor shall be responsible for the disposal of any hazardous waste that is encountered.

Where the Employer designates that the materials are to be retained, the Contractor shall store these materials neatly on the site in a manner and location agreed with the Employer

14.7 General Technical Specifications

14.7.1 Site Security

Security measures are required to reduce the risk of theft and tampering of the Solar FPV plant. These security systems shall be provided, among others:

14.7.2 Painting Works

The new concrete coping must be painted (after cleaning) with at least 3 coats of antifungus paint and the metal supports of the fencing shall be painted as per detail below:

All metal surfaces (metal supports) to be thoroughly cleaned of all scale, rust particles, dirt and grease by scrappers and wire brushes or other method. Treat with one coat of two-pack primer, one coat of undercoat and paint with hard gloss enamel paint, to the satisfaction of the Engineer or representative. Colour to be to CEB's approval. Paint samples shall be provided upon request.

14.7.6 Access Roads

The different types of access roads are enlisted below:

1). Pathways from Floating Solar PV Platform for accessing the building.

These pathways shall be permeable to rain.

The Contractor shall propose an appropriate pathway and shall design same accordingly as approved.

2). Access road from existing road to the CMCS Building This road shall be an asphalted one of a width of at least 5m. The road will lead up to the building premises, driveway and all around building.

Kerbs shall be provided on the two sides of the road.

14.7.7 Tarmac

- Compact surface with a ten ton roller to 95% BS heavy to receive hardcore base.
- Supply and lay 300mm thick hardcore filling and compact with a 10 –Ton roller to receive crusher run.
- Supply and lay crusher run (0/20) in layer of 150mm and compact with a 10 tons roller to 95% BS heavy to achieve a final compacted layer of at least 150mm thick. (Compaction tests shall be carried out)
- Clean off surface of crusher run and apply prime coat.
- Supply, lay, roll and compact to 95% BS heavy a minimum of 60mm thick premix asphaltic concrete grade (0/10) to falls and crossfalls as required.
- Road surfacing shall meet local fire and emergency vehicle access requirements.
- Appropriate drainage system of the roads and pathways shall be provided to ensure run-off to nearby river and avoiding any erosion.

14.7.8 Stoning

- Compact surface with a ten ton roller to 95% BS heavy to receive hardcore base.
- Supply and lay 300mm thick hardcore filling of 75-100 mm size and compact with a 10 -Ton roller to receive blue basalt aggregate.
- Supply and lay100mm thick (or as directed on site) 25-40mm clear dust free blue basalt aggregate spread on surface to a neat flat surface over the whole surface of the access roads in between the concrete kerbs.
- Appropriate drainage system of the pathways shall be provided to ensure rain water absorption into the ground.

14.7.9 Concrete kerbs

- The concrete kerbs shall be precast and of size 380x150x900mm long. Works shall include all necessary excavation, concrete footing, hunching up on both sides. Necessary earthwork support, strutting and shoring to sides of excavations shall be allowed for.

14.7.10 Drainage System

Appropriate drainage system of the whole site inclusive of pathways and access roads shall be designed and provided so that there is no accumulation of water.

Cable trenches/ducts / drawpits

Design and provide cable trenches/Reinforced concrete ducts/reinforced concrete drawpits as required. Works shall include excavation and backfilling with appropriate materials, compaction, compaction tests and warning slabs, among others. Cable trench shall be enclosed casing and rodent proof.

14.7.11 Manholes, septic tank, absorption pits

New Evacuation System of Wastewater (Sewerage)

Allow for the provision of new manholes and new sewer lines, to be connected to a new septic tank.

The evacuation network for waste water and sewerage should consist of PVC pipes for draining sanitary fixtures.

Manholes

- The manholes should be designed and constructed.
- The depth / invert level of the manholes should be decided upon, depending on the site levels.
- The manholes should consist of 110mm diameter PVC pressure soil pipe and 600 x 600 mm cast iron cover.
- The manholes shall be constructed in concrete grade 30 cast in situ and finished above the benching with 6mm thick rendering. The manhole concrete wall thickness shall be at least 150mm. The floor of manholes shall be at least 150mm thick and the channels and benching shall be formed above the level of the floor in concrete grade 30.
- The manhole cover should be flush with the new tarmac level.
- The manhole and sewer lines should be tested for flow by filling with water prior to connection.

New Fiber-glass septic tank

Allow for the design and construction of the perimeter wall complete with the base to contain a fiber-glass septic tank of capacity as required. The contractor shall provide manufacturer's specifications for the septic tank for approval.

The perimeter block wall shall protrude for about 300mm above the new asphalt level. Same shall be rendered and painted as per specifications

- Construct the septic tank wall and the connected absorption pit as per drawings.
- The septic tank to be filled with water and tested for leakages prior to handing over.
- Location of septic tank to be decided on site in order to make optimum use of its capacity.

Absorption Pit

Allow for the design and provision of an absorption pit to be connected to the septic tank at the location as per site plan of a dimension of at least 1.5m diameter x 2.5m depth. The absorption pit should be made as per drawings.

Works shall include all necessary excavation in any type of soil including rock strata and subsequent back-filling with selected blue basalt stones of 200 mm maximum size, blue basalt hardcore materials then 31 mm aggregate and the remainder top layer with 12 mm size aggregate and cart away excavated materials from site. Rate shall also include for reinforced concrete kerb surround including concrete footing and benching.

14.7.12 All Buildings finishes

Rendering

Allow for the provision of 15mm thick external rendering to general surfaces of blockwall/concrete wall /above roof level including surfaces of attached and projecting column, isolated column, coping, cills, beams, soffit in narrow widths and reveals, finished to receive antifungus paint.

Allow for the provision of 12 mm rendering to soffit of slab finished to receive antifungus paint.

The render shall be made up of cement and rocksand (1:4) mixed with an approved quality plasticizer on the surfaces, if directed. Rate shall include for hacking and labour for forming arises and fair edges etc. as per specification.

Tiling works

<u>Ceramic Floor Tiles</u>

Supply and lay 300 x 300 x 9 mm thick (or as approved) antiskid homogeneous ceramic floor tiles (to the gatepost's and building's floor) of European origin, or as approved, with 2mm grouted joints of other approved width on screed backing including pointing of joints with coloured grout. Rate shall include for any necessary cutting, fittings, margins, wastages, borders, patterns, inlays and backing adhesive.

Colour and pattern shall be to the Architect's approval. Samples shall be submitted for approval prior to ordering and start of work. Ceramic tiles shall comply with BS or another approved standard.

Ceramic Wall Tiles

Allow for the provision of ceramic tiles to the internal walls of the toilets for a height of 1.8m as per details below.

Supply and lay in position 200mm x 200mm x 8mm thick ceramic wall tiles of European origin, or as approved, with 2mm thick joints or joints of approved width on rendered surfaces (elsewhere measured) including joints with colour grout. Rate shall include for all necessary cutting, wastages, borders, patterns, inlays, backing adhesive, pointing with joint sealer and PVC strips of approved quality to all exposed edges.

Samples shall be submitted to the Architect for approval prior to start of the work. Colour and pattern shall be to Architect's approval. Ceramic tiles shall comply to BS or another approved standard.

Openings

Aluminum openings (windows/topvents/main doors)

Design, supply and fix in position 80 microns powder-coated aluminium openings complete with frames, mullions, transoms, neoprene glazing beads, aluminium flashings, silicon joints and ironmongeries as per manufacturer's specifications and Engineer's/ Employer's approval.

The new Aluminium openings shall be of dark brown colour. The openings shall be designed to resist wind gusts of 280 km/hr. The current thickness of the glazing and member sizes are of minimum sizes and hence, the contractor shall design the openings to comply with the wind speed requirements. The design calculations must be done and vetted by the Registered Structural Engineer and submitted to the Employer/Engineer.

The contractor shall submit shop drawings for assembly and fixing of the windows and fabrication shall be started only after approval of the shop drawings.

All aluminium windows shall consist of 6mm thick laminated solar reflective glass.

Samples and specifications shall be provided to the Engineer for approval.

Other requirements shall be as follows: -

- Glazing and re-glazing facilities without the need to remove the outer frame.
- Drainage from horizontal members.
- Weather tightness comprising air permeability, water tightness and wind resistance.
- A water test should be carried out to ensure that there is no penetration of water through the windows.

Solid Aluminium Panelled Door (for toilets and bathrooms)

Allow for the provision of single leaf aluminium solid paneled door of overall size as specified in the schedule of openings. The rate shall be inclusive of ironmongeries such as 3 nos. 100mm aluminum washered hinges per leaf, 3 lever mortice sashlock, aluminium handles, etc. as per Architect's specifications.

Fire Exit Doors

Allow for the provision of emergency fire exit door made in metal. The metal door should be made of galvanized square hollow section 65 x 40 mm claddedon both sides with galvanized metal sheets complete with the provision of good quality anti-panic door kit (country of origin Spain or Italy).

The metal door frame should be fixed into jamb with galvanized fishers prior to rendering.

The doors shall be thoroughly cleaned of all scale, rust particles, dirt and grease by scrappers and wire brushes or other method. Treat with one coat of two-pack primer and spray paint with hard gloss enamel paint, to the satisfaction of the Engineer or representative. Colour to be to the Engineer's approval.

Ironmongeries

Supply and fix the required ironmongeries which shall be of the quality and design specified or other approved equivalent. All ironmongeries shall be fixed strictly as per manufacturer's specification and to Architect's approval.

Semi Solid Flush Door

Supply and fix in position 38mm thick semi solid flush door in treated 'Red Meranti' timber framing to BS or other equivalent standard made up of 32mmx100mm high top rail (1 No.); 32mm x 75mm high intermediate rails at an interval of 200mm; 32 x 150mm high lockrail (1 No.); 32mm x 100mm high bottom rail (1 No.); 32mm x 100mm high door stiles (2 No.) all tennoned jointed and faced on both sides with 6mm thick meranti plywood and lipped all around with 44mm wide x 10mm thick lipping. The door shall be provided with 900x 200mm aluminium door kicker plates fixed to both sides of the door.

Architrave to door frame

Supply and fix in position 50mm x 13mm thick overall shaped Architrave around door frame in treated 'sapele' timber with an approved fixing method.

Painting

Prepare, knot, sand and apply one coat of wood primer, one coat of undercoat and two finishing coats of spray applied hard gloss paint to the surfaces of the solid door and the architrave.

Ironmongeries

Supply and fix the following iron mongeries to BS or equivalent standard which shall be of quality and design as specified. All ironmongeries shall be fixed as per the manufacturer's specification and to the Architect's approval. All keys shall be handed to the Client on completion of the project with a plastic tag/key ring on which the door reference and location shall be clearly marked /referenced. All as per Architect's approval and drawings.

Hinges

100 x76 mm heavy duty brass hinges from 'DORMA' or as approved shall be provided.

Mortice lock, escutcheons and strike plate

'Dorma' 3 level mortice sashlock standard range 711 with cylinder lock, stainless steel satin brushed finish escutcheons and strike plate shall be provided. **Flush Bolts**

Supply and fix 'DORMA' satin chromed flush bolts 150mm long.

Handles

Supply and Fix 'Dorma' aluminium brushed finish heavy duty lever handles.

Metal Doors

Supply and fix new Metal doors (single leaf, double leaf or louvered) as per schedule of openings.

The door frames shall consist of 65 x 40 mm hot dipped galvanized angle bars.

The metal doors shall be made of 65x40 mm square hollow sections at the same interval. This frame shall be hot-dipped galvanized.

3 mm thick galvanised metal sheet shall be provided on both sides of the 65x40 SHS frame.

The doors shall be thoroughly cleaned of all scale, rust particles, dirt and grease by scrappers and wire brushes or other method. Treat with one coat of two-pack primer and spray paint with hard gloss enamel paint, to the satisfaction of the Engineer or representative. Colour to be to the Engineer's approval.

The doors shall be provided with good quality heavy duty handles, good quality hinges and locksets complete with all necessary fittings and accessories. Samples should be provided for approval prior to fixing.

Prior approval shall be sought for the Ironmongeries.

Door Stop

Supply and fix rubber and aluminium bodied floor /wall stop of approved type from ‘DORMA’ for all doors.

Door Closer

Allow for the supply and fixing of door closers type ‘DORMA TS83’ with hold open delayed closing option to all doors.

Note:

Doors shall be as per the schedule of openings and Architect’s approval and specification.

Painting Procedure

Concrete Surface

Prepare and apply one coat of undercoat and at least three finishing coats of high quality antifungus paint to MS3 standard on the internal and external surfaces of the building.

Surface preparation and paint application shall be done strictly as per Manufacturer's recommendation/s and specifications. Colour shall be to Architect's approval.

Paint can be applied by conventional brush or rollers. The coating must be neat and smooth just after application. The application of coating materials shall be carried out in a neat workmanlike manner by skilled personnel.

Metal Surfaces

All metal surfaces to be thoroughly cleaned of all scale, rust particles, dirt and grease by scrapers and wire brushes or other method. Treat with one coat of two pack primer, one coat of undercoat and paint with hard gloss enamel paint, to the satisfaction of the Engineer or representative.

Epoxy Flooring

Allow for the Epoxy painting of the switchgear, inverter and transformer rooms and as and where applicable.

Allow for the cleaning of the floor surface free from traces of oil, dirt and any trace of paint to receive new epoxy painting.

Paint the floor with one coat of approved epoxy primer followed by at least two coats of approved epoxy paint (‘Hi-built’ or similar), to the satisfaction of the Engineer.

Notes

Coating shall not be applied to surfaces upon which there is any moisture, or during rain or misty weather without suitable protection. Each coat shall be protected during initial curing period against possibility of moisture condensation or contamination with foreign matter.

All coated areas which are defective or damaged, shall be cleaned and repaired. Coating that are loose, weakly bonded, blistered, abraded or otherwise defective shall be removed and the surface re-cleaned. The surface shall then be re-coated in accordance with the appropriate clause in this specification.

Horizontal Blinds

Supply and install in position 50mm wide horizontal blinds to BS standard or similar approved equivalent to all window openings as specified by the Architect.

Blinds to have either ceiling or wall- mounted brackets and with side gear with protection against unwinding. The system shall consist of high quality materials. Rate to include for fixing of necessary fitting and accessories.

The Horizontal blinds:

- Should be of 'Aluwood' type;
- Should be discreet, smart, practical and easily adjustable to give control over privacy and amount of light to allow in the office;
- Should consist of aluminium head and bottom rails;
- Should consist of Aluminium slats with wooden outlook;

  Samples should be provided for selection by CEB.

False Ceiling and accessories

Allow for the provision of false ceiling to the SCADA room.

False ceiling

The false ceilings shall be standard false ceilings, made of removable gypsum board panels 600 x 600 mm or otherwise to be approved by the Engineer/ Employer. The panels should not contain any harmful substance such as asbestos and formaldehyde. The ceiling shall be quick and simple to install and shall facilitate the simple integration of other essential services such as lighting. The board panel shall be about 10mm thick and shall have a high humidity resistance and light reflectance property and shall be of standard patterns to CEB choice, and should satisfy the BS 476, as far as fire propagation and fire protection rate are concerned.

The supporting metal grid shall be of a concealed type system. It may be suspended or fixed directly to the main support. Any component damaged during assembly shall be replaced by the Contractor. The false ceiling assembly shall be satisfactorily plane, especially the edge components.

The contractor shall work in close collaboration with the Electrical Contractor in installing pockets and positioning the light fittings incorporated into false ceilings.

The ceiling shall be quick and simple to install and shall facilitate the simple integration of other essential services such as lighting, electrical, data and phone systems.

Sanitary Wares

The sanitary wares and fixtures shall be of good quality. The number of sanitary wares and fittings would depend on the number of toilets/bathrooms as designed by the Architect.

Wash hand basins (in each toilet or as approved) shall be of ‘Ideal Standard' or similar approved 'Portman' pedestal type with single tap hole and overflow fitting, bead chain waste, plastic bottle, trap with 75mm seal, fixing clips and bolts, isovalve, servicing valve and complete with all other necessary fittings. Colour shall be to CEB's approval.

Allow for the supply and fixing of approved European type ‘Armitage shanks’ vitreous toilets complete with wall hung, mid-level cistern, necessary fittings and accessories. The system shall be connected to the water reticulation and waste disposal system.

Supply and fix ‘Armitage Shanks’ (or similar good quality) vitreous china Urinal bowels (at least 2 or as approved) with approved bottle trap and fittings. Each Urinal to be supplied with good quality chrome plated press taps and chrome plated water pipes. The system shall be connected to the water reticulation and waste disposal installation.

Allow for the supply and fixing of ceramic separators in between the urinals.

Allow for the supply and fixing of shower equipment in the bathroom and 1 no. solar water heater of minimum capacity 200L.

Allow for the supply and fixing of ‘Armitage shanks’ or similar approved hand spray near toilet bowl with flexible water cable and angle valve complete with wall hook and chrome plated handle and all necessary fittings and accessories and connection to the water reticulation and waste disposal system.

Allow for the supply and fixing approved chrome plated paper holders in the toilets.

Allow for the supply and fixing of approved chrome plated towel holders and soap holders near the wash hand basins and in the bathroom.

Supply and fix 6mm thick approved quality polished glass mirrors (above the wash hand basins) overall size 600 x 600mm high with bevelled edges with 6mm aluminium backing fixed to walls with 4 No 38mm brass dome screws with chrome cap.

Allow for the supply and fixing of Liquid soap dispensers ref. ‘Mediclinics’ DJ 0030CS or similar approved equivalent with stainless steel satin finish of approved capacity near WHB and in bathroom.

Supply and fix in position 100 x 100 mm floor gully in brass/aluminium plated anti-rust epoxy polyster coated in all toilets and bathrooms. The floor gully shall be connected to the soakaway.

Allow for the provision of alucobond trunking / box to conceal the pipes in the toilets and bathroom. The trunking should be easily removable in case of any repairs required.

All above-mentioned fittings shall be approved by CEB prior to fixing and drawings to be referred to prior to fixing.

Plumbing works

Allow for the provision of new plumbing work from the new CWA mains and from Tamarind Falls reservoir to the water tanks.

Allow for the distribution pipes and accessories from the water tanks to the toilets, bathrooms found in the new building and some additional taps (if required) as approved by CEB.

The distribution networks shall be made with good quality ('PN 25') PVC pressure pipes and brass fittings (country of origin Italy).

Brass fittings shall be provided as and where required and directed.

Approval should be sought for all pipes and fittings prior to fixing.

A stop valve shall be provided at the entrance to the buildings, similarly, isolation taps shall be provided to each sanitary fixture.

Allow for the provision of waste disposal pipes as required.

In general, the various works, connections and fittings used and their method of installation shall comply with the standards in force.

Testing

Allow for the provision of new plumbing work from the new CWA mains and from Tamarin Falls reservoir to the water tanks.

Allow for the distribution pipes and accessories from the water tanks to the toilets and bathrooms found in the CMCS building and some additional taps (if required) as approved by CEB.

The distribution networks shall be made with good quality ('PN 25') PVC pressure pipes and brass fittings (country of origin Italy).

Brass fittings shall be provided as and where required and directed.

Approval should be sought for all pipes and fittings prior to fixing.

A stop valve shall be provided at the entrance to the buildings, similarly, isolation taps shall be provided to each sanitary fixture.

Allow for the provision of waste disposal pipes as required.

In general, the various works, connections and fittings used and their method of installation shall comply with the standards in force.

Testing

The whole of the water installations must be tested by the Contractor and any defective work or part to be made good or replaced immediately and shall be retested until found satisfactory.

Allow for the supply and connection of a roof water storage tank 1000L, complete with necessary fittings and accessories.

All the water reticulation PVC pipes shall be clipped to the blockwall or should be buried into the earth below asphalt as directed on site.

Notes: -

- The capacity of the water tanks shall be to the Architect's approval.
- The PVC water storage tanks shall be supplied with a guarantee certificate of at least ten years.
- The roof water tank shall be laid on a reinforced concrete platform on the roof (to be designed and constructed).
- The water tanks shall be located close to vehicular access for ease of replenishment.

Soakaways

Allow for the design and construction of gully traps/ catchpits and soakaways conncected to rain water pipes and disposal pipes from WHBs, bathrooms as per Architect's drawings of dimensions 1000mm x 1000mm x 600mm.

Road Marking

Allow for marking of lines, texts, etc. using (rubber based) road marking paint. The marking should be carried out as per the markings shown in drawings.

The paint should be petroleum based pigmented liquid, applied in a wet film thickness of some 400 microns (0.4mm) and offering quick drying characteristics of between 5 and 15 minutes, depending on weather conditions.

The paint shall be applied using machine mounted spray equipment in which the pressurized liquid and special nozzles give a clean edged result without masking discs or as approved.

The Contractor shall provide all necessary equipment/means for the monitoring of the thickness of the paint.

Specifications of road paint shall comply with BS 6044.

Waterproofing to roof slabs

A. Allow for new waterproofing works to roof slab of the building inclusive of all parapet walls as per details below: New Screed

Lay new screed made up of cement sand mortar and mixed with Jaycocrete or similar products to falls and cross-falls to a slope of 1:100 on roof, in accordance with the manufacturers specifications. Slope direction should be according to location of rain water pipes.

Exact dimensions to be taken on site.

Screed to be cast using ready mix screed complete with Jaycocrete or similar products and placed using mechanical concrete pump.

Height of up stands at the edge of roof slab to be increased if the height is reduced below 75mm after placing new screed (if applicable).

B. Waterproofing Membrane

Supply and lay, "Mariseal 250" liquid applied polyurethane waterproofing membrane or other approved equivalent, on the roof slab, any upstand beams, parapet walls and slab edges over the whole surface area so as to cover same completely, as directed on site.

Exact dimensions to be taken on site.

Surface shall be prepared as per specialist contractor’s recommendation to receive liquid waterproofing. All Concrete surface to be to be clean dry and free from contamination, then primed with Mariseal 710 Primer, 3 coats Maris Polymers, Mariseal 250 liquid-applied polyurethane waterproofing membrane or similar approved equivalent on screed to fall to outlets all strictly as per manufacturer's specifications and recommendations and to Engineer's/ Employer’s approval.

Methodology of application shall preferably be hand-applied using roller brush or similar.

C. The Contractor shall submit manufacturer’s specifications, methodology of application and sample for approval together with the bid as well as a written statement that a ten-year warranty would be provided upon completion of the works.Tests on Completion

a. No-Ponding test

The Contractor shall carry out a No-Ponding Test, to the Engineer’s approval, after the laying of the new screed.

b. b. 24-hour No-Leak Test

The Contractor shall carry out a 24-hour No-Leak Test, to the Engineer’s approval, after the application of the new waterproofing treatment, to verify for any leakage.

D. Rain water pipes

Allow for the provision of 5 nos. (or as directed) new PVC rain water pipes 75 mm diameter with plastic clamps at every 1m as directed on site.

Specifications

Waterproofing System

Performance Specifications of the waterproofing system

- The system shall, unless specified otherwise, be resistant to foot traffic and light concentrated loads associated with installation and maintenance operations.
- The system shall comply with European, South African or American standards.
- The system and its installation shall conform strictly to the Manufacturer's specifications.

Preparation of surface to receive Waterproofing treatment

The waterproofing Contractor shall ensure that the slope of the slab is adequate to prevent water ponding and is according to Manufacturer's specifications.

All concrete surfaces to be waterproofed shall be reasonably smooth and free from holes and projections, which might puncture or otherwise damage the waterproofing treatment to be applied.

The surface of the substrate shall also be dry and shall be thoroughly cleaned of dust and loose materials prior to the laying of the waterproofing system Prior to the application of the new treatment, the waterproofing Contractor shall be required to issue a certificate stating that the surface is ready to receive the new waterproofing treatment and is according to the Manufacturer's Specifications.

It is hereby made clear that, should the waterproofing system fail to perform as required, no discharge of responsibilities shall be allowed on the grounds of the existing conditions prior to the application of the waterproofing system.

Inspection of Waterproofing Treatment

The waterproofing treatment shall be carried out to the satisfaction of the Engineer.

The Contractor shall ensure that the waterproofing treatment is free from wrinkles, buckles, blisters (trapped air) and other damage. Any damaged or defects to the waterproofing system shall be corrected at the Contractor's cost, and to the Engineer's approval.

The Contractor shall clean adjacent surfaces of spillage and spattering of any adhesive materials used in the works

Water Test

The Contractor shall carry out a no-ponding test, to be carried out after the laying of the new screed, and which shall be to the Engineer's approval The contractor shall carry out a 24 hours water test to be carried out after laying of new waterproofing membrane to verify for any leakage. The test shall be to the Engineer's approval.

Guarantee Certificate

On satisfactory completion of the waterproofing works, the Contractor shall submit a certificate of guarantee against leakage, defective materials and defective installation of the completed waterproofing system. Any such defects or leakage occurring during the guarantee period shall be promptly and completely attended to, including all affected work, at no additional cost to the Employer

The said guarantee shall be in effect for a period of ten (10) years from the date of the Practical Completion Certificate. The guarantee shall be signed by the Contractor and shall be submitted to the Employer.

Site clearance and Professional Cleaning at the end of all works

Allow for the provision of professional cleaning services at the end of all works. The whole building, the openings and all the finishes as well as the yard shall be thoroughly cleaned.

The Contractor shall abide to the following conditions:

1. The Contractor shall remove all debris, surplus materials from site as they accumulate and at completion. Clean all surfaces internally and externally. Remove stains and touch up paint to the satisfaction of the Engineer/ Employer.
2. The Contractor must ensure that the method and equipment used do not cause any damage to CEB's plant and equipment and vehicles parked in the yard. Approved scaffolding must be erected to ensure safety on site
3. The Contractor shall abide by the Occupational Safety, Health & Welfare Act of 2005(Check whether this act is latest).
4. The Contractor shall allow for all necessary watching for the security of the works and all materials and tools brought on site. The CEB shall not be responsible for any loss of equipment or materials that might occur during execution of works.
5. No part of the works shall be covered up or put out of view without the approval of the Civil Engineer and the contractor shall afford full opportunity for the Civil Engineer to examine any such part of the works which is about to be put out of view.
6. Access to site to be agreed with CEB prior to commencement of work.
7. The Contractor shall provide all necessary plant, general tools, scaffolding materials and labour for the prompt and efficient execution of the works. Moreover, the Contractor shall provide all the proper safety gears to their personnel on site.
8. The Contractor shall be solely responsible for the procurement of his own water supply and electricity. The Contractor will be required to arrange for the installation of a temporary connection as required or directed, remove same and make good disturbed surfaces on completion to the satisfaction of the Engineer/ Employer and pay all charges for meter hire and consumption until the completion of works.
9. Materials, goods and workmanship shall be of the best quality of their respective kinds, and those for which there is a Mauritian Standard, a British Standard or Code of Practice (referred to herein as MS, BS and COP) respectively shall comply therewith unless otherwise stated.
10. The Contractor at his own cost, for the CEB’s approval shall supply samples of all materials. Once approved no other material shall be used without the permission of the CEB.
11. The Contractor shall, with due care and diligence, execute and complete the works and remedy any defects therein in accordance with the provisions in the Contract. The contractor shall provide all superintendence, labour, materials, plant, and all other

things, whether of a temporary or permanent nature, required in and for execution, completion and remedying of any defects to the satisfaction of the Civil Engineer. The Contractor shall take full responsibility for the adequacy, stability and safety of all Site operations and methods of construction.

12. The Contractor shall be deemed to have inspected and examined the site and its surroundings before submitting his proposal, as to be aware of: -

a) the extent and nature of work and materials necessary for the execution and completion of the works and the remedying of any defects therein, and

b) the means of access to the site and the accommodation he may require, and, in general, shall be deemed to have obtained all necessary information as to risk, contingencies and all other circumstances which may influence or affect his Quotation.

13. The Contractor shall execute and complete the Works and remedy any defects therein in strict accordance with the contract to the satisfaction of the Civil Engineer. The Contractor shall comply with and adhere strictly to the Civil Engineers instruction on any matter, whether mentioned in the Contract or not, touching or concerning the Works. Materials or work, which in the opinion of the Civil Engineer, do not comply with the specification, shall be classified as rejected materials or defective work and shall be cut out and removed from the works and replaced as directed by the Civil Engineer.

14. The Contractor shall be responsible for: -

a) the accurate setting-out of the Works in relation to original points, lines and levels.

b) the correctness, of the position, levels, dimensions and alignment of all parts of the Works, and

c) the provision of all necessary instruments, appliances and labour in connection with the foregoing responsibilities.

If at any time during the execution of the works, any error appears in the position, levels, dimensions or alignment of any part of the works, the contractor, shall at his own cost, rectify such error to the satisfaction of the Civil Engineer.

The checking of any setting out or any line or level by the Engineer shall not in any way relieve the contractor of his responsibility for the accuracy thereof and the contractor shall carefully protect and preserve all benchmarks, sight-rails, pegs and other things used in setting out the works.

15. Rejected Materials and Defective Work.
Materials or work, which in the opinion of the Engineer, do not comply with the specification, shall be classified as rejected materials or defective work and shall be cut out and removed from the works and replaced as directed by the Engineer.

16. Program of Works
The contractor shall submit in his offer a practicable work schedule which shall include a comprehensive bar chart for recording both the planned program and actual performance. Same shall be regularly updated and made available at regular site visits.

17. Plant & materials
    The Contractor shall provide all necessary plant, general tools, scaffolding materials and labor for the prompt and efficient execution of the works. Moreover, the Contractor shall provide all the proper safety gears to their personnel on site and necessary facilities such as toilets, bathrooms etc. for his personnel.

18. Foreman
    A competent general foreman shall be always present on site during working hours and any instruction given to him by CEB Engineers shall be deemed to be given to the Contractor.

19. Safety
    The attention of the Contractor is drawn to the fact that the works may be effected in the vicinity of live parts where special arrangements regarding access to the site of work and supervision will have to be made for the successful tenderer. The latter will be called upon to submit a written undertaking to comply with the safety instructions from the Officer - in - Charge of the work, before calling on site to start work and be fully compliant to OSHA-2005.

14.8 Civil Works – Specifications

14.8.1. Materials Specifications

14.8.1.1. Quality of Materials

(a) <u>General</u>
All materials used in the Works shall be of the qualities and kinds specified and shall be approved by the Engineer. They shall comply with the requirements of the British Standards (hereinafter abbreviated to OS) published by the British Standards Institution, or A.A.S.H.O. and ASTM Specifications as specified elsewhere in the Specifications. All materials may be checked both at the source and on site and approval of any material at its source does not necessarily imply that it will be approved on site.

All materials shall be delivered on to the site in sufficient period before they are required for use in the works, so that such samples as the Engineer may wish are taken for testing and approval, and the Contractor shall furnish any information required by the Engineer on the materials.

(b) <u>Defective Materials</u>
All materials which do not comply with the requirements of the Specifications will be rejected and all such materials, whether in place or not, shall be immediately removed from the site by the Contractor at his own expense.

(c) <u>Order of Materials</u>
The selected Contractor shall place orders for all materials, tools, equipment, and fittings etc. within one week after being allocated the contract. He shall keep the

Engineer informed of the order placed and of their expected delivery for use in connection with or in the works.

14.8.1.2. Handling and Storage of Materials

(a) <u>Stockpiling of Aggregates</u>

Approved aggregates shall be delivered to the Site in prescribed sizes or grading and shall be stockpiled on paved areas in separate units.

Special care shall be taken to avoid segregation, contamination and mixing of different classes of aggregates. Stockpiles shall be built by layers about 80 cm high. Material to be loaded shall be taken from the upper layer and never from the toe of the stockpile. Fine aggregates shall be allowed to drain until uniform moisture content is reached before it is used.

(b) <u>Storage of Cement</u>

Cement shall be stored in well ventilated, watertight building with floors raised 30 cm above ground level and no cement shall be within 15 cm of the sides of the buildings to ensure circulation of air. Each consignment shall be kept separately, and the Contractor shall use the consignments in the order in which they are delivered on Site. When being conveyed to the site in lorries or other vehicles, they shall be properly covered with tarpaulins or other effective waterproof coverings. Cement, which has become unsuitable through absorption of moisture shall be rejected and removed from the site by the Contractor at his own cost.

(c) <u>Storage of Steel Reinforcement</u>

Steel reinforcement shall be stored, sheltered and supported by wooden blocks as to prevent sagging. Bars shall be stored in separate lots according to diameter and quality.

14.8.2 Engineer's specifications

14.8.2.1. Equivalency of Standards and Codes

Wherever reference is made in the Contract to specific standards and codes to be met by the goods and materials to be furnished, and work performed or tested, the provisions of the latest current edition or revision of the relevant standards and codes in effect shall apply, unless otherwise expressly stated in the Contract. Where such standards and codes are national, or relate to a particular country or region, other authoritative standards that ensure a substantially equal or higher quality than the standards and codes specified shall be accepted subject to the Employer's Representative's prior review and written consent. Differences between the standards specified and the proposed alternative standards shall be fully described in writing by the Contractor and submitted to the Employer's Representative at least 28 days prior to the date when the Contractor desires the Employer 's Representative's consent. In the event the Employer's Representative determines that such proposed deviations do not ensure substantially equal or higher quality, the Contractor shall comply with the standards specified in the documents.

14.8.3. Specification for Excavation, Under Floor/Hardcore Filling

14.8.3.1. Inspection of Site

The contractor is deemed to have visited the site and to have ascertained the nature of the material to be excavated, and likely accumulation of rain water, prior to submission of his offer as no claims will be allowed on the grounds of ignorance of conditions under which works will be executed.

The Contractor shall ascertain the nature of the ground to be excavated/disturbed, carted away, thereafter likely to cause any problem of dust nuisance to the Environment. All remedial measures to stop blowing of dust such as by watering etc will be deemed to have been included in his price.

14.8.3.2 Dealing with water

The Contractor's attention is drawn to the depths below ground level on the foundations and to the water level requiring him to deal with water. Unless otherwise specified the Contractor will be required by pumping or other means to the Engineer's approval to keep the excavations dry during construction.

14.8.3.3 Shoring and strutting

The Contractor's attention is drawn that the rate for excavation includes for any

The Contractor's attention is drawn that the rate for excavation includes for any shoring and/or strutting required to the sides of the excavation to walls footings, column bases, etc.

Also, the rate includes for propping/strutting of caves in excavation where required.

The structure of the adjacent or nearby building or buildings shall be shored as required by the drawings and/or instructions of the Engineer before starting excavation in proximity of the existing structure. The Contractor's attention is drawn to the need to carry out the excavation in stages approved by the Engineer.

14.8.3.4. Excavate to Reduce level and to Dimensions

Excavate site as shown on drawings to form the foundations to width and depth indicated, the bottom of all excavation to be clean perfectly level, and/or stepped as shown or as instructed.

The price of excavation is to include for excavation (and their removal from site) of all materials encountered, upholding the sides of excavations; to that effect, the

Contractor must visit the site of works to assess the nature of the subsoil likely to be encountered.

The price of excavation is to include for excavation required for working space, keeping excavation dry during construction, shoring and strutting, as well as for any overbreak due to nature of soil/rock, method of excavation or any other reason.

The ground below basement slab, column bases and strip footing to walls will be excavated to exact required level, i.e. last 150mm depth by hand and where found in sand and/or loose stratum, it shall be compacted with 8 passes (i.e. 4 in each direction) with 1.25 ton vibrating roller or mechanical tempers before blinding.

Any overbreak due to nature of soil/rock/boulders, method of excavation or due to any other reasons, excavations to width or depth greater than those shown on the drawings or as instructed by the Engineer shall be filled by the Contractor at his own expense in such depths or width of excavation beyond that instructed or shown, with concrete grade 15/20 to the satisfaction of the Engineer.

14.8.3.5. Rock

"Rock" means any hard material, which in the opinion of the Engineer can be removed only by use of compressors or by wedging and the Engineer's opinion shall be final. Decomposed rocks, tuff or other material which can be removed by pick, traxcavator, or any other mechanical means will not be classed as rock. All material classified as rock may if approved by the engineer, be used as hardcore filing and the measured quantities of imported hardcore will be adjusted accordingly. All rock so used must be broken to the required size as hereafter described for hardcore before being used.

Boulders of a dimension 400 mm or less and/or of volume 0.064 m^3 or less will not be classed as "Rock".

No blasting will be permitted.

14.8.3.6. Bottom of excavations to receive foundations

The contractor shall report to the Engineer when secure bottoms to the excavations have been obtained. Any concrete or other work executed before the excavations have been inspected and approved, shall if so directed, be removed and new work substituted after the excavations have been approved, all at the Contractor's expense.

The surface of the bottoms to excavations shall be leveled or graded to falls as required, compacted as specified above just prior to blinding. Bottom formed in clay or silty stratum shall not be left exposed before inspection by the Engineer. Upon arrival, a layer of concrete class 15/20 blinding (maximum 20 mm gauge aggregate) or concreted with mass concrete as shown on drawing shall be placed and finished to a smooth surface with a wood float.

To receive tanking membrane, all corners and edged are rounded off or filled with 25mm radius with cement sand (1:3) mortar.

14.8.3.7. Under floor filling

Where shown approved filing under the thickness of hardcore shall be made of any of the following or mixed:

- Excavated material of decomposed rock when stacked/ stored separately from material other than rock.
- Sand
- Stones of size not exceeding 225 mm
- Pieced of concrete blocks and site cast concrete mixed of size not exceeding 225 mm.

The stone/excavated decomposed rock fill should not contain clay/silty soil in excess of 10% by volume if found mixed.

The layers of approved fill shall be well watered, compacted before placing the layer of hardcore.

14.8.3.8. Materials found in excavations

No material found in the excavations should be used in the works without the written permission of the Engineer.

14.8.3.9. Hardcore filling

Hardcore where shown under floors, etc. shall be good hard stone ballast to the approval of the engineer broken to pass not greater than 150mm ring or to be75% of the finished thickness of the layers being compacted whichever is the lesser and graded so that it can be easily and thoroughly compacted by rolling crusher run may be used instead of hardcore, with prior approval of the Engineer.

The hardcore is to be laid in layers each of a consolidated thickness not exceeding 225mm and well-watered and rolled with a vibrating roller (minimum one and a quarter tons) or a ten ton roller, each layer for minimum of 8 passes until no visible settlement is noted. Where rolling is impossible, compaction shall be by hand or mechanical tempers. Thereafter, top surface of the hardcore shall be leveled or graded to falls as required and blinded with similar material broken to 25 mm gauge and surfaced with a 15 mm layer of rock sand, well-watered and rolled. Rolling for minimum 4 passes until no visible settlement of the top is noted.

14.8.4. Blockwork Specification

14.8.4.1. Concrete Blocks

Concrete cellular blocks shall be obtained from an approved manufacturer and shall have been manufactured in accordance with BS 6073: Part 1: 1981. The blocks sizes are to be 457 x 303 x 150 or 200mm. An average compressive strength from a sample of 10 blocks on gross area shall be as specified on the drawing. No individual block shall have a compressive strength less than 80% of the specified on gross area. Where compressive strength is not specified, the specified minimum strength will be 3.5 N/mm^2. Blocks shall be tested in accordance with Appendix B of BS 6073: Part 1. Alternatively testing in accordance with Appendix B of BS 6073: Part 2 may be allowed subject to approval from the Engineer.

14.8.4.2. Mortar

Cement mortar for laying of blocks shall consist of 1 part of ordinary Portland cement: 3 to 4 parts washed rock sand by weight, materials as specified for the use of concrete and an approved plasticizer in liquid shall be mixed and proportioned as specified by the manufacturer.

The ingredient of the mortar shall be measured by proper gauge boxes, or by weigh batcher. When measured by the gauge boxes, the dry density of the sand shall be taken as 1360 kg/m^3 and of cement as 1440 kg/m^3. The mixing by hand shall not be permitted. Mixing shall be by an approved mechanical batch mixer of capacity not less than $0.1m^3$ (finished product).

14.8.4.3. Setting and jointing

Mortar shall be used within one hour of mixing. The blocks shall be laid in a stretcher bond with 10mm thick joints. The joint shall not vary ±3mm and shall achieve the specified height in specific number of courses shown on the drawings. The work shall be carried out with horizontal joints truly horizontal and level and no part shall be 4 courses above adjacent work during construction. The vertical joint shall be 10mm thick with ±3mm tolerance.

No extra claim of labour and/or material or whatsoever will be allowed by the Employer due to non-availability of specified sizes of concrete blocks. The Contractor shall build to the specified height floor to floor by cutting the concrete block and/or placing extra concrete height of the ring beams. The adjustment of thickness of mortar joint shall not be permitted.

No vertical joint in any courses shall be within 110 mm of a similar joint in the course immediately above or below except where shown otherwise.

A written approval of the design engineering consultants is required by the Contractor for the following:

- Changes in position of load bearing walls
- Sizes of structural opening for doors, windows and others
- Cutting of a vertical chase more than 25 mm wide x 20 mm deep
- Cutting of a horizontal chase in the wall of length more than 900 mm and depth 20 mm
- Built in services in wall requiring cutting of the walls

- Number of lengths of cutting in walls for conduits, services, etc in excess of 2 of nature mentioned in (4) or (5) above

No pipes carrying hot water shall be embedded in masonry wall. All cutting in the walls for fixings of doors, windows, etc shall be kept minimum, meaning that fixings may be built with courses of masonry. The damaged or displaced block shall have to be removed and made good before concreting ring beam above and/or rendering whichever is earlier at no extra cost to the Employer.

14.8.4.4. Reinforcement for Blockwork

All external block walls exposed to rain and wind shall be reinforced with brick reinforcement for every 3rd course and will be anchored at ends and bends to r.c wall ties or columns.

The reinforcement at the tee and right-angle junctions of masonry with or without r.c. wall tie columns shall be built with the courses of masonry. The r.c. wall tie columns shall be connected in heights not more than 6 courses of masonry along with the masonry. The construction of the r.c. wall tie column will not be permitted ahead of construction of walls. The concrete to the r.c. wall tie column shall be class 25/20 nominal mix with slump not more than 50mm unless otherwise specified on the drawing. The reinforcement to the r.c. wall tie column shall be as shown on the drawings.

Whenever removable panel for future door or window is anticipated, the same will be built with bricks reinforcement at alternate courses and good bonding is ensured to make the joints leak proof.

At the end of each working day of the masonry work, horizontal and vertical joints on both faces shall be rake out 4mm deep with a scraper. Faces of the r.c. wall tie columns and ring beams shall be roughened and hacked with a chisel hammer between 16 hours and 32 hours after they have been concreted. This is essential for proper bond between rendering and walls.

14.8.4.5. Curing

The completed masonry work shall be cured continuously for 72 hours with water. Curing of masonry works shall start 4 hours after they have been laid.

14.8.4.6. Load bearing walls

Load bearing wall shall comply with British Standard BS 5628: Part 1: 1992 and BS 5628: Part 2 and 3: 1985 where not inconsistent with these Preambles.

14.8.4.7. Fixing blocks and leaving holes

Provide and build into walls all necessary fixing blocks and leave out as necessary holes for pipes, conduits and the like and make good after fixing by other trades and specialists as required to the specialist's detail to achieve movement and watertightness.

14.8.4.8. D.8 Build in lugs

Form or leave mortices in walls for, and build in lugs and all necessary fixing for metal windows and doors, door frames and lining, sanitary fittings, rainwater pipes, clips and bearer of various types.

When building up the walls, the openings shall be made as per structural dimensions of the schedule for doors/windows, the frames are placed, completewith lugs, the walling completed in concrete mix type C.

14.8.4.9. Damp-proof course

Unless and otherwise indicated on drawing provide a layer of 2-ply felt dampproof course. Felt to be of a manufacture approved by the Engineer and to be laid on a 10mm (minimum) thick bed of cement mortar (1:3) on walls.

The damp-proof courses to stand the full thickness of walls, partitions and beams in one width and to be overlapped 150mm at all jointing and corners.

14.8.4.10. Measurements

The contractor must allow in his prices for block walling for plumbing angles, all straight and raking cutting, cutting and fitting to columns, cutting and pinning to beam, cutting, and fitting around end of cills and lintols, cutting and pinning ends of structural timber.

The rates of blockwork must also include for fixing all door, window and like openings, forming reveals to same and for cutting and waste to walling in short lengths to mullions and jamb of openings.

The rates of blockwork must also include for hoisting and building off beams and slab at any level, all necessary scaffolding and for work built overhead.

14.8.5. Specifications for Concrete

14.8.5.1. Code of Practice for Concrete Works

All workmanship, materials, tests and performance in connection with the British Code of Practice BS 8110 for the Design, materials and workmanship for "The Structural Use of Concrete" and BS 8007: 1987 "Code of Practice for Design of

Concrete Structures for Retaining Aqueous Liquids “where not inconsistent with these Preambles.

14.8.5.2. Cement

Cement unless otherwise specified shall be Portland Cement of strength class 42.5N complying with the requirements of BS 12: 1991 and a manufacturer’s certificate of Test in accordance with BS 12: 1991 shall be applied for each consignment delivered to site.

Cement may be delivered to the site either in bags or in bulk.

If delivered in bags, each bag shall be properly sealed and marked with the manufacturer’s name and shall be stored in a waterproof shed of adequate dimensions with a raised floor. Each consignment shall be kept separate and marked so that it may be used in a sequence in which it is received. Any bag found to contain cement which has set or partly set, shall be completely discarded and not used in the works. Such bag/bags shall be removed from site within 24 hours. Bags shall not be stacked more than 1.5m high.

If delivered in bulk, the cement shall be stored in waterproof silo either provided by the cement supplier or by the contractor but in either case the silo shall be to the approval of the Engineer.

14.8.5.3. Aggregates

Aggregates shall conform to the requirements of BS 882:1992 and the sources and types of all aggregates are to be approved in all respects by the Engineer before work commences.

The grading of aggregates shall be one within the limits set out in BS 882 and as later specified and the grading, once approved, shall be adhered to throughout the works and not varied without the express prior approval of the Engineer.

Fine aggregates shall be clean, washed, crushed rock sand and coral sand of hard quality and shall be free from lumps of stone, earth, loam, dust, salt, organic matter and any deleterious substances. The maximum quantities of material passing the 75µm sieve shall not exceed the values given in Table 6 of BS 882:192.

Coarse aggregate for concrete shall be crushed blue basalt stones to the approval of the Engineer. It shall be hard, clean and roughly cubical in shape, non-porous, free from dust, decomposed stone, clay, earthy matter, foreign substances or friable, thin, elongated or laminated pieces. It shall be graded within the limits of Table 3 of BS 882 for graded aggregates. The flakiness index shall not exceed 40.

If in the opinion of the Engineer, the aggregate meets with the above requirements but is dirty or adulterated in any manner it shall be screened and/or washed with clean water, if he so instructs, at the Contractor’s expense.

Aggregates shall be delivered to the site in their prescribed sizes or gradings and shall be stock piled separately on paved areas or boarded platforms in separate units to avoid intermixing, excessive segregation and contamination with other materials. On no account shall aggregates be stock piled on the ground. Fine aggregates shall be allowed to drain until it has reached a uniform moisture content before it is used.

Moisture/water content in fine and coarse aggregate will be measured daily and the amount of free water is taken into account before adding water to arrive at the w/c ratio of the approved design mix of concrete.

14.8.5.4. Quality of Mixing Water

Water of chemical composition acceptable for drinking is suitable for concrete. The water used for making and curing concrete and mortar shall be free from objectionable quantities of silt, organic matter, alkalis, salt or other impurities. In particular, inorganic matter in solution shall not exceed 500 parts per million by weight and in suspension shall not exceed 30 parts per million by weight and the total alkali bicarbonate/carbonate content of the water shall be less than 1000 parts per million by weight.

The water shall be from an approved source and shall contain no deleterious matter which significantly affects the setting time or strength or durability of the concrete or which has any effect on the appearance of the hardened concrete by discoloration or efflorescence or prevents the achievement of the approved test cube strengths at 28 days for the appropriate grade of concrete.

The contractor shall test the water which he proposes to use and shall submit the records of such tests to the Engineer before placing any concrete in the permanent works.

The contractor shall make regular tests of the water during concrete construction works. The water shall be sampled at the point of discharge into the mix and the frequency of sampling shall be as approved by the Engineer.

14.8.5.5. Admixtures

Concrete admixtures shall comply with BS 5075 or ASTM C494 shall be allowed with the prior approval of the Engineer. “Plasticiser” where used will be added to the mixing water in proportion recommended by the manufacturer and strictly in accordance their written instructions, to achieve better workability. No additional cost will be paid for the use of plasticizer.

14.8.5.6. Floor Hardener

Where floor hardener is specified for concrete floor, it shall be ‘Sika’ Chapdur Premix or approved equivalent and shall be used as per manufacturer’s instruction.

14.8.5.7. Reinforcement Materials

Steel reinforcement shall be plain mild steel bars or high yield deformed bars complying with MS 10 (2002), or cold worked deformed bars complying with MS 10. Steel reinforcements shall be cut straight from straight bars free from kinks and bends or other damage and cold bent by experienced competent workmen. At the time of incorporation in the works the reinforcement shall be clean and free from loose mill scale and loose rust.

Bars of diameter 20 mm or greater shall be bent in a bending machine designed for the purpose and approved by the Engineer. Bending and cutting shall be in accordance with BS 4466 unless otherwise specified or ordered by the Engineer. The contractor shall supply the Engineer with the certificates of the manufacturer issued in compliance with MS 10 for all the required tests, including the rebend test, in respect of each consignment delivered to site.

Steel fabric reinforcement shall comply with MS 34 & MS 35.

Steel reinforcement shall be stored sheltered and supported by wooden blocks so as to prevent sagging. Bars shall be stored in separate lots according to diameter and quality. No claim on account of non-availability of bars up to 12 metres lengths will be allowed.

14.8.5.8. Fixing reinforcement

Reinforcement shall be accurately bent to the shapes and dimensions shown on the drawing and in accordance with BS 4466. Reinforcement must be cut and bent cold and no welded joints will be permitted unless so detailed and approved by the Engineer.

Reinforcement shall be accurately placed In position as shown on the drawings and shall be secured against displacement by using No 18 S.W.G annealed binding wire or suitable clips at intersections and laps, and shall be supported by approved concrete, plastic or metal supports, steel chairs, spacers or metal hangers to ensure the correct position and cover before concreting and shall be kept in the same position during concreting. However, metal supports, chairs, etc. shall have minimum 12mm cover made of concrete blocks, or shall have approved plastic shoes.

14.8.5.9. Position and Correctness of Reinforcement

No concreting shall be commenced until the Engineer has inspected the reinforcement in position and until he has approved the same. The Contractor shall give two clear days notice of his intention to concrete. The minimum period between two inspections shall be 24 hours.

Irrespective of whether any inspection and/or approval of the fixing of the reinforcement has been carried out as above, it shall be Contractor's sole responsibility to ensure that the reinforcement complies with the details on the drawings and is fixed exactly in positions shown therein and in the position to give the prescribed cover.

The contractor will be held entirely responsible for any failing or defect including crack in any portion of the reinforced concrete structure and including any consequent delay, claims third party claims, etc., where it is shown that the reinforcement, has been incorrectly positioned or it is incorrect in size or quantity with respect to the detailed drawings.

Unless otherwise allowed by the Engineer, reinforcement shall not be bent after being embedded in hardened concrete.

Unless otherwise instructed concrete cover to reinforcement bars in any face shall be as per Table 13.3.

Table 14.3: Concrete Cover to Reinforcement Bars

	A For all members of structures located more than 300m away from the sea and at altitude less than 350m, above Mean Sea Level and for internal members fully covered to weather for structures located in B (mm)	**B** For external members exposed to weather for structures located in proximity of sea within 300m from sea and for structures at altitude greater than 350m (mm)
Substructure Foundations against earth face	75	75
Foundations against Blinding	50	50
Columns & walls below ground or against water face	40	40
Ground beams	30	35
Slab on hardcore	30	35
Superstructure Columns: >200 mm	35	35
200mm or less	25	25
Beams and walls	30	35
Suspended slabs	20	25

The above cover shall be decreased by 5mm for concrete surfaces to be finished with cement mortar rendering/screed.

For underground work, likely to be affected by sea water, the above cover shall be increased by 25 mm.

For post-tensioned slabs, the minimum cover to polyethylene sheaths of unbounded tendons or to metal ducts for bonded tendons should not be less than 25m.

14.8.5.10. Design of proposed mix

Table 14.4: Proposed Mix

Maximum Nominal Size of Aggregate in the Mix (mm)	Minimum ratio	Maximum Ratio for Normal concrete	Max. ratio for Pumped Concrete
10	0.45	0.55	0.55
14	0.40	0.50	0.50
20	0.35	0.45	0.47
40	0.30	0.40	0.43

Table 14.5: Concrete grades and strengths

GRADE OF CONCRETE	CHARACTERISTIC COMPRESSIVE STRENGTH AT 28 DAYS (N/mm^2)	COMPRESSIVE STRENGTH COMPLIANCE REQUIREMENTS			
		Any individual test result (N/mm^2)	First 2 (N/mm^2)	First 3 (N/mm^2)	Any consecutive 4 (N/mm^2)
15/20	15	13	15	16	17
20/20	20	17	21	22	23
25/20	25	22	26	27	28
30/20	30	27	31	32	33
35/20	35	32	36	37	38
40/20	40	37	41	42	43
45/20	45	42	46	47	48
50/20	50	47	51	52	53

Note: the strength requirements given above shall apply irrespective of the maximum size of aggregates used.

Table 14.6: Maximum Cement Content and Maximum Water/Cement Ratio

GRADE OF CONCRETE	Maximum Cement Content (Kg/m^3)	Maximum water/cement ratio	
		A	B
15/20	200	0.70	X
20/20	250	0.65	X
25/20	300	0.60	X

30/20	325	0.60	0.55
35/20	350	0.58	0.53
40/20	400	0.55	0.48
45/20	425	0.50	0.45
50/20	450	0.47	0.45

Notes:

(a) The minimum cement contents given above are per cubic metre of compacted concrete made with 20mm nominal maximum size of aggregates. For maximum aggregate size of 12 mm, the minimum cement content should be increased by 40 Kg/m³.

For maximum aggregate size of 40 mm, the minimum cement content may be reduced by 30 Kg/m³.

(b) Under the heading "Maximum water/cement ratio", column A applies to sheltered and average conditions and column B applies to severe conditions and water retaining structures. Also, the column A and B apply respectively to members mentioned in Column A and B of Table 13.3.

(c) Use of "An approved Concrete Admixture" to BS 5075 or ASTM C494 to achieve the strength with the maximum water/cement ratio as tabulated above is allowed.

(d) Use of more than 40 kg over and above the minimum cement content specified and tabulated above is not allowed.

Table 14.7: Nominal Volumetric Mix

Description	Mix 30/20 1:1.8: 2.8	Mix 25/20 1 : 2.4 : 3.8	Mix 20/20 1: 2.7 : 4.2	Mix 15/20 1: 4: 6
Cement	A bag of 50 Kg	A bag of 50 Kg	A bag of 50 Kg	A bag of 50 Kg
Crushed rock sand	0.0355 m³	0.0497 m³	0.0532 m³	0.071 m³
10mm to 5mm graded aggregate	0.0284 m³	0.0355 m³	0.0426 m³	0.071 m³
20mm to 10mm graded aggregate	0.0710 m³	0.1094 m³	0.1136 m³	0.1419 m³
Maximum water/ Cement ratio	0.55	0.60	0.65	0.70
Maximum Slump	50 mm	50 mm	50 mm	50 mm

Note: 1 bag of cement i.e., 50 Kg = 0.0355 m³

14.8.5.11. Ready Mixed Concrete

The contractor shall ensure that the requirements of these specifications are complied with.

Further to the above requirements, the contractor shall ensure that transport and delivery of ready mixed concrete comply with the recommendations of clause 4.10.4 of BS 5328: Part 3: 1990.

The concrete shall be transported to the site in truck mixers from the mixing plant premises and shall be continuously agitated until it is delivered on site. The Contractor shall ensure that no further water is added after water added in the preparation at the mixing plant.

For plant mixed concrete the Contractor shall check that the delivery notes for each truck shows:

1. Volume of concrete in m^3
2. Cement in kg per m^3 of mixed concrete
3. Grade of the concrete
4. Initial setting time with or without hardener
5. Type and quantity of admixture added per m^3 of mixed concrete
6. The maximum allowable time interval between the completion of discharge and the mixing of water at the mixing plant.
   This time interval should be 30 minutes less than the initial setting time of the cement. Any concrete which is not placed in its final position within this time interval should not be used.

The concrete delivery note showing the above information should be signed by approved qualified/experienced supervisors, one at the plant before departure of truck and another one on site before the truck is discharged.

Sample of works cube shall be taken by the Main Contractor at the place where concrete is finally placed in the structural members at the rate specified in Article below.

14.8.5.12. Quality Control of Concrete Production

a) <u>Sampling</u>

b) For each class of concrete in production at each plant for use in the permanent works, samples of concrete shall be taken at the point of mixing and /or of deposition as instructed by the Engineer, and in the presence of a representative of the Engineer, all in accordance with the sampling procedures described in BS 1881 and with further requirements set out below.
c) Six 150 mm cubes shall be made from each sample and shall be cured and tested all in accordance with BS 1881, two at 7 days and two others at 28 days.
d) At least one sample should be taken of each grade of concrete on each day that concrete is placed. The actual rate of sampling shall be increased for critical elements if instructed by the Engineer.

e) **Testing**

f) The consistency of all concrete shall be determined by means of the slump test in accordance with British Standard Specifications No. 1881 “Methods of testing Concrete”. The contractor shall provide the necessary number of slump cones and rods as required by the Engineer.

14.8.5.13. Failure to comply with requirements

1) Quantity of concrete represented by strength results the quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches. Similarly, the first two or three results shall be taken as representing all the intervening batches. For the individual test result requirements given in Table 13.5, only the particular batch from which the sample was taken shall be at risk.

2) The contractor shall take any action instructed by the Engineer to remedy concrete which does not comply with the specification. The results of such actions do not nullify the previous establishment of non-compliance with the specification based on requirements for cube test results. The Contractor shall be responsible for all costs and delays for such actions. Such action may include but is not necessarily confined to the following:

   I. Increasing the frequency of sampling until control is again established.

   II. Cutting test scores from the concrete and testing in accordance with BS 1881.

   III. Carrying out strengthening or other remedial work to the concrete where possible or appropriate.

   IV. Removing the failed concrete.

   V. Carrying out non-destructive testing such as load tests on beams.

14.8.5.14. Mixing concrete

Before any plan for batching, mixing, transporting, placing, compacting and finishing concrete is ordered or delivered to site, the Contractor shall submit to the Engineer for approval full details of all the plant which he proposes to use and the arrangements he proposes to make, including qualified/experienced technical personnel separately for supervision of these activities.

Concrete for the permanent works shall be batched and mixed in one or more central plants unless the Engineer agrees to some other arrangement.

Mixer shall be of a capacity sufficient to take two whole bags of cement per mix. Smaller size mixer shall not be used. Weigh batching machines with water measuring device shall be of an approved type and shall be properly maintained and checked weekly for its accuracy. All materials shall be thoroughly mixed dry before the water is added and the mixing of each batch shall continue for a period of not less than two minutes after the water has been added and until there is a uniform distribution of the materials and the mass is uniform in colour.

The entire contents of the mixer drum shall be discharged before recharging. The volume of mixed materials shall not exceed the rated capacity of the mixer. Whenever the mixer is started, 10% extra cement shall be added to the first batch and no extra payment will be made on this account.

14.8.5.15. Conveying

1) The concrete should be mixed as near to the place it is required as is practicable to avoid rehandling and only as much as is required for a specific section of the work shall be mixed at one time, such section being commenced and finished in one operation without delay. All concrete must be efficiently handled and used in the works without twenty (20) minutes of mixing. It shall be discharged from the mixer direct either into receptacles or barrows and shall be distributed by approved means which do not cause segregation and loss of ingredients or otherwise impair the quality of the concrete. Approved mechanical means of handling will be encouraged, but the use of chutes for placing concrete is permitted provided they are not longer than 6m and their slope do not exceed 1 vertical to 2 horizontal and is not less than 1 vertical to 3 horizontal. Conveying of concreting by hand-buckets or similar shall not be allowed. Similarly conveying of concrete by belt conveyor shall not be allowed.

2) Pumped concrete – coarse aggregate size shall be limited to 20mm for pumped concrete mixes. The slump of concrete discharged into the pump may exceed the specific slump by the amount of slump loss in the pumping system up to a minimum 25mm. the slump loss shall be the difference between slump tests made at both ends of the pumping system. If the tests indicate a loss greater than 25mm, the Contractor shall modify the pumping system as required to reduce the slump loss to 25mm or less.

3) A super plasticiser should preferably be used in the pump concrete. The slump of the concrete mix shall not exceed 75mm before addition of super plasticiser.

14.8.5.16. Depositing of Concrete

Placing of concrete in supported elements, e.g., slab, beam shall not be started until the concrete previously placed in top parts not exceeding 300mm depth below the bottom of the beam/slab of columns is no longer plastic and has been in place at least for two hours.

Concrete shall be placed from height not exceeding 1.5m directly into its permanent position and shall not be worked along the shutters to that position. Unless otherwise approved, concrete shall be placed in a single operation to the full thickness of slabs with beams and similar members. The engineers shall allow concrete to be placed for wall exceeding 150mm thickness from a height up to 3m and in layer not exceeding 750mm if ACROW or other approved system of formwork is used.

In addition, Contractor will ensure that the concrete shall be deposited continuously such that no concrete shall be deposited on concrete which has hardened sufficiently to cause the formation of seams or places of weakness within the section. Placing shall be carried out at such a rate that the concrete which is being integrated with fresh concrete is still plastic.

Concrete in columns may be placed to a height of 3 m with careful placing and vibration to achieve satisfactory results. Where the height of the column exceeds 3m suitable openings to engineer's approval must be left in the shutters so that this maximum lift is not exceeded.

Concrete shall be placed continuously until completion of the part of the work between construction joints as specified hereinafter in article 2.25 or of a part of approved extent. At the completion of a specified or approved part construction joint of the form and in the positions hereinafter specified shall be made.

14.8.5.17. Placing Concrete under water

Concrete shall be deposited under water by an approved method e.g., tremie concreting in such a way that the fresh concrete enters the mass of previously placed concrete from within, causing water to be displaced with minimum disturbance at the surface of the concrete.

14.8.5.18. Precautions of mixing and placing

Any accumulation of set concrete on the reinforcement shall be removed by wire brushing and the area is cleaned thoroughly before further concrete is placed. The contractor shall provide runways well supported on metal sands for concreting to the satisfaction of the Engineer. Under no circumstances will runways supports be allowed to rest on the reinforcement. Overnight before concreting, the foam work and reinforcement shall be thoroughly wetted with clean water and it is again lightly wetted just before concrete is deposited.

Care shall be taken that the concrete is not disturbed or subjected to vibrations and shocks during the setting period.

Mixing machines, platforms and barrows shall be cleaned before commencing mixing and be cleaned on every cessation of work.

Where concrete is laid on hardcore, concrete blocks or other absorbent materials of the base shall be suitably and sufficiently wetted before the concrete is deposited.

14.8.5.19. Compaction of concrete

Compaction

At all times during which concrete is being placed, the Contractor shall provide adequately trained and experienced labour to ensure that the concrete is compacted in the forms to the satisfaction of the Engineer.

Concrete shall be placed neither at a rate greater than will permit satisfactory compaction nor to a depth greater than 750mm before it is compacted.

14.8.5.20. Vibration of concrete

During and immediately after placing, the concrete shall be thoroughly compacted by means of continuous tamping, spading, slicing, rodding, forking and vibration. Vibration is required for all concrete of grades with 28 days strength greater than 15 N/mm^2.

Care shall be taken to fill every part of the forms, to work the concrete under and around the reinforcement without displacing it and to avoid disturbing recently placed concrete which has begun to set. Any water accumulating on the surface of newly placed concrete shall be removed and no further concrete shall be placed thereon until such water is removed

Internal Vibrators

Internal vibrators shall have a frequency of not less than 7 000 cycles per minute. Such vibrators shall visibly affect the concrete within a radius of 225mm from the vibrator.

Vibrator shall not be used to move concrete from place to place in the formwork. At least one internal vibrator shall be operated for every two cubic metres of concrete placed per hour and at least one spare vibrator shall be maintained on site in case of break down during concreting operations.

External vibrators

External formwork vibrators shall be of the high frequency low amplitude type applied with the principal direction of vibration in the horizontal place. They shall be attached directly to the forms at no more than 1.2m centres. In addition to internal and external vibration the upper surface of the suspended floor slabs shall be levelled with manual tamping or vibrating elements prior to finishing. Vibrating elements shall be of the low frequency high amplitude type operating at a speed of not less than 3000 r.p.m.

14.8.5.21. Curing and Protection

Care must be taken that no concrete becomes prematurely dry and fresh concrete must be carefully protected within two hours of placing from rain, sun and wind by means of hessian sacking, polythene sheeting or other approved means. This protective layer and the concrete itself must be kept continuously wet for at least three days for members less than 300mm thickness and 6 days for members greater than 300 mm thickness after the concrete has been placed. The contractor must allow for the complete covering of all fresh concrete for a period of three days.

Hessian or polythene sheeting shall be in the maximum widths obtainable and shall be secured against wind. The contractor will not be permitted to use old cement bags, hessian or other material in small pieces. When temperature exceeds 30°C the new concrete shall be covered with a layer of drip dry hessian. Traffic or loading shall not be allowed on the new concrete except with the written permission of the Engineer.

When curing compound or membrane are used, full details of the manufacturer's literature and test certificate from the independent testing laboratory should be submitted to the Engineer. The curing compound should have an efficiency index of not less than 90% when tested in accordance with BS 7542. SIKA Top 71 or approved equivalent, without diluting, curing compound shall be applied strictly in accordance with the manufacturer's recommendations. The floor slab shall not be cured by curing compound but by ponding of water for at least three days or 6 days as specified above.

The method of monitoring the application rate and the area to which curing compound has been applied shall be submitted by the Contractor for Engineer's approval and the approved method shall be strictly followed by the contractor. The engineer shall, at his discretion, require the Contractor without claiming extra cost to adopt an effective alternative means of curing any area of the structure where curing compound or membrane curing is unsatisfactory in the opinion of the Engineer.

14.8.5.22. Faulty Concrete

Any concrete which fails to comply with these preambles, or which shows signs of setting before it has been placed shall be taken out and removed from site. Where concrete is found to be defective by the Engineer after it has set, the concrete shall be cut out and replaced in accordance with the Engineer's instructions. On no account shall any faulty, honeycombed, or cracked or otherwise defective concrete be repaired or patched until the Engineer has made an inspection and issued instruction for the repair. The whole of the cost whatsoever, which may be occasioned by the need to remove faulty concrete shall be borne by the Contractor.

14.8.5.23. Construction Joints

Position of construction joints

Construction joints shall be permitted only at the locations shown on the drawings or as instructed by the site Engineer. In general, they shall be perpendicular to the lines of principal stress and shall be located at points of minimum shear, viz. vertically at, or near, midspans of slab ribs and beams.

Where construction joints are not shown on drawings, the contractor shall submit the plan of floor layout, column and wall elevations showing the construction joints to comply with all requirements of this Article and seek the Engineer's written approval immediately on or before fixing reinforcement. The Contractor shall keep record of position and details of all construction joints and submit to the Engineer within a week of completion the drawing showing them.

Maximum distance between construction joint

Suspended slabs are generally to be cast using alternative bays not exceeding a length of 12m. At least 48 hours shall elapse between the casting of adjacent bays. Joints between bays shall be in positions to be agreed with Engineer. Beams shall be cast with the slab.

Mass concrete shall be cast in alternate bays in lengths not exceeding 7.5m and in depth not exceeding 1.5m. Adjacent sections shall not be cast within 48 hours of each other. Ground floor slab on hardcore shall be cast in alternate bays not exceeding 4.0m in length and/or width, unless otherwise shown on the drawings. At least 48 hours shall elapse between the casting of adjacent bays.

Under no circumstances shall concrete be allowed to tail off but shall be deposited against stopping-boards.

Preparation of Construction joints

Before placing new concrete against new concrete already set, the face of the old concrete shall be thoroughly hacked or roughened to expose the coarse aggregate without damaging the edges of the concrete. Edges of concrete if damaged shall be repaired with Epoxy Mortar of approved quality. The surface shall be cleaned, laitance and loose material removed therefrom. Immediately before placing the new concrete the surface shall be saturated with water. All construction joints of roof, external walls and columns; and external beams shall be treated with epoxy resin in accordance with the manufacturer's instruction by an experienced skilled worker. Main contractor shall ensure that full watertightness of external construction joints is achieved.

Before the final set of the concrete, the construction joint at its top shall be made good with surface troweling.

Reinforcement across Construction joints

At construction joints in slabs, minimum reinforcement of 0.15% of the cross section of the slab should be provided for each face of the slab unless otherwise as detailed shown by the Engineer.

Prices for concrete shall include for construction joints.

14.8.5.24. Expansion/Contraction joint

Joint fillers shall be flexcell except where high density styropor is shown on the drawing. Sealants shall be Elastometric of an approved type unless otherwise shown on the drawings. Reinforcement or other embedded items bonded to the concrete shall not extend through any expansion/contraction joint.

External peripheral strip of the joint fillers shall be sawn and fixed so that it can be removed easily to form correct and true depth and width of the sealants. Unless otherwise shown on the drawing the depth of the sealants shall be equal to the width of the expansion joint.

The gap for sealants shall be cleared of any mortar and foreign material. The edges of concrete on the sides of the expansion joint shall be protected from breaking. Broken edges shall be repaired with Epoxy Mortar of approved quality such that the width and the line of the expansion joint is perfectly maintained.

The elastometric sealants shall be applied after the application of approved separating membrane and the primer all as per manufacturer's specification.

14.8.5.25. Waterbars

Type

Waterbars shall be PVC waterbars to British Standards 2782 Part 3 and of an approved type, shape and size (min 240mm wide where not shown) shall be provided in the positions indicated on the drawings. At places galvanized m.s.strip of minimum thickness 1.0mm in corrugated shape and of 300 mm minimum width in the following properties i.e. can be used as waterbar, pvcwaterbars where shown as such i.e.

(i) Tensile strength min 12.5 N/mm²

(ii) Elongation at break 300%

(iii) Hardness

And resistant to aggressive water, diluted acids, moderate alkalis and salt etc.

Joints

Joints shall be continuously heat welded in accordance with the manufacturer's instructions. Where the waterbar is to be fixed vertically, metal clips as manufactured by the supplier of the water bar or of other approved design shall be provided to suspend the waterbar from the reinforcement.

Additional waterbar

The contractor shall adhere strictly to the position and type of construction joints as specified or detailed on the drawings. Any deviation from this procedure or the provision of additional construction joints will require the prior approval of the Engineer and any additional waterbars which may be required will be at the Contractor's expense.

Formwork to Waterbar

Formwork shall be designed with sufficient timber formers and blocking pieces to support the waterbar and to ensure that is not displaced during concreting. In vertical walling and similar members the formwork shall be so constructed as to permit the kicker or upstand of concrete surrounding the lower half of the waterbar to be poured in the same operation as the slab or other member from which it springs.

Formwork to walls or similar members where a waterbar is positioned at the base of the lift shall have sufficient openings not less than 300mm square at approximately 225mm above the level of the waterbar to permit checking that the waterbar is correctly positioned and not displaced during concreting.

No concreting to a member will be approved where kicker or upstand forms its integral part, until the formwork to the upstand is fixed and the waterbar position is secured.

14.8.5.26. Formwork

Material and design

Formwork shall be constructed of timber or steel or precast concrete or other approved material with sufficient strength to withstand pressure resulting from placing and vibration of the concrete and with rigidity to achieve the specified tolerances.

The design and engineering of the formwork as well as its construction shall be the responsibility of the Contractor.

The formwork shall be designed for the loads, lateral pressure, pressure due to cyclonic winds and other loads likely to be encountered on site.

Shop drawings for formwork including the location of shoring and reshoring shall be submitted for approval by the Engineer before erection. As and when requested by the Engineer, the calculations for the design of formwork will be submitted for approval by the Engineer before erection.

Construction

All formwork shall have joints close enough to prevent leakage of liquid from the concrete and formwork shall be jacked or wedged and clamped or bolted to permit adjustments before concreting and to permit easing and removal without jarring of concrete. Formwork shall be securely braced and strutted against lateral deflections and vertical movements. Where formwork is supported on previously constructed portions of the reinforced concrete structural frame, the Contractor shall by consultation with the Engineer ensure that the supporting concrete structure is capable of carrying load and/or is sufficiently propped from lower floors or portions of the frame to permit the load to be temporarily carried during construction. Formwork shall be cambered by the contractor to the amount approved by the Engineer to compensate for anticipated deflections prior to hardening of the concrete. Unless where shown/directed otherwise, the amount of camber to be 1/500 of the span; e.g., for 10m span camber to be provided is 20mm.

Preparation for concreting

The Contractor’s attention is drawn to the various surfaces textures and applied finishes required and the faces of the formwork next to the concrete must be of such material and construction and be sufficiently true to provide a concrete surface which will in each particular case permit the specified surface treatment or applied finish.

At construction joints contact surface of the form for surfaces shall overlap minimum 300 mm and shall be held tight against the hardened concrete to prevent offsets or loss of mortar.

Methods of fixing and positioning of the formwork which results in holes through the concrete and/or left in metal ties or similar in the concrete shall require the Engineer’s approval.

All surfaces which will be in contact with the concrete shall be oiled or greased to prevent adhesion of mortar.

Surplus moisture shall be removed from the forms prior to placing of the concrete. For surfaces to receive waterproofing membrane, an approved water-based mould oil compatible with the specified waterproofing materials shall be used. For fair-face concrete to receive paint, an approved mould oil compatible with paint shall be used.

Temporary openings shall be provided at the bases of the columns, wall and beam forms and at any points where necessary to facilitate cleaning and inspection immediately before the pouring of concrete.

Before the concrete is placed, the shuttering shall be trued-up, and the interior of the form shall be completely cleared of all extraneous materials including accumulated water.

The reinforcement shall then be inspected for accuracy of fixing. Immediately before placing the concrete the formwork shall be well wetted and inspection openings shall be closed.

Defective formwork

Defective formwork shall be removed or strengthened and improved by the Contractor according to the instructions by the Engineer at the Contractor’s own cost.

Formwork to construction joints, etc.

Formwork forming the construction joints and expansion joint shall be rigid, tight to avoid loss of mortar and true in square.

Formwork shall be inspected and approved by the Engineer before placing reinforcement unless previously agreed with the engineer, then it will be inspected along with the inspection of reinforcement prior to concreting.

14.8.5.27. Stripping formwork

Formwork shall be removed without undue vibration or shock and without damage to the concrete.

Contractor should submit concrete test results at 3days/ 7 days and seek the Engineer's approval before the removal of formwork. No formwork shall be removed without the prior consent of the Engineer and the minimum periods that shall elapse between the placing of the concrete and the striking of the formwork will be as follows:

(a) Beam sides, walls and columns (unloaded) 24hours

(b) Slab soffits except of flat slab, shell roof, folded plate construction (with props designed to left under) 84hours

(c) Soffits of ribbed slab and hollow block composite floor slab except solid strips (with props designed to left under) 5 days

(d) Flat slab, shell roof and folded plate construction slab soffit and sides (with props designed to left under) 10 days

(e) Beam soffits including those of solid strips of hollow block composite floor slabs, waffle slab (with props designed to left under) 10 days

If the formwork is not designed for removal of soffits with props left in place, the soffits and props should be left in position until the appropriate period for removal of props given below. (subject to works cubes achieving at 7 days strength equal to 2/3 of specified 28 days strengths and the loads due to constructions on them being lighter than the designed superimposed loads,

(a) Slab soffit except of flat slab, shell roof, folded plate construction 10 days

(b) Flat slab, shell roof folded plate construction slab soffits and sides 14 days

(c) Beam soffits including those of solid strips of hollow block composite floor slab, waffle slab 14 days

if the contractor wishes to take advantage of the shorter stripping times as permitted above for beam and slab soffits when props are left in place, he must so design his formwork that sufficient props as agreed with the Engineer can remain in their original position without being moved in any way until expiry of the minimum time for removal of props. Stripping and re-propping will not be permitted.

For system of construction of RC walls by slip forms or similar; the full details of the system of formwork, its rate of travel, method of making good and curing of concrete, method with detailed drawings for reinforcement starters for structural RC members to be supported on the RC walls and other relevant details to be submitted for the approval by the engineer before commencement of works.

For systems of construction such as prestressing or post-tensioning, stripping of foam work should be carried out after the concrete attains the requisite strength and after tensioning of tendons, but in no case shall it be less than 72 hours. Contractor shall be responsible for consequent damage arising from early stripping of formwork.

14.8.5.28. Making Good

After removal of formwork, all projections, fins, etc., on the concrete surface shall be chipped off, and made good to the requirements of the Engineer. Any voids or honeycombing shall be treated as described in the “Faulty Concrete” section.

14.8.5.29. Surfaces finishes from formwork or moulds

Type A finish

This finish is obtained by the use of properly designed formwork or moulds of closely-jointed sawn boards. The surfaces will be imprinted with the grain of the sawn boards and their joints. Alternatively, steel or other suitable material may be used for the forms. Small blemishes caused by entrapped air or water may be expected, but the surface should be free from voids, honeycombing, or other large blemishes. Permissible tolerances are to be as per the “tolerances section” of this specification.

Unless and otherwise shown, this is the finish required for all rendered surfaces after hacking as specified for rendering to Architect’s specifications.

Type B finish

The finish is obtained by the use of properly designed forms of closely-jointed wrought boards. The surfaces will be imprinted with the slight grain of the wrought boards and their joints. Alternatively, steel or other suitable material may be used for the forms. Small blemishes caused by entrapped air or water may be expected, but the surface should be free from voids, honeycombing, or other large blemishes. Permissible tolerances are to be same as (1) above. Unless and otherwise shown, this is the finish required for surfaces covered by false ceiling and by metal framework to fix wall cladding etc.

Type C finish

This finish can only be achieved by the use of good quality concrete and by using properly designed forms having a hard, smooth surface. The concrete surfaces should be smooth with true, clean arrisses. Only very minor surface blemishes should occur and there should be no staining or discolouration from the release agent.

Permissible tolerances are to be half of those mentioned in “Tolerances section” of the specification.

Unless and otherwise shown, this is the finish required for “Fair face” concrete or precast concrete.

Type D finish

This finish is obtained by first producing a Type B finish on thoroughly compacted high-quality concrete, cast in properly designed forms. The surface is then improved by carefully removing all fins and other projections, thoroughly washing down and then filling the most noticeable surface blemishes with a cement and fine aggregate paste. Every effort should be made to match the colour of the concrete. Care should be taken, in the choice of any release agent used, to ensure that the finished concrete surface is not permanently stained or discoloured.

Unless and otherwise shown, this is the finish required for “off shutter” concrete where shown without rendering and to remain exposed after painting to architect’s specifications.

Type E finish

This finish is obtained by first producing a Type C finish and then, while the concrete is still green, filling all surface blemishes with a fresh, specially manufactured and marketed approved cementious paste/slurry coloured or plain to architect’s approval as a base coat and thereafter applying on the same day a finished coat, total thickness to be specified by the architect, finished even and smooth with a steel trowel without any marks. Every effort should be made to match the colour of the concrete. Thereafter the unit is properly cured, the faces rubbed down where necessary, to produce a smooth and even surface. This finish is used only where so specified by the architect for special surfaces.

A sample for each of the above surface finishes will be made for at least of $10m^2$ area for approval by the Architect and the Engineer. The sample will be used for comparison for acceptance of similar specified finished surfaces.

14.8.5.30. Grade of finish of free surfaces

Horizontal or nearly horizontal surfaces which are not cast against formwork shall be finished to the grade shown and/or specified by the Architect. They are defined hereunder.

Grade U1

This is a hard smooth steel trowelled surface for use where appearance is important, for laying of finished product with minimum thickness of adhesive and for laying of epoxy thereon.

To start with, the surface shall be floated as for a U2 finish. When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, it shall be steel-trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

The tolerances to be achieved for the finished surface when measured should not be more than half of what is specified in “tolerance section (3), (5) and (6).

Grade U2

This is a floated finish for roof or floor slabs and other surfaces where a hard steel trowelled surface is not required e.g., for laying waterproofing membrane, pvc tiled floor on adequate thickness of filler/adhesive all to architect's specification.

The surface shall first be treated as a class U3 finish and after the concrete has hardened sufficiently, it shall be floated by hand or power floated sufficient only to produce a uniform surface free from marks and thereafter wood floated.

The tolerances to be achieved for the finished surface when measured should not be more than what is specified.

Grade U3

All surfaces on which no higher class of finish is called for on the drawings or instructed by the Engineer shall be given a U3 finish.

The concrete shall be leveled; all voids filled with concrete, (and screeded where so stated/specified, screed to be monolithic with concrete) to produce a uniform plain or ridged surface without any voids or projecting coarse aggregates, surplus materials being struck off by a straight edge immediately after compaction.

A sample for each of the above grades of finish on Free Surface will be made at least 10.0m² area for approval by the architect and the Engineer. The samples will be used for compaction for acceptance of similar specified finish for the free surface.

Tolerances

1. On all setting out dimensions of 10.0m and over a maximum non-cumulative tolerance of plus or minus 10mm will be allowed, and for those under 10m the allowable maximum non-cummulative tolerance will be plus or minus 5mm
2. On the cross-sectional dimensions of structural members, unless otherwise required by the drawings, a maximum tolerance of plus or minus 5mm will be permitted.
3. The top and soffit surface of slabs shall be within 5mm for area less than 40sqm and within 10mm for area 40sqm and above of the normal levels shown on the drawings. The top of the upstand beam and soffit of downstand beams shall be truly level and line and non-cumulative tolerances of 5mm for length up to 10m and not more than 10mm for full length of the beam exceeding 10m length.
4. Walls and columns shall be truly plumb and non-cumulative tolerance of 10mm in each storey and not more than 20mm out in their height will be permitted.
5. Surface tolerance for slab on grade industrial buildings, warehouses, etc., shall be based on a 3m long straight edge which rests in contact with the floor surface. The maximum gap under the straight edge should not exceed 5mm.
6. Where drawings call for tolerance other than those given in the above paragraphs the drawings shall prevail.

7. The contractor shall be responsible for the cost of all corrective measures required by the Engineer to rectify work which is not constructed within the tolerance set out above.

14.8.5.31. Precast Concrete

General requirements

Unless otherwise approved by the Engineer, all precast concrete construction shall be carried out on the site and shall conform to requirements given elsewhere in these preambles.

The maximum size of the coarse aggregate in precast concrete shall not exceed 20 mm except for members of thickness less than 75 mm where it shall not exceed 12 mm. Minimum cement/m³ of concrete will be increased as per guidance given in Table 13.6 and Table 13.7. The compacting of precast concrete shall conform with requirements given elsewhere in the preambles except for thin slabs where use of immersion type vibrators is not practicable, the concrete in these slabs may be consolidated on a vibrating table or by any other methods approved by the Engineer.

Curing

The precast work shall be made under cover and shall remain under the same for 3 days. During this period and for a further 4 days, the concrete shall be shielded by hessian sacking or other approved material which including concrete must be kept continuously wet. It shall then be stacked in the open for at least a further 7 days to season before being set in position. Where steam curing is used these times may be reduced subject to the approval of the Engineer.

Steam curing of precast concrete will be permitted. The procedure for steam curing shall be subject to the approval of the Engineer.

Method of handling

Precast concrete units shall be constructed in individual forms. The method of handling the precast concrete units after casting, during curing and during transport and erection shall be subject to the approval of the Engineer, providing that such approval shall not relieve the Contractor of responsibility for damage to precast concrete units resulting from careless handling.

Repairs

Repair of damage to the precast units, except for minor abrasions of the edges which will not impair the installation and/or appearance of the units will not be permitted and the damaged units shall be replaced by the Contractor at his own expense.

Moulds

Except where precast work is described as “fair face” or as having an “exposed aggregate” or terrazzo finish the moulds shall be made of suitable strong sawn timber true in form to the shape required. Unless otherwise described faces are to be left rough from the sawn moulds.

Where precast work is described as “fair-face” the moulds are to be made of metal or are to have metal or plywood linings or are to be other approved moulds which will produce a smooth dense fair to the finished concrete suitable to receive a painted finish direct and free from all shutter marks, holes, pitting, etc. In his prices for such precast work, the contractor shall include for all rubbing down to produce the finished required, to the satisfaction and approval of the Engineer/Architect.

Where precast work is to have an “exposed aggregate” or terrazzo finish the moulds shall be constructed to the requirements given for moulds for “fair-face” work. The method of achieving the exposed aggregate finish shall be “aggregate transfer” or other approved methods. A sample showing the required finish and shape shall be approved by the Engineer before commencement of the works. The precast units shall be installed to the lines, grades and dimensions shown on the drawings or as directed by the Engineer.

Predalle

Moulds shall be made of metal or concrete and shall be rigid enough to achieve the required dimensions and thickness. The mould shall be approved by the Engineer before commencing. Mould oil shall be compatible with the specified paint to the soffit of predalle.

The reinforcement in fabric mesh or as detailed shall be placed in exact position. The lifting hooks and/or reinforcement shall be adequately lapped and tied with 18 S.W.G. wires or welded if approved to the reinforcement.

The concrete shall be specified except that the minimum size of aggregate shall be 14mm to BS 882 instead of 20 mm. The concrete shall be placed in one operation in moulds laid horizontally and shall be vibrated by means of maximum 25 mm diameter poker type vibration or a vibrating table or an external vibrator. The top surface of the concrete shall be finished rough. Removal of laitance by water at approved pressure in hose pipe shall be allowed 12 hours after concreting.

Any unit found of thickness less than shown or not being cured properly or with reinforcement incorrectly placed in position or cracked/damaged; shall be rejected by the Engineer.

14.8.5.32. Composite Floor slabs

Size, type & concrete mix for floor block

Concrete hollow blocks for use in the composite floor slabs are to be size and shape as shown on the drawings with 30 mm wall thickness and are to be adequate strength to support the concrete during placing and consolidation by vibration. Blocks are to be manufactured in accordance with the procedure specified in BS 6073 or MS 42.

No coral sand shall be used in making of concrete blocks. The compressive strength of concrete block on gross area to be not less than 3.5 N/mm² at 28 days.

Concrete blocks are to remain under cover and stored for at least 14 days before use on the site. Concrete blocks are to be well wetted before 12 hours and immediately before concreting.

Composite floor construction

The hollow block floor construction is generally to be as shown on the Engineer's drawing. Care shall be taken in placing blocks to ensure that they are set out in accordance with the details shown on the drawings and that they run truly in line without encroaching on the width of the in-situ ribs and solid strips. Concrete blocks where shown on the drawings for less than full width e.g. ½ and 1/3 width shall be cut by grinder or manufactured as such. The length of the concrete block where it encroaches the solid strip shall be cut by grinder. Contractor to include cost of the cutting in his prices.

The open ends of hollow blocks adjacent to the concrete to be placed in-situ are to be plugged or stopped previously with concrete 25/20 grade 40 mm thick to prevent the concrete from flowing into the void and the Contractor is to include for this in his prices.

The Contractor should note that slip tiles are not to be used to the soffit of ribs. The formwork shall be for whole area covering the blocks and ribs and he is to take this into consideration in pricing the items of formwork to the soffit of hollow block floor construction.

Before concreting is carried out, the blocks are to be thoroughly wetted. Care should be taken during concreting that the width of ribs between the rows of blocks and of the solid in-situ concrete shown on the drawings adjacent to supporting beams is not encroached upon by the blocks.

The purpose made spacer blocks of approved size is made in mortar of not less than half strength as of specifie0d strength of concrete with grooves and tying wires shall be used to maintain the width of the ribs and positioning of reinforcement. Contractor to include for this in his pricing.

It is required that the concrete for topping is placed along with concrete to the ribs between hollow blocks.

Fixing of rib reinforcement

Reinforcement shall be positioned accurately with required cover in accordance with the drawings and using the particular spacing block with wire ties as previously described. Spacer blocks shall be provided in ribs at no more than 1.2 m centres. Care must be taken during concreting that the reinforcement is not displaced.

Holes for services, etc.

Where holes for services, etc. occur, the necessary holes or openings shall be accommodated by the replacing of a hollow block by in situ concrete or the widening of a rib including extra reinforcement all in accordance with the Engineer's instructions. Prices for holes/openings etc. through hollow block construction are to include the re-arrangement or substitution of the hollow block with solid concrete and reinforcement in addition to the actual formation of the hole.

Embedded items in concrete

All sleeve, insert, anchors and embedded items required for adjoining structural work or for its support shall be approved by the Engineer and shall be placed prior to concreting and shall be used after an interval of time approved by the Engineer.

Electrical conduits shall be of size not exceeding 20mm overall diameter. They shall be placed at least 75 mm apart in the central thickness of the slab and beam. The group (consisting of maximum 3 @ 75 mm each apart) of conduits to space at not less than 2000mm apart. At crossing the conduits should not be more than 2 Nos. vertically. Where diameter of conduits exceeds 20 mm, a written approval of such drawings showing their exact position and numbers should be obtained from the Engineer. The same applies to insert for electrical sockets, similar fittings into the concrete members.

Specification for electrical conduits for concrete for embedded items and electrical conduits shall apply except (i) no electrical conduits will be placed in the topping less than 70 mm thick and (ii) where conduits are required to be placed in toping, they shall be placed in size not exceeding 20 mm before placing reinforcement to topping i.e., below the reinforcement on top of the concrete blocks.

14.8.5.33. Notes concerning measurements and pricing concrete work

The contractor must allow for costs incurred during the progress of the Contract for complying with the provisions concerning the preparation and use of specified grades of concrete mixes.

Prices for concrete shall include for mixing and depositing as described or indicated and for hoisting and depositing at the various levels required throughout the building, and shall also include for forming or hacking a satisfactory key for construction joints and for all faces receiving asphalt and plaster work.

Prices for slabs shall also include for leveling of the surface as described under “compaction”, and all temporary formwork to form construction joints at bay edges.

Prices for reinforced concrete shall, in addition, include for filling into, between or on formwork and thoroughly compacting between and around rods or fabric reinforcement and for forming all addition construction joints between varying mixes. Where described as vibrated, prices must include for fully vibrating as described.

Formwork (use and waste only) is measured net to the actual face of the concrete to be supported and the prices for formwork shall include for extra material at joints, extra labour and waste for narrow widths, small quantities, overlaps, passings at angles, straight cutting and waste, splayed edges, notchings, etc., and for fixing at the various levels including battens, struts, and supports and for bolting, jacking, wedging, casing, striking and removal. Prices for linear items such as boxings shall include for angles and ends. Strutting has been measured at varying levels to slab soffits only and prices for other items include for strutting at any level.

Prices for steel rod reinforcement shall include for all waste in cutting to lengths and all labour in bending and cranking, forming hooked ends, handling, hoisting and fixing in position and for providing all necessary tying wire and supports, e.g., steel chairs. Prices for fabric reinforcement shall include for all straight cutting and waste, handling, hoisting and fixing in position, providing all necessary tying wire, and supports, e.g., steel chairs and all extra material in laps. Prices for steel rod reinforcement shall include for lengths up to and including 12 metres. Prices shall include preparation of bending schedule and calculation. of weights from reinforcement drawings, submission of the same for the Engineer's approval before commencement of their placing into works.

The prices for post tensioning work shall include tendons, ducts, and vents, anchorages, their assembly/installation, stressing operations, grouting of ducts protection of anchorages and all associated works required by the specifications/drawings/contract documents and as necessary to complete the post-tensioning work. (In the case of post-tensioning with unbounded tendons, provision of ducts and vents and their grouting are not required). Prices shall include for all wastes in cutting to required lengths and for handling, hoisting and fixing in position including all necessary tying wires, spacers, chairs, and the like.

For calculation of increased costs due to change in prices of reinforcement bars, the wastage to be allowed for calculation will not be greater than 4% for bars up to size of 12mm and 6% for bars of sizes above 12mm, both of the weights measured from the schedule of reinforcement.

14.8.6. Specifications for Roadworks

14.8.6.1. Site Clearance

Clearing site shall consist of clearing the ground of trees, bushes, hedges, shrubs stumps, loose boulders, piles of boulders and other objectionable material excluding soil and rock. It shall include disposal by burning, burying or carting to tip.

14.9.6.2. Removal of Topsoil and Roots

The whole area of the works shall be cleared completely of all roots, grass and vegetable soil irrespective of depth. The Contractor must assume an average depth of 225 mm of topsoil will require to be moved I this operation.

Selected topsoil shall be stockpiled on site and retained for use in verges and side slopes where indicated on the drawings.

The remainder shall either be carted away to tip or shall be neatly spread, leveled and finished off as directed by the engineer.

14.8.6.3. Protection of fences, Trees and Hedges etc.

All existing paths, fences, walls, hedges, trees, shrubs, lawns and other features which the Engineer instructs shall not be removed or otherwise dealt with shall be protected from damage and upon completion of the works shall be handed over in a proper state to the satisfaction of the Engineer.

When fences, walls and other structures are damaged by the contractor they shall be made good at the Contractor's expense to the satisfaction of the Engineer.

14.8.6.4. Setting out

Before starting work the contractor shall set out the road centerline with temporary markers every 20 metres and at the horizontal intersection point.

Permanent pegs outside the working area should be established as follows:

(a) Pegs at both sides of the road at right angles to the centerline at each 20m station, from which the centerline station point can readily be obtained at any time.

(b) Reference marker pegs from which the horizontal intersection point can readily be obtained.

(c) Temporary pegs shall also be established at the limit for stripping topsoil.

(d) Temporary pegs should be 12 mm diameter mild steel rods at least 600 mm long with about 200 mm left projecting above ground.

(e) Permanent pegs shall unless otherwise agreed by the Engineer, be 450 mm mild steel rods 12 mm diameter set in concrete at least 300 mm deep by 250 mm diameter. The steel rod should be projecting about 20 mm above the concrete. The station and distance from the centre line should be clearly marked to be the Engineer's satisfaction.

(f) Before starting the works the Engineer shall check and agree the setting out and the level of the existing ground with the Contractor.

(g) All permanent marks shall be carefully preserved so that the work can be checked at any time.

(h) Permanent bench marks shall be established in suitable positions and agreed with the Engineer. These should be maintained so long as they are needed to check the work.

14.8.6.5. Measurement and Payment

- Site clearance will be paid as a lump sum as inserted in the bill of quantities and the lump sum shall include the cost of disposal in accordance with the specification.

- Removal of top soil will be measured per square metre.
- Setting out- No separate payment will be made for any work in connection with the Contractor's basic and detailed setting out or any other works required to ensure that the accurate location and construction of the works.

14.8.6.6. Drainage of works

All cuttings, embankments and borrow pits shall be kept free of standing water and drained during the whole of the construction.

Should water accumulate on any part of the earthwork either during construction or after construction until the end of the maintenance period, giving rise to soaking or eroding conditions in the earthworks, the Engineer may order the contractor to remove and replace at the Contractor's expense any material which has been so affected.

All drains shall be maintained throughout the Contract in proper working order. Well in advance of commencing earthmoving operations over swampy or waterlogged areas, the Contractor shall cut drains and ditches and carry out any other works as are necessary to assist in draining the ground.

The contractor must allow in his rates for drainage the earthworks satisfactorily at all stages during the construction and arrange his methods and order of working accordingly. No work above the subgrade shall be executed until the subgrade has been inspected and approved by the Engineer.

14.8.6.7. Excavation

Excavation shall be completed to the lines and level shown on the drawings. Excess excavation below the levels shown on the drawings shall be avoided. Excess excavation shall not be paid for and the Contractor shall at his own expense reinstate and make good with approved material thoroughly compacted in layers not exceeding 200mm thick to a density of not less 95% BS Heavy M.D.D.

14.8.6.8. Ground Water

The Contractor shall keep dry by pumping or other approved means all excavations and trenches for as long as directed by the Engineer.

Dewatering of excavations will not be paid for as an extra.

14.8.6.9. Excavated materials

All excavated material shall either be used for fill (if approved by the Engineer) or disposed of (spoil) if in the opinion of the Engineer, it is unsuitable for incorporation in the works.

14.8.6.10. Ground to be inspected before filling

Before any fill is commenced, the Engineer shall inspect the area. The Contractor shall inform the Engineer of either soft spots or underground seepage encountered. The Engineer shall order and give details of any subsoil drainage where required.

The subgrade shall be cleaned of all foreign matter and any potholes, loose material, ruts, corrugations, depressions or other defects which have appeared in the subgrade layer due to improper drainage, traffic or any other cause shall be corrected and if directed by the Engineer, the Contractor shall scarify, grade and recompact the subgrade to line and level at his own expense.

14.8.6.11. Materials for embankment and fill

Two types of materials shall be considered.

1) Material for construction of main body of embankments which shall have a plasticity index of not more than 30% and contain boulders not greater than 250mm maximum dimension.
2) Selected materials for the construction of the top 30cm of the embankment or for filling areas from where unsuitable material has been removed.

(a) The plasticity index shall not be more than 25%.

(b) The maximum size of boulders not greater than 100mm.

(c) CBR value after 4 days soaking at 95% B.S Heavy M.D.D shall be not less than 10%. The CBR specimen shall be prepared at B.S Heavy OMC +2%.

(d) Swelling not more than 1%.

14.8.6.12. Filling and compaction of embankments and Fills

Materials for constructing the embankments shall be approved fill material obtained from the excavations, cuttings and approved stockpiles or borrow pits. Embankments shall be constructed in layers parallel to the final road grade. The compacted thickness of layers of fill material shall not exceed 300mm and shall not be less than 100 mm. Rockfill may be used in the bottom layers of the embankments and each layer should not exceed 600mm in thickness. The maximum particle size in a layer of fill shall not have any linear dimensions greater than 150 mm for normal fill material and 400 mm for rockfill.

The top 600 mm embankment shall consist of normal material and not rock. Where rock has been placed below this layer, the Contractor shall blind each layer of the rock with approved fine material to prevent later downwards percolation of fine particles from the upper layers and the whole layer then compacted by an approved method. More fine materials shall be added and the layer again and compacted until the voids are then completely filled.

Where directed, the contractor shall excavate benching on natural side slopes greater than 1 in 3 steps not less than 3m wide prior to the construction of embankments. The existing slopes shall be benched by cutting steps at right angle to the slope as directed by the Engineer. The material so excavated shall be used as fill material for forming embankment or carted to spoil as directed by the Engineer. All fills shall be compacted to a density of 95% BS Heavy Compaction at ± 1% to -2.5% of optimum moisture content for the full design width and depth. In addition, the top 300 mm of fill shall be compacted to 95% BS Heavy Compaction at ± 1% to -2% of optimum moisture content for the full design width.

In tipping and forming the embankments, the contractor shall make allowance in the height and width of these for consolidation and shrinkage. On completion of the Contract, the dimensions of the embankments shall be to the profile shown on the drawings and the necessary allowance being made for the surface finish. No sand slurry, mud, peat, organic, soft or otherwise unsuitable material, shall be placed in embankments.

14.8.6.13. Unsuitable material in Subgrade

Where, in the opinion of the Engineer, material unsuitable for the direct support of the pavement occurs in cuttings, the Contractor shall excavate it to the depths and widths directed and replace it with selected fill material or hardcore material not exceeding 200mm in size to form an improved subgrade. The work will be paid for at the appropriate rates of “spoil” and “fill” and no additional payment will be made.

14.8.6.14. Subgrade Compaction

The top of the subgrade in both cuttings and embankments shall be compacted to 95% B.S Heavy M.D.D unless directed otherwise by the Engineer.

The maximum compacted thickness in the top layer of the subgrade shall not exceed 200mm. The layer shall be scarified and mixed. Water shall be mixed in, or the material allowed to dry out to within +3% to +1/2 % of the optimum content before rolling.

Rolling shall include a minimum of 4 passes of a 10-ton vibrating roller, and rolling shall be continued until no further movement is visible under the roller wheels.

During this process the surface shall be graded parallel to the cambered road surface indicated on the drawings.

Tolerances

a) The following tolerances will be permitted in the levels of the upper surface of the top of subgrade layer:

Table 14.6: Tolerances in levels of upper surface of the top subgrade layer

Name	Variation permitted		
	Level (mm)	Camber (mm)	%Grade in 30m

Top of subgrade layer	+0mm -60mm	+0mm -30mm	0.1

b) in the final trimmed slope of cuttings, a tolerance of 1/8 will be permitted, i.e. if the slope of 1 in 2 is specified, the acceptable slope shall be not steeper than 1 in 1 78/8 or slacker than 1 in 2 1/8, and the rate of change of slope not be greater than 1/8 in 50m.

c) in the final trimmed slopes of embankments, a tolerance of plus ¼ only will be permitted, i.e., if the specified slope is 1 in 2, the acceptable slope shall be not steeper than 1 in 2 or slacker than 1 in 2 ¼, and the rate of change of slope shall not be greater than ¼ in 30m.

d) The tolerance permitted in the overall width of the bottom of cuttings shall be 75mm in the distance between the centre line of the road and the toe of the cutting slope.

e) The width of embankments measured as the distance from the centre line of the road to the top of the embankment, shall be never less than the design width.

The contractor shall be paid for the net volume of the earthworks measured from the standard cross-sections and the original ground levels. Any additional material excavated or filled within or beyond those tolerances will be at the Contractor's expense.

14.8.6.15. Measurement of earthworks

Prior to construction of any earthwork or excavation the levels of the existing ground shall be agreed between the Contractor and the Engineer. If the Contractor fails to take the requisite level, then the ground levels shown on drawings or determined by the Engineer shall be taken as correct. All excavation for earthworks for road cuttings and embankments will be measured as the net volume in cubic metres of the compacted embankments as measured off the cross-section drawings, called "fill", and the net volume of the spoil heaps measured from ground levels before spoiling and ground levels after spoiling, called "spoil".

If a cutting is over excavated, then the volume of overcut measured in cut when compacted to the standard cross section, shall be deducted from the volume of spoil as measured.

14.8.6.16. Compaction standards

The terms used for compaction shall be ascribed to them the meaning given in British Standards B.S. 1377 Part I, General.

The standard of compaction used throughout the work shall be the British Standards test as described in B.S. 1377, Part 4. Wherever the text of the specification the "X% B.S. Compaction" is used, it shall mean a standard of compaction such that the dry density of the compacted material is X% of the maximum dry density ascertained from the aforementioned British Standard Compaction Test.

14.8.6.17. Hand Packed Hardcore Sub-base

Just prior to placing of hard core, rock sand shall be evenly spread on the prepared subgrade and rolled with a 10 ton roller for at least 2 passes to give a compacted layer of 50mm thickness.

The stones shall then be positioned by hand with the greatest dimension vertical and the largest and flattest end downward. The larger stones shall have a maximum dimension slightly greater than the required thickness of the compacted layer. The smaller stones shall have a reasonably uniform grading and be of a nominal size suitable, in the opinion of the Engineer, for filling the surface voids in the larger stones as placed.

After placement of the stones in the specified manner the material shall be initially compacted with a 10 ton roller or an equivalent 1½ to vibratory roller until the layer is thoroughly keyed and the compacted layer contains no more than 10% void. Rock sands shall then be spread and broomed into the interstices and rolling shall continue until no more fines will go in to give a homogeneous compacted layer of sub-base. Sprinkling of water to enable rock sand to go in shall be to Engineer's approval.

The irregularities that may show up during compaction shall be corrected by loosening the surface and removing or adding material as may be required, and recompacting. Samples of the compacted layer will be excavated to check on the density and void content achieved.

Hardcore shall consist of clean broken basaltic stone of size not exceeding 150mm free from an excess of flat or elongated particle, clays, loam, topsoil, or other deleterious matter. Hardcore shall comply with the following:

- Aggregate crushing value: not greater than 40%
- Los Angeles Abrasion Value: not greater than 65%
- Plasticity index: On product of Los Angeles test not greater than 12.

14.8.6.18. Crusher Run Base Course

Crusher Run Material

The crusher run shall be made from approved blue basalt rock and shall contain particles that are roughly cubical in shape and free from excess of flat or elongated particles or clay, topsoil, or other deleterious materials and shall be to the Engineer's approval.

Grading of Crusher Run

The crusher run for base and sub-base shall conform to the following grading Table 13.9 below:

Table 1.7: Grading of Crusher Run

Nominal Size of the Sieve (mm)	Percentage passing by Weight	
	0-31.5mm	**0-20mm**
50	100	-
31.5	92-100	100
20	78-91	90-100
10	56-76	60-80
6	42-64	45-64
4	36-55	36-54
2	25-42	25-40
1	17-30	17-49
0.5	10-21	12-21
0.08	3-8	5-8

The Los-Angeles value shall not exceed 32 for 0-31.5 mm and 30 for 0-20 mm.

The sand equivalent value shall be more than 50 for 0-31.5 mm and 60 for 0-20mm.

The flakiness index shall not exceed 40%.

All the material shall be non-plastic.

Note: the frequency of testing shall be at least:

- Sieve analysis: 1 per day
- Sand equivalent: 1 per 500m³
- Log Angeles: 1 per 2500 m³

Where the crusher run material is deficient in fine aggregate, and in the opinion of the Engineer the Contractor has made every reasonable effort to produce the required grading, the Engineer will allow admixing of crusher fines.

The percentage of added fines will be decided by the Engineer, and shall in any case not exceed 15 per cent by weight of the mixture. The plasticity index of fines shall not be greater than 6 and the liquid limit not greater than 20.

No extra payment will be made for providing and mixing in of such fines.

Mixing and spreading

Every reasonable effort shall be made to prevent segregation after mixing and during the dumping and spreading operation.

Where the addition of fine materials is necessary it shall be thoroughly mixed in with the crusher run aggregate before the introduction of any water that might be required.

Water shall be added as necessary so that compaction of the spread material is carried out within the range of -2% to 1% of the optimum moisture content.

The batching and mixing plant and method of operation shall be to the Engineer's approval.

Upon completion of mixing, the material shall, without delay, be spread by approved mechanical means.

The crusher run shall be laid and compacted in layers not exceeding 200 mm. Where a greater depth is required, the material shall be laid in two or more layers.

Compaction and Slushing

As soon as possible after spreading each layer, compaction shall be carried out. During compaction, care shall be taken to maintain the moisture content evenly at the required amount. The main compaction shall be carried out with either a power driven three-wheel roller weighing not less than 10 tons or a vibratory roller approved by the engineer. Compaction shall be continued until:

The specified density is achieved when measured by a Nuclear Moisture/ density gauge (Type ELE-CPN Nuclear gauge or MC3 Portaprobe moisture/density gauge or approved equivalent), or other approved mean.

And

The compacted pavement layer contains not more than 15% voids for road base, or 20% voids for sub-base. Voids being air voids plus voids filled with water.

Rolling shall be carried out in a longitudinal direction and shall commence from the outer edges of the road and progress inwards towards the centre except that on super elevated curves, rolling may progress from the lower to higher edge.

Any irregularities that show up during rolling shall be corrected by loosening the surface and removing or adding material as required.

After the main rolling, each layer shall be saturated with water, slushed and rolled until all excess fines have been brought to the surface and the surface shows a tightly bound mosaic of stones and no appreciable movement is visible under the wheels of a roller. Any patches of voids shall be filled by loosening up the layer and grouting with screenings approved by the Engineer.

Drainage of Crusher Run Base

It is essential to provide free drainage paths maintained in good working order so that water passing through the crusher run layers can drain away.

Any soft spots which subsequently appear in the subgrade due to moisture accumulation shall be removed together with the overlying layers and replaced the required standard at the Contractor's expense.

Tolerances in Crusher Run Layers

The thickness of the crusher run layer shall not vary by more than 0 mm or ±10 mm.

The final surface of the crusher run layer shall not vary by more than ±6 mm from a 3 m straight edge.

14.8.6.19. Prime Coat

Priming of surface

Before priming, any surplus fines and loose or foreign material shall be brushed off or otherwise removed to reveal a closely knit compact mosaic of stones (to be approved by the Engineer)

Priming shall be applied by a pressure distributor of a type approved by the Engineer. Hand spraying shall not be permitted except for small areas where approved by the Engineer, or to make good a defective area left by a blocked nozzle.

The primer shall be medium curing cut back bitumen M.C.30 or other approved binder.

The rate of spray will depend upon the texture and density of the surface but will usually be in the range of 1.0 to 1.3 Kg/m^3. The quantity must give complete coverage of the surface with a slight trace of run off in places. Should the contractor find that when using the rate of spray directed by the Engineer, the coverage is inadequate, or there is too much run-off, he shall immediately inform the Engineer, and amend the spray rates as directed by the latter.

Before the spraying is commenced the apparatus shall be tested on a clean metal sheet. Spraying shall not commence if any nozzle is not working properly.

Spraying shall be discontinued immediately in case any nozzle becomes defective and the defective patches made good by hand spraying.

During spraying, all kerbs, road furniture, curlverts headwalls and the like shall be protected from splashing of bitumen. Any such feature which is accidentally marred by bitumen shall be cleaned off or made good at the Contractor's expense.

Curing of Prime Coat

The prime coat shall be allowed to dry out before anything is allowed to pass over the surface. Where the primer puddles, the surplus shall be blinded with sand or quarry dust until the free bitumen is absorbed. Forty-eight hours after priming, the Engineer may permit pneumatic-tyred vehicles to run over it, provided the surface is lightly sanded or dusted where necessary to prevent adhesion of the bitumen to the tyres. Such use of the surface is to be discouraged and may only be undertaken on the express written instruction of the Engineer.

Any repriming or other reinstatement that become necessary as a result of the Contractor allowing traffic to run over the primed surface, shall be carried out at the Contractor's expense.

The prime coat surface shall be approved by the Engineer before any laying of premix commences.

14.8.6.20. Tack Coat

A tack coat shall be applied between the bituminous base course and wearing coarse or in the case of resurfacing works between the existing road surface and the reshaping course and between the reshaping course and the wearing course. The new tack coat may also be ordered by the Engineer at the Contractor's expense if the coated surface becomes contaminated by the action of traffic and weathering. The surface of the length to be tacked shall be swept clean of all loose particles and dust with a mechanical broom immediately prior to the application of the tack coat which shall comprise either R.C. 70 or rapid setting, bituminous emulsion applied at the rate of 0.5L/m².

14.8.6.21. Heating of Bitumen and Safety Precaution

Bitumen shall be heated in approved boilers or storage containers equipped with adequate pumps and accurate thermometers to the temperatures within allowable limits for each penetration grade.

Table 14.10: Heating Temperature of Bitumen

MATERIAL	TEMPERATURE °C	
	MINIMUM	MAXIMUM
Penetration Grade 60/70 and Grade 70/80	160	180
M.C.O (M.C.30)	35	65
M.C.I (M.C. 70)	45	85

No bitumen shall be heated above the maximum temperature given above, and any that is accidentally over-heated shall be removed from the site and disposed of by the Contractor at his own expense.

The Contractor should take every reasonable precaution to avoid fire or health hazards while heating and handling bitumen

14.8.6.22. Construction Limitation

No bituminous construction work will be permitted during adverse weather conditions or whenever so directed by the Engineer.

14.8.6.23. Surface Dressing

Materials for surface dressing

The chippings used shall be approved basalt nominally single sized, free from dust and having a flakiness index not exceeding 35% and complying with grading requirements of B.S. 882.

Rate of spread of chipping

The rate of chippings applied must be sufficient to cover the entire surface of the binder film after rolling. The recommended range which depends on the shape, size, specific gravity as well as the traffic density is given below.

Table 14.11: Rate of Spread of Chipping

NOMINAL SIZE OF CHIPPINGS (mm)	RATE OF APPLICATION (Kg/m²)
6	6-8
10	9-12
14	12-15
20	15-20

Rate of application of Binder

The amount of binder required depends on the size of chipping, the shape and absorbency of the chipping, the absorbency of the road surface. Typical rates of spread of binder lie in the range of 0.9 to 1.5 l/m². The Engineer may, from time to time, direct the Contractor to vary the rates of application, and the Contractor shall allow in his price for such variation in application.

Application of bitumen

The surface having been primed must be thoroughly brushed and lightly sprayed with water. Any defect in the primed surface must be rectified by patching with a mixture of fine chipping and bituminous emulsion.

Bitumen shall be sprayed mechanically by means of an approved pressure distributor having an automatic control of the rate of application such that spraying is uniform whatever the running speed. The distributor must contain a temperature gauge and it is essential that the correct temperature is maintained during application. All road furniture, kerbs culverts, etc. must be protected from splashing of bitumen.

Application of chippings and Rolling

Chipping shall be spread immediately after application of binder by mechanical means or an approved "spreader box" mounted on a tipping lorry and adjusted as to rate of delivery and lorry speed to give the rate application specified. Immediately after application of the chipping, the surface shall be rolled so that the whole area receives at least one pass within five minutes of the bitumen being sprayed. Immediately after initial rolling, any area deficient in chipping shall be made good by hand spreading. Brooming of material to effect redistribution will not be permitted. The rolling shall recommence at the shoulders working inwards to the centre of the road. A minimum of 5 passes shall be required. Pneumatic tyred rollers are preferred for initial rolling of all surface dressing work although the Engineer may approve smooth steel wheeled rollers of 2-6 tons equipped with approved devices for moisturing the tyre surface.

As soon as the chippings are firmly anchored in the bitumen, rolling should be discontinued. At the Engineer's discretion, the application of the second coat in double seal coat work may be delayed. If this is done, the first coat must be brushed, cleaned, and patched as necessary before the second coat is applied. After the application of chippings, the contractor shall maintain labour to sweep loose chippings back on to worn tracks on the road for a period of 2 weeks, or longer if ordered by the Engineer. Thereafter, surplus chippings ("whip-off") shall be removed and may if sanctioned by the Engineer, be re-used.

Single surface dressing

Where single surface dressing is specified the rate of application of binder shall be 0.9 to 1.1 l/m² and 10 mm nominal size of chipping shall be spread at a rate of 9-12 kg/m² and rolled as specified. These average rates will be adjusted on site as directed by the Engineer.

Double surface dressing

Bitumen shall be applied at the rate of 1.0 to 1.2 l/m² on the primed surface and 20 mm nominal size of chipping shall be spread and rolled as specified. The second application of binder shall be at the rate of 1.2 to 1.4 l/m² and shall be followed by spreading of 10mm nominal size chipping. The surface shall be rolled with 6-10 passes of pneumatic tyred roller.

14.8.6.24. Asphaltic Concrete

General

The bituminous surfacing to be used is a mixture of dried, hot aggregate and hot straight run bitumen. The mixture is designed in accordance with this Specification, which makes provision for the use of aggregate of pre-determined grading, together with adequate bitumen to meet the specified strength and stability criteria.

The bitumen binder shall be of grade 80/100 penetration unless otherwise ordered in writing by the Engineer.

Aggregate

The aggregate for asphaltic concrete shall consist of crushed rock.

The aggregate shall be of approved homogeneous stone free from harmful material with an aggregate crushing value of less than 25% and the loss after 5 cycles of the Sodium Sulphate Soundness test less than 12%.

Coarse aggregate for bituminous materials (wearing course and base course) shall be obtained from approved source of homogenous stone, free from harmful material, and shall consist of crushed rock of 37.5mm minimum size prior to crushing.

The aggregates shall be obtained by mixing 3 classes D/d of materials defined for each class by the maximum size (D mm) and minimum size (d mm) of particles.

Dimensions D and d will be chosen in the following series of sieves sizes: 2-6.3- 10-14-20-25.

Before the work starts, the Contractor shall submit to the Engineer's approval, the grading curve of reference for each class of material.

The grading curve of reference shall satisfy the following requirements:

(a) Percentage by weight of material retained by sieve D mm shall not be more than 10%.

(b) All material shall pass sieve 1.25 D mm.

(c) Percentage by weight of material passing by sieve d mm shall not be more than 10%.

(d) All material shall be retained by sieved 0.63 d mm.

(e) Percentage by weight of material passing sieve (D=d) divided by two mm shall be within the range 33-67%.

The total variations, by percentage, around the grading curve of reference for each class of material such as proposed by the Contractor at the commencement of work shall not exceed the following values for pavement course (wearing course and base course)

Table 14.12: Percentage variations around the grading curve for pavement course

Nominal size of the Sieve (mm)	Percentage by weight passing	
	Wearing Course	Base Course/Reshaping
25	-	100
20	-	95-100
16	-	91-99
12.5	100	75-91
10	94-100	51-79
5	51-63	38-57
2	32-42	23-38
0.6	16-23	10-19
0.08	7-9	5-7

Clean, cubical, moderately sharp natural sand consisting of grains of quartz or other durable rock free from a coating of any injuries material and also free from clay, loam, organic matter, may be used with the approval of the Engineer to replace all or part of the aggregate smaller than 2.35 mm B.S test sieve. Rounded sands will only be permitted with the approval of the Engineer to replace up to half the aggregate smaller than 2.36 mm.

Filler

The filler for asphaltic concrete shall be defined as the material passing the 75 micron B.S Sieve.

For base course asphalt the rock dust filler shall not exceed 2% by mass of the total aggregate including filler. The remainder of the filler shall be mineral filler. For wearing course asphalt the rock dust filler shall not be varied once the design mix has been approved without the consent of the Engineer.

Mineral filler for asphaltic concrete shall be ordinary portland Cement to B.S. 12 or rock dust. At least 75% by mass shall pass the 75 micron B.S. test sieve and the bulk density in toluene shall not be less than 0.5 g/ml and not more than 0.9 g/ml as measured in accordance with B.S. 812.

Asphaltic concrete Gradings

The Grading of the combined aggregate and the filler shall be a smooth curve within and approximately parallel to the approximate envelope limits given in paragraph (2) above.

If in the opinion of the Engineer the available aggregate is such that adhere to one or all of the above grading envelopes means that the specified mix properties cannot be satisfactorily obtained, then the Engineer shall issue revised gradings to replace those given above.

Absorptive Aggregates

Where aggregates have water absorption in excess of 1% as measured in accordance with B.S 812, some absorption of bitumen will occur that will affect the voids in the mix. In this case, the voids in the mix and voids filled with bitumen are to be calculated using the specific gravity of the coated uncompacted mix determined in accordance with ASTMD 2041.

Mix requirement

The working mix shall comply with the following requirements for the Marshall Stability Test ASTM D 1559 based on 75 blow compaction of the specimens.

Table 14.13: Working Mix Requirement

Name	Requirement Name Base	Wearing Course
Marshall stability at 60ºC	800kg	1100kg
Flow Value	2mm- 4mm	2-4mm
Voids in Mixed Aggregates	14-18%	6-20%
Voids in Total Mix	3-8%	3-5%
Voids filled with Bitumen	66-77%	70-80%

Job Mix formulas

The contractor shall carry out trial mixes to determine then job mix at least 30 days before production of bituminous mixes is started and as soon as possible after commencement of aggregate production.

The contractor shall submit for the approval of the engineer the job mixes formulas and results of the tests carried out on the trial mixes including the results of tests carried out at ranges of bitumen content from below the proposed bitumen contents of above. Specimen tests on each asphaltic content shall be made in quadruplicate.

Mixing plant

Asphaltic concrete shall be prepared in a central mixing plant conforming to requirements of ASTM designation D995 which shall be capable of and operated so as to produce a mixture within the Job Mix Formula.

Preparation of Aggregates

Aggregates shall be furnished in at least three sizes. Each type of aggregate as delivered shall be stockpiled separately. Where cold feeder bins are used, each fine aggregate shall be placed in a separate bin, or, should the number of aggregate types being used make this impossible, the fine aggregates shall be thoroughly blended in such a manner and in such proportions as approved by the Engineer prior to being placed in the feeder bin. Aggregates shall be handled and transported between the crushing and screening plant and the stockpiles and the dryer, by plant and methods which shall ensure that segregations does not occur and that moisture content variations are not large enough to affect the uniformity of the temperature of heated aggregates at entry to the mixer. Aggregates shall not be permitted to roll down the slopes of stockpiles in either placing or feeding the dryer.

Stockpile layer of aggregate with moisture contents differing sufficiently to affect the uniformity of the said temperatures shall not be worked simultaneously. The mechanical feeders shall be adjusted to provide delivery of the desired proportions to the dryer. The aggregate shall be heated and thoroughly dried before entering the hot-bins such that the moisture content of the aggregates, determined as it enters the mixer shall be such that the temperature of the finished mixture will be within the tolerance specified. The heated and dried aggregate shall be separated into at least three sizes as approved by the Engineer. Filler shall be stored and batched separately and may not be heated.

Preparation of asphaltic Concretes

The aggregate without filler, prepared as specified above, shall be accurately weighed, and conveyed into the mixer in the proportionate amounts of each aggregate size required to meet the Job mix. The required amount of bitumen for each batch shall be introduced in the mixer. In batch mixing, the bitumen shall be added after the aggregates have been introduced into the mixer and mixed for 5 to 10 seconds.

The filler shall be added after the bitumen and mixing shall continue after the addition of filler for at least the length of time recommended by the manufacturer or such longer time as is necessary to ensure adequate coating of aggregate and uniform distribution of filler. The plant shall both be operated at a higher production rate than the manufacturer's rated capacity.

Bitumen shall be heated to enter the mixing chamber at a temperature such that its kinematic viscosity is in the range of 150 to 300 centistokes. At no time shall bitumen be heated in excess of 180ºC and any that is so heated shall be removed from site at the Contractor's expense. The aggregates, excluding filler which shall not be heated, shall be heated to enter the mixing chamber at a temperature varying not more than 150 ºC from that of the bitumen. The temperature of the aggregate and bitumen shall be chosen within the above limits and having regard to the prevailing air temperature and haulage distance to ensure that the temperature of the mix is between 120ºC and 200 ºC shall be provided in the bitumen heating tank and for use in the mixing chamber or at its discharge point. Thermometers for observing air and surface temperature between 1 ºC and 66 ºC and for observing mix temperatures between 93 ºC and 180 ºC shall be provided at each laying point.

The volume of the aggregate and bitumen shall not be so great as to extend above the tips of the mixer blades when the blades are in a vertical position. All overheated and carbonized mixtures, or mixtures which foam or show indication of moisture will be rejected. When moisture is detected in the finished mixture all aggregates in the bins shall be removed and returned to stockpiles.

Transport of mixture

The mixed materials shall be transported from the asphalt plant to the site of work in trucks having clean, tight smooth bodies which shall be treated to prevent adhesion of the mixture.

Soapy water or lubricating oil may be used for coating of the bodies; gasoline, kerosene or other solvent shall not be used for this purpose.

The bodies of the truck shall if required by the Engineer be covered and insulated to maintain the heat loss within the requirements.

Laying of Mixture

Immediately before placing the mixture, the existing surface shall be cleaned of all loose and deleterious materials. The speed of the approved mechanical paver shall be regulated to eliminate pulling or tearing of the mix during placing. The temperature of the mixes measured in the receiving hopper of the asphalt paver shall not be lower than 130 ºC. Mixes which have lower temperature shall be discarded.

The 150mm width of strip along the edge adjacent to the area on which the succeeding lane will be placed shall be left unrolled until the adjacent lane is placed. After the preceding lane has been compacted, the adjacent lane shall be placed, finished and compacted a for the preceding lane, except that the rolling shall be extended to include the 150 mm width of strip not previously compacted.

The contractor shall so arrange his work that all adjacent lanes over any section of the road being surfaced are placed, compacted and finished off the same day. At joints with existing compacted bituminous surfacing, whether it is new or old, the edge of the existing surfacing along the joint shall be neatly cut away in straight lines over a sufficient width to ensure full specified thickness of new surfacing being placed and the exposed edges in the existing work shall be painted with hot bitumen immediately in advance of placing the new work.

If for any reason, the pave should drift away from an adjacent lane during construction, the unfilled space so made shall be carefully filled with fresh hot mixture obtained from the hopper of the pave or from the truck. Stealing mixture from that already spread to fill up those areas will not be permitted.

In limited areas, where the use of mechanical spreading and finishing equipment is impractical, the mixture may be spread by hand. When hand spreading is permitted, the mixture shall be dumped on metal sheets outside the areas by means of hot shovels. The mixture shall then be spread by means of hot rakes using the back of the rake for distributing the material and reducing the amount of raking to a minimum in order to avoid segregation of the various size of aggregate in the mixture.

Any fresh mixture spread accidentally on the existing work at a joint shall be carefully removed by brooming it back on to uncompacted work, so as to avoid formation of irregularities at the joint. The finish at joints shall comply with the surface requirements and shall present the same uniformity of finish, texture and density as other sections of the work.

Any defects in the surfacing work, caused by faulty workmanship, shall be corrected and made good by the Contractor at his own expense and to the satisfaction of the Engineer. Care shall be exercised at starting and stopping of the paver to prevent the formation of lumps and depressions.

Compaction of mixture

Roller operators shall be fully trained and experienced men. Immediately after spreading, the mixture shall be rolled with an 8-10 tons smooth steel wheeled rolled or a pneumatic tyred roller. All rolling shall be longitudinal and shall commence at the outer edges of the road. The layer shall be compacted while the mixed materials temperature is within 130 ºC to 115 ºC. The roller shall be driven so that the driven wheels are closest to the spreader and all steering shall be carried out when on compacted material. Rolling shall continue until the surface is of uniform texture and density, free from roller wheel marks, and true to grade and cross-section. Rolling speed should be about 3km/hr. the roller wheels shall be clean and smooth and to prevent adhesion of the mix the wheels shall be kept moistened with water, but an excess of water will not be permitted. At all places not accessible to the roller, the mixture shall be thoroughly compacted with hot hand tampers. Hand tampers shall weigh not less than 12 kg and shall have a tamping face of not more than 0.03 m^2.

Any mixture which does not comply with the specification or is in any way defective shall be immediately removed and replaced with fresh hot mix which shall be immediately compacted to conform with the surrounding area, all at the contractor's expenses. Skin patching on a rolled area will not be permitted.

The voids ratio in the compacted layer shall be in the range of 2% to 4% in footpath, 3%-6% for the road wearing coarse and 3%-8% for the base coarse. The density shall be more than 97% of the density determined in the Marchall Test.

The roller must never be allowed to stand on freshly laid premix.

Trial Area

The contractor shall arrange for a trial area of bituminous concrete to be laid in an area to the required thickness using the plant and methods to be used for the permanent surfacing to the full width normally produced by the plant and not less than 50m long. Samples shall be taken and tested in accordance with this specification from a representative part of the road base, base course, and surfacing where directed by the Engineer.

In case the trial lay fails to meet the design standards, the mix and workmanship shall be adjusted and new trial lays repeated until a satisfactory and specification complying layer is achieved all to the expense of the Contractor.

At the risk of the Contractor the trial area may be laid as part of the permanent work. In that case any layer proved by tests to be defective shall be removed by the contractor at his own cost. The Contractor shall allow for the cost of complying with the above in his tender.

Joints

Transverse joints in the wearing curse shall be offset at least 500 mm from those in the base course. Longitudinal joints shall be offset at least 150mm. At transverse joints between existing compacted surfacing and newly laid surfacing, the edge of the existing surfacing along the joint shall be neatly cut away in straight lines over sufficient width to ensure that the full specified thickness of new surfacing is placed. The exposed edge in the existing work shall, if directed, be painted with hot bitumen immediately in advance of placing new work. Where the bituminous layers are laid in half widths, the longitudinal joints between them shall, if directed, be treated similarly to the transverse joints.

Dimensional tolerances

The finished surface of the premix wearing coarse shall be true to line, grade and cross-section and when tested with a 3m long straight edge applied parallel to the centre-line of the road and when tested with a crown template or camber board conforming to the specified cross-section applied at right-angles to the centre line of the road, the variation of the surface from ach testing edge, between any two contacts with surface, shall at no point exceed 4 mm.

Any irregularities exceeding such specified tolerances shall be suitably corrected by the contractor at his own expense until these requirements are met. Corrective work shall be carried out in such a manner as to blend in colour, texture and finish with adjacent work.

The thickness of any layer of premix shall at no point be less than the specified thickness.

Extra payment shall not be made for layers thicker than that specified.

Working mix Tolerance

When the Job Standard Mix is approved by the Engineer, The Contractor shall maintain the composition of the working mix within the following tolerances from the Job Standard Mix.

Bituminous binder:
Design mix +0.1 to -0.2% by mass of total mix

Aggregate retained on 5 mm B.S. Sieve:
Design mix ±4% by mass of total mix

Aggregate passing 5 mm B.S. Sieve but retained on 75-micron B.S. Sieve
Design mix ±3% by mass of total mix

Aggregate passing 75-micron B.S. sieve
Design mix ±1.5% by mass of total mix

The bituminous concrete shall be checked periodically and when ordered by the Engineer and shall comply with the above specified requirements.

Defects

Any defects in the asphalt work caused by the faulty workmanship shall be corrected and made good at the contractor's expense. Care shall be taken where starting and stopping the paver to prevent the formation of humps and depressions. Skin patching of an area that has been rolled will not be permitted. Any mixture that becomes mixed with foreign material or is in any way defective, shall be removed and replaced with fresh material and compacted as specified.

Preparation of Existing Bituminous surface prior to resurfacing works

Before any resurfacing operation, the existing bituminous surfaces shall be repaired where required by the Engineer.

Potholes and trenches backfilled with unsuitable or unstable material or poorly compacted shall be repaired as follows:

The edges of the hollows shall be neatly cut to a rectangular shape with appropriate tools.

Unsuitable materials shall be excavated to a minimum depth of 20 cm.

The excavation shall be filled in two layers with crusher run 0/20. The first layer shall be compacted as much as possible and the second compacted to at least 97% of B.S. Heavy compaction with a vibrating roller.

Wherever required the crusher run shall be treated with lime. The process of treatment and the rate of application of lime (between 3 or 5%) shall be submitted for the approval of the Engineer. After compaction the surface of repaired area shall not present bump or hollow of more than one centimeter.

14.8.7. Specifications for Drainage Works

14.8.7.1. Drainage program

All drainage work must be carefully programmed to ensure that their completion and incorporation in the works minimizes any temporary drainage work and coincides with the corresponding stages of earthworks, road works and planned temporary and permanent road diversions.

14.8.7.2. Drainage work proposals

Drains shall be of the types shown in the Contract Drawings and as directed by the Engineer.

All channel and drains shall be constructed in the position and to the dimensions shown on the drawings or as may be directed by the Engineer. Precast concrete drains shall be jointed with cement mortar.

14.8.7.3. Excavation

The contractor shall excavate all drainage channels, trenches and foundations for pipes, culverts, cut-off trenches, head and wing walls, etc., to the lines, levels, slopes and dimensions shown on the Drawings or as instructed from time to time by the Engineer.

Excavation for trenches, catch basins, chambers and manholes shall comply with the following requirements:

- Excavation of open side drains in cuttings and alongside embankments shall be considered as earthworks and executed in accordance with the provisions of the relevant part of these Specifications.
- The contractor is advised to fully investigate subsoil conditions where trenches are to be excavated particularly in areas where it is anticipated that unstable materials may be encountered requiring interlocking steel trench sheeting to be provided, and dewatering operations to be carried out.
- If any excavation is effected to a greater depth or width than is necessary, then the contractor shall reinstate, at his own cost, with approved materials, compacted to a density of the adjacent ground, to the correct levels and dimensions to be approved by the Engineer.

- Where, in the opinion of the Engineer, the material encountered in the bottom of an excavation is unsuitable, the Contractor shall excavate additional material to lines and levels indicated by the Engineer and backfill with improved foundation material compacted to 90% BS Heavy Compaction.
- Where, in the opinion of the Engineer, foundation material has become unsuitable due to the Contractor's method of working, the Contractor shall bear all costs arising for complying with the specification.

14.8.7.4. Timbering of pits, Trenches and other excavations

The sides of the pits, trenches and other excavations shall where required, be adequately timbered and supported to the satisfaction of the Engineer, and all such excavation shall be of sufficient size to enable pipes, culverts and concrete to be laid accurately, and compaction of backfill to be carried out properly.

14.8.7.5. Water in trenches

Trenches shall be kept free from water until in the opinion of the Engineer, any concrete or other works therein are sufficiently set, and the Contractor shall construct any sumps or temporary drains that the Engineer may consider necessary.

The Contractor shall make good at his own costs, any damage caused by prolonged and/or excessive pumping and shall take all necessary precautions for the safety of adjoining structures and buildings by shoring or otherwise during the time the trenches are open.

14.8.7.6. Concrete pipes

Measurement of the width of trench for single pipes shall be of diameter of the pipe, plus 500 mm for pipe diameter up to and inclusive of 1metre diameter.

Pipes shall conform to BS and shall be precast and delivered to site in 1metre length or such other lengths approved by the Engineer. The date of casting of the pipe shall be painted on the barrel. All pipes shall be capable of supporting a test load of 2010 Kg per metre run for 1 minute without sign of cracking or other sign of distress or failure in accordance with BS 5711: Part 1-3. A minimum of 10% (ten percent) of the pipes shall be tested from the initial batches prepared by the Contractor and thereafter the frequency of testing shall be decided by the Engineer.

14.8.7.7. Concrete protection to pipes

Concrete protection to pipes where required shall consist of plain concrete bed and concrete surround and shall be of grade 25/20 along such lengths as are shown on the Drawings or ordered by the Engineer in writing.

In carrying out this work, the Contractor shall take care to compact the concrete under and around the pipes to ensure even bedding and strength of the concrete. The concrete must not be directly thrown on the pipes. The upper surface of the concrete shall be struck off with a wooded float and neatly finished off.

No concrete surround or haunching shall be placed until the pipework concerned has been inspected and approved by the Engineer.

The concrete protection shall be placed to the full width of the trench and never less than 150mm wider on each external side of the barrel of the pipe.

When support for excavation is provided, building paper shall be placed against that support before concreting to facilitate withdrawal of the support.

In the case of spigot and socket pipes with flexible joints the concrete protection at each joint shall be interrupted in a vertical plane at the edge of the socket by a strip of fibreboard or other material approved by the Engineer and of the following thickness:

Up to 300mm nominal bore	13mm
Over 300 and up to 600mm nominal bore	25mm
Over 600 and up to 1200 mm nominal bore	38mm

14.8.7.8. Connecting chambers

Cast in situ or precast catch basins, manholes and the like shall be provided and constructed in accordance with the Drawings.

14.8.7.9. Gratings

Iron and steel castings for covers, gratings and frames shall conform to the requirements of the latest edition of AASHTO Standard Specification M102.

The gratings shall be hot dipped galvanized.

The gratings of catch basins shall be properly secured so as to be held rigidly in place to proper grade and alignment. Rocking gratings shall not be accepted.

14.8.7.10. Masonry Drains

Stone for masonry shall consist of fieldstone or rough, unhew quarry stone as nearly rectangular as practicable. The stone shall be dense, undecomposed basalt, resistant to the action of air and water and suitable in all respects for the purpose intended.

Generally, the stones shall be in the range of 150 to 250mm (mean diameter or sieve size)

Mortar for pointing shall be composed of one part of cement and three parts of sand, by dry loose volumes with sufficient water to make a mortar that can be easily handled or troweled as specified unless otherwise indicated by the Engineer. Re-tempering of mortar not used for 45 minutes or longer shall not be permitted.

All stones shall be placed from the bottom of the trench well bedded in freshly made mortar over a mass concrete blinding 100mm thick. The mortar joints shall be full and the stones carefully settled in place before the mortar has set. Joints and beds shall have an average thickness of not less than 20 mm. The finished face of the drain shall be as smooth and true to the lines, levels and grades shown on the drawings.

14.8.7.11. Outlet structure

The outlet structure of drains shall comprise rip rap protection against scoring all in accordance with the Drawings. The specifications for masonry drain as above apply.

14.8.7.12. Backfilling over pipes

Where no concrete haunch or surround is called for, selected fill material, consisting, of the best available from the excavation 25mm down, shall be mixed, watered if necessary and thoroughly compacted along the barrel of the pipe. A minimum density of 90%BS Heavy Compaction shall be achieved. Similar selected material shall then be laid in layers, not exceeding 150mm loose thickness, mixed, watered if necessary and compacted, and brought up uniformly across the width of the trench to a height of not less than 300mm over the crown.

The remainder of the trench shall then be backfilled with the best selected material available, placed in layers not exceeding 150mm loose thickness, mixed, watered if necessary and compacted.

All backfilling material shall be compacted to a density of 90% BS Heavy Compaction.

Timbering and sheeting shall be eased up 150mm at a time in step with the backfill layer and compaction of the backfill to 90% BS Heavy Compaction shall be obtained under such timber and sheeting.

Over a pipe, which is not laid in a trench, bedding material shall be used in the filling operation within a distance of at least one-half of the pipe diameter of the barrel to completely surround the pipe.

In all cases there shall be cover of at least 600mm compacted thickness over the crown before any construction equipment is allowed to drive over it.

Where directed by the Engineer that the acidity of the soil used for backfilling shall be neutralized, the Contractor shall add 5% of lime, by weight, to the fill material throughout the width and depth directed by the Engineer. The lime shall be evenly spread over the surface of each layer of fill material before it is compacted and shall be mixed in the raking.

14.8.7.13. Backfilling to Structures

All material used for backfill shall be of a quality acceptable to the Engineer and shall be free from large lumps, wood or other organic or extraneous matter. All spaces excavated and not occupied by culverts, or other permanent works shall be backfilled with approved material up to the surface of the surrounding ground, with sufficient allowance for settlement.

All backfill material shall be placed in horizontal, uniform layers not exceeding 150mm in thickness, before compaction, and shall be brought up uniformly on all sides of the structure. Each layer of backfill shall be compacted to a density of not less than 90% BS Heavy Compaction. For filling to structures above existing ground level, the contractor shall so arrange his programme for the construction of structures and earthworks that the filling behind and around any structure is carried out concurrently with, and as part of, the earthworks operation.

14.8.7.14. Pipes

Pipes for and storm drainage shall be Pitch fibers of approved manufacture, cut, laid, jointed and handled strictly in accordance with the maker’s instructions with all necessary bends, angles, collars, etc. Diameters of foul drains shall be as shown on drawings with falls as follows: -

Table 14.14: Diameters of Foul Drains

100mm diameter	1.40
125mm diameter	1.50
150mm diameter	1.60

Storm water drains shall be 100mm diameter laid to falls of 1:100.

14.8.7.15. Drain pipes for soil drainage

All pipes for soil drainage which include the conveyance of discharges from WCs, basins, sinks, urinals, baths and showers shall be salt-glazed earth ware pipes, bends junctions and tapers complying in all respects with B.S No. 65 for “British Standard Pipes” and must be stenciled with the registered mark o B.S.I. Other fittings shall comply with the dimensions laid down in B.S. 539. If the above type of is unobtainable then the Commercial Quality may be used on conditions prior approval of the Architect is obtained.

14.8.7.16. Drainpipes for water drainage

Pipe conveying storm or surface water shall be second quality distinguished by a black band.

14.8.7.17. Laying of drainpipes

The pipes to be laid in straight runs to even and regular falls, and put together with great care, the spigot of one piece shall have one lap of tarred gaskin wrapped round it and then placed into the socket of the pipe previously laid. After adjustment the gaskin shall be caulked lightly home but not so as to occupy more than one quarter of the socket depth. The socket shall then be completely filled with cement mortar (1:1) and shall be formed round the joint, with a trowel forming an angle of 45 degrees with the barrel of the pipe. The joint inside to be struck with a scraper, so as to give a perfectly clear unobstructed water way.

14.8.7.18. Fall in drains

All pipes except where otherwise shown shall be 125mm diameter laid to a fall of 1:50.

14.8.7.19. Concrete bed to drains

Concrete (1:3:6) shall be laid 150mm thick to form bed for drains where the soil is found to be soft. After the pipes have been tested it shall be haunched upon both sides to a 3/4th of the internal diameter of the pipe.

14.8.7.20. Concrete cover to drains

All pipes passing under buildings or under roadways shall, in addition to a 150 mm concrete bed under, be completely surrounded in concrete in concrete of the same thickness of (1:3:6) mix.

14.8.8. Miscellaneous Specifications

14.8.8.1. V Groove

Walls built against cast concrete columns and beams shall have 6mm deep V groove in the rendering internally and externally. Joint on floor screed shall fall immediately above the construction joint in the concrete floor and shall have a 20mm deep x 6mm wide saw cut for making panel not exceeding 40sqm.

14.8.8.2. Preparation of Surface To Receive Screeding

The surface of the concrete shall be hacked to form a good key, well washed and brushed perfectly clean with a brush to remove all impurities, dust etc., damped and grouted with a mixture of cement and water in the form of slurry, using 2.75Kgs of cement per sqm. of surface area, before screeds are laid.

14.8.8.3. Sample Panel

The Contractor shall prepare samples of plastering, tyrolean finish, bush hammered finish as directed until the quality texture and finish required is obtained and approved by the Architect, after which all plastering, tyrolean and bush-hammered finish executed in the work shall conform to the respective approved samples.

14.8.8.4. Arises

Vertical and horizontal arises shall be formed to beams, columns, openings and the like and shall be rounded. Particular care shall be taken to ensure that the rendering is strong at the corners.

14.8.8.5. Cracks, Blisters, etc.

The contractor shall make good all cracks, blisters and other defects and leave the whole of the plaster, tyrolean, bush hammered finish perfect at completion. When making good defects, the plaster shall be cut out a rectangular shape with edges undercut to form dovetailed key and all finish flush with face of surrounding plaster, all at the Contractor's own expense

14.8.8.6. Kerbs

Kerbs shall be either precast or cast-in-situ to a fair face finish as shown on the drawings. They shall be to the dimensions shown on the drawing. Concrete Grade 30/20 shall be used.

The units shall be bedded to the lines and details shown on drawings. The bottom of excavation shall be cleaned, trimmed, and compacted prior to placing of concrete.

Joints between precast unit shall not be thicker than 10 mm and shall be filled with 1:1:6 (cement: lime: sand) mortar. Tapering, radius or other kerbs which are cast-in-situ shall have a visible surface matching precast units and shall be cast in lengths not exceeding 4m.

14.8.8.7. Cover Slabs

Cover slabs shall be built in precast concrete to the type and dimensions given on the drawings or as directed on site by the Engineer. They shall be executed in Grade 30/20 concrete.

They shall be fixed in place to the lines and levels directed by the Engineer on a smoothly prepared level surface so that no rocking occurs. The top surface shall be given an anti skid texture by bush hammering or any other method approve by the Engineer.

14.9 Floating System

14.9.1 General

The Floating system comprises of the Floating unit, Module support structure (if applicable) and anchoring/ mooring mechanism for the Floating Solar PV system (FSPV). The scope also includes supply of minimum of 20 life jackets as per IS 6685.

14.9.2 Codes and Standards

The floatation system must conform to the latest edition of any of the following IEC/ equivalent standards for floating system design qualification and type approval. The reports verified by third party NABL (National Accreditation Board for Testing and Calibration Laboratories), India or international accredited agency shall be submitted for approval by Engineer's/ Employer's.

Codes	Description
ASTM D1693 (or equivalent ISO Standards)	Test for Environmental Stress Cracking of HDPE
ASTM D790, ISO 178	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics & Electrical Insulating Materials
ASTM D638, ISO	Standard Test Method for Tensile Properties of

527	Plastics
ISO16770	Full Notch Creep Test (FNCT)
ASTM D2565, ISO 4892 - 2	Standard Practice for Xenon-Arc Exposure of Plastic intended for outdoor Applications
ASTM D4329, ISO 4892 - 3	Standard Practice for fluorescent ultraviolet (UV) lamp apparatus exposure of plastics
ASTM D1693-15 (or equivalent ISO Standards)	Standard Test Method for Environmental stress cracking of Ethylene plastics
RoHS directive 2002/ 95/EC	Test for Restriction of Hazardous Substances

14.9.3 Floating Unit

The floatation units of module shall be modular and easily connected to each other. Once completely connected, the floating platform must be able to support the weight of PV module, module support structure, cables, support railing (if applicable) etc. The floater system shall also be able to support the load of O&M personnel, equipment such as String Combiner Box (SCB), weather monitoring station etc.

14.9.4 Technical Requirements of Floating Unit

a. The floating units shall be standardized and designed for simple on-site installation.

b. The floating units shall be prefabricated and modular in design with appropriate buoyancy to support the weight of at least one solar panel/equipment and one person (with minimum weight of 80 kg) per unit.

c. The floating unit design shall facilitate ease of assembly / disassembling, replacement of any module and enable future expansion or scaling

d. The floatation unit should be manufactured from appropriate thermoplastic (virgin material) with UV stabilizer (HDPE i.e., High Density Polyethylene) such that the life of floatation device shall be able to sustain for a period of 25 years. The material used in manufacturing shall withstand Environmental Stress Crack Resistance (ESCR) and have a combination of hardness and impact strength (ASTM D5397, ASTM D1693).

e. The material used for floatation device shall be chemically resistant to acid, lye, petrol and mineral oil and also partially resistant to benzene and non-detrimental to marine life.

f. In order to increase longevity and prevent unexpected loss of buoyancy, the floating unit shall have an average material thickness of 3 mm, with moisture retention of less than 5%. (Detailed buoyancy calculation to be submitted along with drawings at the time of drawing approval).

g. The floating unit material shall be designed to balance the thermal expansion so that PV Panel are not stretched due to effect of thermal expansion.

h. The complete floating system shall have at least 600 mm floating corridor along the periphery comprising of module floaters and/ or walkway floater to prevent water splash.

i. Approach walkway platform from dam embankment to location of floating island shall be of minimum 1000 mm Wide. SS Handrails of minimum 1000 mm height should be provided along with approach walkway platform on either side.

j. The design of the floating system shall incorporate appropriately sized walking platforms for regular maintenance and inspection. The walking platform shall be continuous with minimum width of 600 mm, excluding cable-laying arrangement.

k. The walkway platform shall be placed in such a way that each module in the array layout can be easily accessed through the continuous walking platform without any additional infrastructure.

l. Floating system should be designed to withstand the maximum wind speed of the location.

m. The floating units once assembled together should form an integrated structure. The relative alignment of the floating unit subsequent to complete installation shall not misalign the solar panels.

n. The floating units shall be re-process able and recyclable at the end of its useful life.

o. The design life of the floating units should be 25 years. Certifications for floater design for suitable international standards to take care for 25 years life, sunlight penetration, dissolve oxygen etc for aquatic life. Further, Float testing shall be done as per applicable codes. <u>Furthermore, the Contractor shall provide a warranty of at least 10 years on the floaters and submit the terms and conditions of the Warranty from the Supplier.</u>

p. Floating system from multiple vendors can be installed. However, minimum capacity from each Vendor shall be 1MWp. Mandatory spares for each floating system as specified in Table 3.2 (a), has to be supplied.

14.9.5 Module Support Structure (If Applicable)

a. The module support structure (MSS) shall be so as to allow easy replacement of any module by authorized personnel.

b. The MSS and associated hardwares / fastners, if used are metallic in nature, shall be non-corrosive and suitable for coastal weather conditions. The structures shall be made of anodised aluminium. All fasteners, nuts, bolts and other hardware shall be of Stainless steel – 304 or higher grade.

c. MSS shall be designed to withstand the extreme weather conditions in the area.

d. The modules shall be mounted at fixed tilt.

e. PV fixation system shall be of proven design and subjected to Mechanical test to withstand unit failure conditions under static and fatigue conditions for base wind speed. The results conforming to above test shall be submitted to Engineer/ Employer on request.

f. The design philosophy and the calculations for the MSS with suitable test reports shall be submitted for Engineer's/ Employer's approval.

14.9.6 Anchoring and Mooring System

a. The design life of the Anchoring system shall be 25 years.

b. Placement of plant: The floating solar PV (FSPV) power plant should be at a distance of 4 meter from the edge of the land surface. However, the exact positioning can be finalized at the time of detailed engineering, after conducting bathymetric study.

c. Prevailing wind load: The floating system comprising of floating unit, PV fixation system and associated anchoring and mooring system shall be designed for basic wind speed of 280 km/h (3s gust 50 years return period) as per the requirements of the Building Codes and able to withstand dynamic conditions as per relevant BS code.

d. The design of the mooring system shall permit minimal lateral movement of the plant in case of maximum wind loads (as per relevant BS code and DNVGL-RP-0584 Edition March 2021). Anchoring design report for the project showing that the system could support the maximum wind load on site shall be submitted to Engineer/ Employer.

e. Water variability: The mooring system should accommodate any fluctuations in water level. Further, the orientation of the plant needs to be maintained; hence, any fluctuations in water level shall allow minimal movement of the FSPV plant as per mooring system design.

f. The materials used in the anchoring system shall not contaminate the water and affect the aquatic ecosystem.

g. Dedicated floating approach walkway to be provided from the end of the reservoir/ land surface to the plant, for each block in the floating system. The block size of the floating system depends on the array layout optimization. The same shall be finalized during detailed engineering.

h. Ground Anchor:- Anchoring & Mooring should be of underwater sinker block / Dead Weight, side anchorage on shore is not allowed. The anchoring system proposed for the FSPV array shall be underwater anchoring. For the given site conditions, concrete sinker blocks shall be used as ground anchor points on all four sides of the FSPV array. This configuration will also be effective in providing resistance to prevent FSPV array uplift under severe wind speed conditions. The concrete blocks shall be designed with sufficient safety factor for uplift, overturning and sliding resistance. Also, with time, these blocks will have subsidence effect into the bed of the reservoir which may add additional holding capacity to them. The blocks shall be deployed under water with the help of specialized equipment at GPS guided coordinates. The blocks size shall be determined during detail engineering stage and also after considering site and machinery restrictions.

i. Structural stability of floating system with anchoring and mooring shall be demonstrated at minimum design wind speed of 216 km/h through reputed software like MOSES, OrcaFlex or equivalent and report of same shall also be submitted.

j. The design of complete system, including CFD modelling, comprising of Floating unit, MSS and anchoring and mooring system, shall be verified by suitable third party national or international accredited agency/ reputed institutions and the same shall be submitted for Engineer's/ Employer's approval.

15. INSPECTION, TESTING, COMMISSIONING AND TAKING OVER

15.1 General

The whole of the Works supplied under the Contract shall be subject to inspection and testing by the Engineer should he so require, during manufacture, erection and after completion. The inspection and tests shall include, but not be limited by, the requirements of this Section. Prior to inspection and testing the plant and equipment shall undergo pre-service cleaning and protection as specified in this Section.

The Contractor shall engage Lloyds Register of Shipping as third-party inspection and certification or any other equivalent classification society of all major plant items PV panels and inverters.

15.2 Attendance of Factory Acceptance Tests by Employer Representatives

Two (2) technical members of staff representing the Employer shall attend Factory Acceptance Tests (FAT) for the PV modules, floating structures and inverter prior to shipment. The Employer shall bear the costs for transportation of its personnel from Mauritius and accommodation and subsistence for the above FAT tests.

15.3 Comprehensive Protection Study

The Contractor shall submit a comprehensive protection study, at least 30 (thirty) Business Days prior to the start of the Pre-Commissioning Tests including but not limited to:

(i) All protection calculations complete with graphs (the graphs shall demonstrate discrimination for faults at both the MV and LV level taking into consideration the fault level at each level of the Solar Facility); and

(j) Grading of the interconnection protection with CEB substation protection

CEB shall provide the relevant network information to the Contractor for the purpose of the protection study.

15.4 Planning for Pre-Commissioning and Commissioning Phase

The Contractor shall submit appropriate, pre-commissioning and commissioning procedures and plans as per applicable standard for the Floating Solar PV farm to the Engineer/ Employer approval at least 3 (three) months prior to the Completion Date. A detail schedule/plan for all tests to be performed shall be submitted to the Engineer/ Employer, for approval, at least 14 working days before the start of the testing phase for the Solar farm. The Contractor shall notify the Engineer/ Employer of any change in the schedule at least 5 working days ahead of the previously planned testing date.

The Contractor shall perform the, pre-commissioning and commissioning phases of the floating solar PV farms as per relevant standards norms. The Contractor shall keep written records of test results and protection settings for submission to the Engineer/ Employer.

15.5 Requirements of the Pre-Commissioning and Commissioning Phase for PV Farm

A number of typical tests, among others, for the PV farm have been identified by the Engineer/ Employer. However, it is the responsibility of the Contractor to ensure that all required tests are performed to ensure compliance of the Solar farm with the requirements of this Contract, relevant standards and requirements of concerned utilities & regulatory authorities at the time of commissioning, unless agreed otherwise with the Engineer/ Employer. This compliance shall include, but is not limited to, compliance with relevant grid codes and technical requirements for HT metering, including subsequent amendments within the Contract period. In case of any discrepancy between the requirements of this Contract and the requirements of concerned utilities & regulatory authorities, the Contractor shall inform the Engineer/ Employer, for his approval, of the discrepancy and of the proposed technical specifications for the Solar farm.

The pre-commissioning tests identified are as follows:

- Earthing continuity of array frame to earth and connection to main earthing terminal
- Polarity of each module string
- PV string Open-Circuit Voltage (Voc) Test;
- PV Short Circuit current (Isc) Test;
- PV array insulation Test;
- Operational Test PV string current;
- Functional Test;
- Protection Relay Testing;
- Insulation resistance Testing; and
- Performance verifications;

The Commissioning tests identified are as follows:

- Demonstration of satisfactory operation of power and weather measurement equipment;

- Function tests of the relay protection and verification of settings;
- Demonstration of satisfactory operation of control equipment;
- Demonstration of satisfactory operation of 22 kV the internal electrical network of the Solar Facility;
- Demonstration of satisfactory operation of the Step-Up Transformer and its associated protections
- 24 hours voltage test on the cables;
- Reactive Power Capability; and
- any other test found deemed necessary by the Commissioning Engineer (refer to Section 14.6 below).

All tests performed shall be approved by the Engineer/ Employer. Further details on the tests to be performed are outlined in the Sections hereunder.

15.6 Pre-Commissioning and Commissioning Procedures

Various tests mentioned under each item for pre commissioning are apart from the manufacturer recommended pre commissioning tests. The commissioning process includes visual inspections as well as measurements and software parameter settings.

Most of the commissioning procedures will be made before the system is energized. These Pre-Commissioning tests shall be performed in the presence of the Engineer/ Employer and its Engineer.

The Engineer/ Employer reserves the rights to request the Contractor to perform additional tests which the Engineer/ Employer may find necessary to ensure conformity to grid connection.

The Contractor shall provide a reputable Registered Professional Electrical Engineer from the Council of Registered Professional Engineers of Mauritius, having at least two years' experience in the commissioning of utility scale PV Farm. The role and functions of the Commissioning Engineer shall be:

- review of the drawings and documents for the project
- review, inspection and monitoring of construction works
- propose and finalise appropriate testing procedures as per IEC norms with the

  Contractor at least 3 (three) months prior the Scheduled Commissioning Date of the Solar Facility
- conducting all tests with respect to the Solar Facility, including independent tests on completion of Construction Works
- issuing the Completion Certificate and certification of the Solar Irradiation Measurement System;

- determining, as required under the Agreement, the period or any extension thereof, for performing any duty or obligation;
- approve the design of the Solar Facility, the Contractor's Distribution Assets and the Contractor's Interconnection Facilities;
- certify that the civil and structural designs of the Solar Facility, Distribution Assets and Interconnection Facilities are cyclone resistant;
- review and approve the Operating Procedures Manual;
- undertaking all other duties and functions as required by the Contractor to ensure conformity to grid connection.

15.6.1. Mounting Structure on Floaters.

The following inspections and tests on the mounting system shall be made:

1) Installation done according to the Engineer/ Employer approved drawings;
2) Torque test on rack screw connections;
3) Load tests (pull out force ≥ design load) conducted at random posts;
4) Damages to galvanization layers;
5) Measurement of earthing and equipotential bonding resistance of the PV array racks to the inverter main earthing terminal.

In case of any defects or failure of the above tests, the Contractor shall carry out remedial actions in order to make the system good. The Engineer and Employer shall verify and approve the remedial works.

The following documents shall be provided and included in the plant documentation:

1) Static design calculations of the mounting structure.
2) Measurement protocols of equipotential bonding and earthing.
3) As built drawings.
4) Load test report (pull out test on IPE piles).
5) Torque test report.

15.6.2. PV Modules

The following inspections and checks shall be made on the PV Modules:

1) Visual failures (e.g. cell breakage, delamination, hot-spots, glass breakage)
2) Dirt and foreign objects on the module surface shall be removed
3) Modules are mounted according to the installation requirements.

In the event, the modules are found to be defective or damaged, the Contractor shall replace same.

The following documents shall be provided and included in the plant documentation:

1) A report of observed visual inspections
2) Module flash list of the installed modules. (Module performance data at STC conditions, provided by the manufacturer).
3) Module datasheet, IEC 61215 and IEC 61730, 62804-1 certificates

15.6.3. DC string cable installation

All PV modules are equipped with touch-safe plug connectors and appropriate number of PV modules are electrically connected in series to form a PV string and all string cables are properly installed:

1) Check that string cable are properly attached on cable trays fixed to the floating platforms.
2) Check if the string cables are protected from direct UV irradiation exposure
3) Check the sharp edges of support structures does not cause any abrasion
4) Check if minimum bending radius of string cables is respected
5) Connectors are tied up to avoid water intrusion at the cable glands and pulling forces on the connectors avoided.
6) Cable pipes ends (if applicable) are properly sealed

A report with all observations shall be provided for each string.

15.6.4. DC Combiner Boxes

Visual checks and measurements must be made at the combiner boxes to ensure correct installation of the PV strings and the combiner boxes.

Visual inspection shall include mainly the following aspects:

1) Mechanical installation according to the manufacturer guidelines
2) DC cable connections correct
3) Torque of DC main cable connections correct
4) Fuse links/Miniature circuit breaker are suitable for the PV module protection
5) Load break switch for each string & Main Cable circuit breaker
6) Surge protection devices
7) Door sealing not damaged

8) Cable glands are tight
9) Communication cable connection is correct
10) Warning sign that warns against disconnection under load
11) Proper cable markings
12) Cable terminations are according to specifications
13) Positioning of the combiner boxes for ease of access
    - Individual String cable insulation in accordance with IEC 62446 (measurement made with 1000V DC test voltage and the insulation resistance must exceed 1MΩ)
    - Polarity check & Open circuit voltage for each string (at stable irradiance conditions the values should vary within ±5%
    - Short circuit current for each string (at stable irradiance conditions the values should vary within ±5%
    - Operational current (after start-up of the inverters) to check the availability of individual strings. As string monitoring is included in the combiner box, the monitoring results can be used to check the operational string currents. (At stable irradiance conditions, the values should maximal vary within ±5%)
    - Earth resistance of each combiner box

A commissioning report with all inspection and measurement results shall be provided for each combiner box.

15.6.5. DC Distribution Board

DC Distribution panel shall receive the DC output from the array field. If the Contractor’s design incorporates a DC distribution board, it shall be inspected and tested in accordance with the respective chapters as mentioned.

A commissioning report with all inspection and measurement results shall be provided for each Dc Distribution panel.

15.6.6. DC main cables

The following inspections and checks shall be made on the DC main cable installations:

1) Visual inspection of the cable routing
2) Cable termination with correct screw torque and correct crimping of cable lugs
3) Correct cable polarity installation
4) Cable insulation measurement to earth (≥ 1 MΩ)

5) Cable pipes (If any) shall be sealed

6) Cable clamping underneath the combiner box and inside the inverter is correct A report with all observations shall be provided for each DC main cable.

15.6.7. LV & MV cables

The LV/MV cable installation shall be checked for:

1) Cable types and dimensions are as per approved design
2) Correct and thorough installation of the terminals
3) As a minimum requirement an insulation test shall be carried out to avoid cable damages after cable laying

A commissioning report with all inspection and measurement results shall be provided for LV/MV cables.

15.6.8. (AC Distribution Panel Board)

If the Contractor's design incorporates an ACDB, it shall be inspected and tested as follows:

1) Visual inspection to include mainly the following aspects:
2) installation is as per approved design drawings
3) AC cable connections with appropriate lugs and cable markings
4) Torque of main cables connections correct
5) Circuit breakers and load break switches are appropriately installed as per approved design drawings
6) Surge protection devices are properly installed
7) Check that door sealing are not damaged
8) Cable glands are tightly fixed
9) Communication cable connection is correct
10) Warning sign indicating prevention against disconnection under load
11) Cable insulation in accordance with IEC 62446 (measurement made with 1000V

    DC test voltage and the insulation resistance must exceed 1MΩ)
12) Earth resistance of each ACDB

A commissioning report with all inspection and measurement results shall be provided for each ACDB.

15.6.9 Inverters

The plant inverters shall be commissioned on site by the Contractor or manufacturer's representative and will confirm that the inverter can be operated locally as per specification and that automatic operations such as wake-up and sleep routines, power tracking, remote monitoring and fault detection responses, amongst others operate as per specifications.

Visual inspection and measurement of the inverter set-up to check that:

1) There is sufficient free space around the unit.
2) The ambient operating conditions are met.
3) The unit is properly fastened to the floor and/or wall.
4) The cooling air is able to flow freely and cooling air volume is sufficient.
5) The inverter is grounded properly.
6) The AC line voltage matches the nominal output voltage of the inverter.
7) The AC transformer is suitable for use with the inverter(s).
8) The insulation of the assembly must exceed 1MΩ.
9) The AC power system is grounded as per approved design.
10) The AC power cable connections of the 3 phases and their tightening torques are Correct.
11) The DC power cable connections of the positive and negative terminals and their tightening torques are correct.
12) The power cables are routed separately from communication and supervisory cables.
13) The auxiliary power supply cable connections and their tightening torques.
14) The auxiliary voltage levels.
15) The external control connections to the inverter (including emergency stop, fieldbus etc.) are properly wired.
16) All shrouds and covers are in place.
17) Operating software are up-to date.

15.6.10 Inverter Duty Transformers

The step-up transformer(s) shall be checked:

1) Transformer installation carried out according to the manufacturer installation manual.
2) Cables terminations and connections to transformer are correct
3) Insulation resistance test at the transformer windings
4) Check of the voltage and phase sequence at the LV side
5) A functional test of the temperature controller shall be carried out
6) Earthing (both tank and neutral) of transformers correct

A commissioning report with all inspection and measurement results shall be provided for the transformer(s).

15.6.11 MV switchgears

The MV switchgear shall be checked:

1) Installation is made according to manufacturer installation manual.
2) Check of the transformer and outgoing interconnection feeder protection
3) Commissioning of the LV auxiliary supply and UPS system
4) Commissioning of the MV switchgear room air conditioning
5) An insulation resistance test shall be made.
6) A hi-pot / pressure test shall be made.
7) The contact resistance (Ductor test) of the busbar connection shall be measured.
8) Commissioning of protection relays and control settings
9) Commissioning of PT's & CT's
10) Test and demonstration of the satisfactory operation of the power measurement equipment
11) Commissioning of meter installation
12) Commissioning of the SCADA system integration
13) SCADA functional test of commands, status signals and alarms
14) Operational and safety equipment and single line diagram board present
15) Correct labelling of all equipment
16) Commissioning of the Station Controller and HMI
17) A commissioning report with all inspection and measurement results shall be provided for the MV switchgears.

15.6.12 Weather Monitoring Stations

The check and commissioning procedure includes:

1) Check of the irradiance sensor installation (mechanical fixing, azimuth orientation and inclination)
2) Check of the module/ambient temperature sensors installation
3) Check of the installation for relative humidity sensor
4) Check of the auxiliary supply voltage and UPS installations
5) Check of the communication and SCADA system integration

A commissioning report with all inspection and measurement results shall be provided for the weather monitoring sensors.

The sensors' calibrations certificates have to be submitted to the Engineer/ Employer.

15.6.13 SCADA & Communication Systems

The commissioning procedure of the SCADA system shall include:

1) The monitoring server is correctly installed and operational
2) Control room air conditioning functional
3) On site, all inputs, outputs and functions shall be successfully tested by simulation prior to connection of field devices
4) Internal and external communication are operational
5) A commissioning report with all inspection and measurement results shall be provided for the SCADA and communication system.
6) Site Acceptance test (SAT) procedure shall be submitted by the bidder for the approval of Engineer based on which SAT shall be conducted.

15.6.14 Test for Compliance with Guaranteed Operating Characteristics

The following tests shall be conducted to ensure the Floating Solar PV farm is in compliance with the guaranteed operating characteristics detailed in Section 11.

1) Fault Ride Through
2) Frequency response
3) Reactive Power Capability
4) Power Quality

5) Ramp rate limits

15.7 Trial Run

Following the successful completion of the pre-commissioning and commissioning tests, the Contractor shall notify its readiness to start the trial run of the floating solar PV Farm in accordance with a program as determined by the Engineer/ Employer.

During the trial operation, FSPV farm shall perform trouble-free operation for seven (7) days during which functionality of all plant components shall be demonstrated and the system shall be in Generating Mode.

The plant will be operated by the station staff under the supervision of the Contractor's engineers during the Trial Run period, but the Contractor shall be allowed to make any minor adjustment which may be necessary.

Should any failure or interruption occur in any portion of the plant due to or arising from faulty design, materials, workmanship or to omissions or to incorrect erection sufficient to prevent safe and full commercial use of the plant, the Trial Run shall be considered void, and the trial run period of 7 days shall re-commence after the Contractor has remedied the cause of defect.

During the test period, an outage of up to 6 hours (the cumulated hours of outages shall not exceed 6 hours) for the floating PV farm shall be allowed to cover for minor faults. If this period is exceeded, the Trial Run shall be restarted. Stops due to faults of the Employer’s staff or Engineer, unacceptable grid variations or lack of electrical load, or other responsibilities of the Employer/Engineer are not considered as stops in this context. Failure of major component shall result in restart of the test.

All adjustments made by the Contractor shall be recorded by him in a manner to be specified by the Engineer.

After successful completion of trial run and acceptance by Engineer/ Employer, FSPV farm shall be deemed to be successfully erected & commissioned

15.8 Performance Guarantees and Liquidated Damages

The tests for which a reduction in the Contract Price is defined are those necessary to prove the Guaranteed PV Farm Net Electrical Output (MWac) G

If the Contractor fails to meet any of these guaranteed performances, the compensation detailed below shall be cumulative and shall be in addition to all other damages specified in the Conditions of Contract.

If the Measured PV Farm Net Electrical Output (MWac) M is within 5-percent compared to the Guaranteed PV farm Electrical Output (MWac) G from the Contractor, then the Project is considered to have met the Guaranteed Project capacity rating.

No additional payment will be made to the Contractor in the event that PV farm actual performances exceed the guaranteed performance values to the Employer's benefit.

15.8.1. Guaranteed PV Farm Net Electrical Output (MWac)

15.8.1.1. Capacity Test Procedure

During the trial run phase, the Contractor, in the presence of Employer Representatives and Engineer, shall conduct the performance test for the PV farm guaranteed net electrical output (MWac).

The PV Project will be tested under field environmental conditions i.e. solar irradiance (W/m2), ambient temperature (°C), and PV farm measured net output capacity (MWac).

(i) Inputs Provided by the Contractor

The Contractor shall specify in Sheet 11 of the Technical Schedule (Section VII-Schedule of Guaranteed Particulars) the Guaranteed Net Electrical Power Exported at POD to the CEB's grid in (MWac)G at site conditions.

(ii) Field Measurements:

Testing shall be generally performed during the hours of 11 AM to 2 PM when the plane of array irradiance is greater than 750 W/m2. Fifteen-minute interval readings will be measured for a minimum of 12 intervals where the following data points are recorded:

- Plane of Array irradiance – W/m2 (minimum two locations in array using Pyranometer - (Irr)M
- Total facility output to the grid at the point of interconnection – (MWac)M
- Ambient air temperature at two locations within the array field in °C (Tamb)M.

Once the data sets have been recorded and logged the following analysis will be used to compare the field measured capacity (MWac)M rating to the guaranteed capacity in MWac:

The calculation procedure is shown in the example below as a guideline:

A. Inputs supplied by the Bidder

- (MWac)G from Bidder is the Guaranteed Net Electrical Output Minimal Capacity at site ambient temperature of 30 °C as submitted in its bid.
- Cp = - 0.5 %/°C from Bidder (in this case from module manufacturer) as submitted in their bid.

B. Measurements in the field for Capacity Testing - in time interval stated above:

- (MWac)M = 1.7 MWac
- (Irr)M = 900 W/m2
- (Tamb)M = 34 °C

Note that the above values are measured at 15 minutes intervals between 11 AM to 2 PM and the average values recorded.

STEP 1 - Adjust (MWac)M for (Irr)M :

(MWac)M x 1000/ (Irr)M = (MWac)M Adj 1

Example:

(MWac)M Adj 1 = 1.7 x 1000/900
(MWac)M Adj 1 = 1.89 MWac

STEP 2 – Adjust (MWac)M Adj 1 for (Tamb)M measured on site:

Then, (MWac)M Adj 2 = (MWac)M Adj 1 + (P % change) (MWac)M Adj 1

(P % change) = (30-34) x (Cp)
(P % change) = -4 x – 0.0045 = 0.018

Then, (MWac)M Adj 2 = (MWac)M Adj 1) + (0.018 x (MWac)M Adj 1)

= 1.89 + (0.018 x 1.89) = 1.924 MWac

STEP 3 – Compare the (MWac)G to the (MWac)M Adj 2

Compare the capacity measured in the field to the capacity guaranteed.

MWac = 2.0 MWac Compare to 1.924MWac-meas2 (1.924/2.0) = 0.962

Since the difference between Guaranteed and Measured values is 3.8% and thus within the acceptable deviation of 5%, the bidder shall not pay any liquidated damages to the Employer.

Payment of Performance Liquidated Damages

In the event, the deviation from the measured and guaranteed values exceed 5%, the bidder shall have to pay Liquidated Damage (LD) as per principle below:

LD = 0.6% of Contract Price for each deviation of 1% in excess of the acceptable 5% limit.

Hence if actual deviation is 7%.
Applicable LD = (7%-5%) x 0.6 = 1.2% of the Contract Price.

Applicable LD for net electrical output (MWac) shall be limited to 5% of the total contract value, however actual deviation of net electrical output beyond 13.33% is not acceptable.

15.8.2. Guaranteed PV Farm Performance Ratio:

The Acceptance test for evaluating Performance ratio shall be conducted at site and witnessed by Engineer and Employer's representative. Based upon the result, The Engineer/ Employer will provide its acceptance the system.

The target Performance Ratio (PR) shall be provided in Contractor's technical proposal. The Contractor shall specify the PR target in Sheet 12 of the Technical Schedule (Section VII- Schedule of Guaranteed Particulars), the Target Performance Ratio (Should not be less than 75%) at site conditions at any time during the year.

The target PR (≥75%) shall be supported by energy estimation tool e.g. PVSyst, PVSol.

The value of PR shall be determined as follow:

$$PR\ (\%) = \frac{\text{AC Yield (kWh)}}{\text{Installed Capacity (kWp) x} \quad \text{(Measured Global Inclined Insolation (kWh/m}^2\text{) during the period / kW/ m}^2\text{)}} \times 100$$

The assumptions for calculating PR Acceptance Tests are as follow

- Temperature as per latest version from PVSyst for determining standard value of PR
- Soiling loss=1%
- LID=2%
- Cable loss=2%
- Thermal Loss Factor (Uc, Uv)= Uc-24 Watts/m2-K Uv-2.0 Watts/m2-K

a. PAN and OND file have to be furnished by the Contractor. In case same is not available, PAN and OND file of equivalent product may be taken.

b. For the purpose of measuring Global Horizontal Insolation (GHI), a pyranometer shall be installed by the Contractor on returnable basis, mounted at the plane of the module.

c. For energy calculation during acceptance test, energy meter of inverter shall be used.

d. Measuring instruments to record on site data will include a pyranometers (with sensitivity of 7µV/(W/m2)), temperature sensor and a signal converter.

e. The vendor will be responsible to conduct the PR test only after achieving the physical completion and synchronization of the plant.

f. The test shall be conducted for a period of 60 minutes having GHI more than 600 W/m2 and the Measured PR shall be determined as per the actual generation.

g. If failed to achieve the guaranteed performance levels, the contractor will at its own cost rectify all the defects identified during the test and take necessary steps/efforts to pass the PR test within the stipulated time span. Subsequent to rectification the PR will be restarted.

h. In case the measured PR is less than target PR, then Contractor has to rectify first, else Contractor has to install additional module string equivalent to the percentage shortfall of PR.

i. In case there is no scope of any additional of module string, equivalent amount shall be adjusted from the contract value as per the applicable LD clause mentioned below. Applicable LD for PR shall be limited to 5% of the total contract value.

$$\textbf{Applicable LD} = \frac{\textbf{(Target PR - Measured PR) x Contract Value}}{\textbf{(Target PR)}}$$

The procedure for PR demonstration test shall be as follow:

Any consecutive **72-hour** period for the purpose of conducting performance ratio test shall be chosen on the discretion of Engineer/ Employer

a. Contractor has to quote the month wise Target Performance ratio (Should not be less than 75%) in the bid.

b. In addition to the two pyranometers to be supplied under the scope of work, the contractor shall install one more calibrated pyranometers at horizontal plane at locations mutually agreed by Contractor and Engineer/ Employer. The additional pyranometer shall be free of cost on returnable basis.

c. Contractor shall also install data logger to store all the pyranometers data during test period. A valid test reports for the installed pyranometers shall be submitted by the Contractor for approval to Engineer/ Employer. The output of both pyranometers mounted on horizontal plane shall be made available at SCADA during the complete PR test duration i.e. 72-hour period.

Following factors shall be considered for computing the "Target PR" and shortfall (if any)

a. Effect of any meteorological parameters shall not be considered except of solar radiation.

The test shall be repeated in case of outage of following equipment's during the test.

a. Converter transformer

b. Power Conditioning Unit

c. SCADA and data logger combined

d. Both pyranometers.

If Contractor is not able to demonstrate PR test during these three (03) days he shall be given one more chance to demonstrate the PR test. In that case, the steps for PR test shall be repeated again as above after carrying out necessary modification/replacement.

15.9 Taking Over Certificate

The Taking Over Certificate shall be issued after successful completion of the site inclusive of the trial run period. The issuing of any such certificate, however, shall not relieve the Contractor of any of his responsibilities in respect of any of the remedies provided under this Contract in the event of the guarantees failing to be proved.