Potential Assessment and Technical Feasibility Study Report for Floating Solar PV Project

Coimbatore, Tamil Nadu, India

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Glossary

Acronym	Meaning
AC	Alternating Current
ACB	Air Circuit Breaker
ACCB	Alternating Current Combiner Box
ACDB	Alternating Current Distribution Board
AutoCAD	Autodesk make Computer Aided Design software tool for drafting
AMC	Ahmedabad Municipal Corporation
BoM	Bill of Materials
BoS	Balance of System
BIS	Bureau of Indian Standards
CCMC	Coimbatore City Municipal Corporation
c-Si	crystalline Silicon
CdTe	Cadmium Telluride
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CFD	Computational fluid dynamics
CoD	Date of Commissioning
CRGO	Cold Rolled Grain Oriented
CT	Current Transformer
DC	Direct Current
DCDB	Direct Current Distribution Boards
DG	Diesel Generator
DHI	Diffused Horizontal Irradiation
DISCOM	Distribution Company
ESE	Early Streamer Emission
FRLS	Flame Retardant, Low Smoke Low Halogen
FSPV	Floating Solar Photovoltaic
GHI	Global Horizontal Irradiance
GI	Galvanized Iron
GII	Global Inclined Irradiation
HDPE	High Density Polyethylene.
HSE	Health, Safety and Environment
HSMF	High Modulus Synthetic Fibers
HV	High Voltage

Acronym	Meaning
HT	High Tension
ICLEI	International Council for Local Environmental Initiatives
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Ingress Protection
IS	Indian Standard
kVA/kW	kilo Volt Ampere / kilo Watt
kWp	Kilo Watt peak
LA	Lightning Arrester
LED	Light Emitting Diode
LID	Light-Induced Degradation
LV	Low Voltage
LT	Low Tension
MCCB	Molded Case Circuit Breaker
MFM	The Multi-Function Meter
MNRE	Ministry of New and Renewable Energy
MPPT	Maximum Power Point Tracker
MU	Million Units (Million kWh)
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Mega Watt
NABL	National Accreditation Board for Testing and Calibration Laboratories
NCES	Non-Conventional Energy Sources
NEC	National Electrical Code
O&M	Operation and Maintenance
OCTC	Off Circuit Tap Changer
OLTC	On load Tap Changer
ONAN	Oil Natural Air Natural
ONAF	Oil Natural Air Forced
OPC	Ordinary Portland Cement
PERC	Passivated Emitter and Rear Cell
PID	Potential Induced Degradation
PoC	Point of Connection
POE	Polyolefin Elastomers
PPC	Portland Pozalano cement
PR	Performance Ratio

Acronym	Meaning
PSM	Physical Solar Model
PT	Potential Transformer
PV	Photo Voltaic
PVSYST	A computer software for simulation of PV plants
PVC	Polyvinyl Chloride
RE	Renewable Energy
RfP	Request for Proposal
SCADA	Supervisory Control and Data Acquisition
SLD	Single Line Diagram
SMSE	NASA Surface Meteorology and Solar Energy
STP	Sewage Treatment Plant
STC	Standard Test Conditions
TANGEDCO	Tamil Nadu Generation and Distribution Corporation
TEDA	Tamil Nadu Energy Development Agency
TDS	Total Dissolved Solids
THD	Total Harmonic Distortion
TMY	Typical Meteorological Year
TNEB	Tamil Nadu Electricity Board
TPO	Thermoplastic Polyolefin
UoM	Unit of Measurement
UPVC	Unplasticized Polyvinyl Chloride
UV	Ultraviolet
VCB	Vacuum Circuit Breaker
WMS	Weather Monitoring System
Wp	Watt Peak
XLPE	Cross-linked polyethylene
XLPO	Cross linked polyolefin

Executive Summary

International Council for Local Environmental Initiatives (ICLEI) - Local Governments for Sustainability has been working closely with a regional network of local governments to achieve tangible improvements in regional and global sustainability through local initiatives. ICLEI – South Asia as a consortium partner is working in Capacity Building for Low Carbon and Climate Resilient City Development project (CapaCITIES) Phase II along with other implementing agency partners namely South Pole Group and econcept AG. As part of the CapaCITIES project, Ahmedabad and Coimbatore cities receive technical assistance from the project in preparation of the Climate Resilient City Action Plan addressing both climate change mitigation and adaptation aspects, and in identifying and implementing pilot demonstration projects and bankable projects.

Ahmedabad Municipal Corporation (AMC) and Coimbatore City Municipal Corporation (CCMC) have shown interest in deploying FSPV projects in the cities' water bodies to offset their energy consumption with technical support under the CapaCITIES Phase II project. Coimbatore city has proposed to consider one of the four lakes namely Periyakulam lake, Kumaraswamy lake, Kurichikulam lake, and Valankulam lake for FSPV project implementation. This assignment entails potential assessment and development of a technical feasibility study report for deployment of MW scale FSPV projects. It also includes identification of suitable location for deployment of a pilot project in Coimbatore, providing inputs to the bidding process and bid assessment for the pilot project.

ICLEI has appointed RINA Consulting Pvt. Ltd. ('RINA') and TruBoard Partners ('TruBoard') as consultants ('the Consultants') to assist in this study.

The detailed feasibility assessment and technical specifications of the FSPV projects in Coimbatore is contained in this report "Potential Assessment and Technical Feasibility Study Report for Floating Solar PV Project".

Potential assessment and study area selection

As part of the CapaCITIES project, four lakes out of eight lakes, namely Periyakulam lake, Kurichikulam lake, Valankulam lake, and Kumaraswamy lake have been considered for evaluation of high level FSPV project capacity and study area selection for the feasibility study and pilot project implementation. Periyakulam lake is the biggest lake in Coimbatore. The location selected for the development of both pilot project of 140 kWp (111 kW AC) and MW scale project of 18 MWp (12 MW). The projects shall be deployed at the southern part of Periyakulam lake.

Site assessment

This section describes about Periyakulam lake which include accessibility, energy consumption, and climatic conditions. Photographs presenting key observations during site visit are shown in this chapter. The city experiences annual solar radiation of about 1,869 kWh/m^2 and a daily average ambient temperature of 26.5 °C. As per IS 875 part – 3, the basic wind speed for Coimbatore is 39 m/s and as per IS 1893 part – 1, Coimbatore comes under Seismic zone – III. The project sites are accessible by road. As per available data in FY 2019-20, total electricity consumption by the

Coimbatore Corporation Facilities is 80 Million Units (MU). An additional capacity of more than 50 MWp solar shall be required considering future electricity demand.

Technology selection

The available technological options for different components of FSPV plants are described in this section. Crystalline-silicon technologies are the most deployed in global solar PV installations. Considering the maturity, long-term proven track record and availability of the crystalline silicon technology, crystalline silicon technology is the preferred one for the FSPV installations. HDPE floats and floats with combination of pontoons and metal frames can be explored for the FSPV plant considered in this study. Different type of anchoring and mooring system are explained in this section. String inverter is recommended over central inverter considering ease of mounting on the floats. Above water cable laying is recommended over submarine cable considering techno-economic aspects. This section also describes key equipment manufacturer's experience.

Project conceptualization

A number of key considerations apply to FSPV installations and are assessed in the conceptualization of the Project. There are transmission line towers but those have no shadow impact in the selected study area. The selected tilt angle is 5 degree with an inter row spacing of 0.2 m at 0 degree azimuth angle. The project layout and SLD developed for each project showing evacuation point, evacuation voltage etc. The layout is developed and plant capacity is estimated considering 540 Wp PV module. The 140 kWp pilot project shall be evacuated to existing 11 kV transmission line and distribution transformer of TNEB in South – East corner of lake whereas for 18 MWp project the generated power shall be evacuated at 11 kV to upcoming 110 kV / 11 kV Selvapuram substation in West side of the lake.

Bill of Materials (BoM)

We have developed BoM and equipment specification considering the Project layout and SLD developed as a result of the Project conceptualization. The BoM includes a list of key equipment, their ratings, quantity and a list of preferred makes. The BoM will change based on detail design engineering that will be undertaken by the EPC contractor.

Irradiation and Energy Yield

An Energy Yield Assessment (EYA) was carried out to determine the expected energy yield of the proposed plant. The analysis was based on the indicative design information developed by us for the concept design and irradiation data from satellite and ground station database.

On the basis of the system design and loss assumptions, a Performance Ratio (PR) has been calculated using industry standard PVsyst software and our inhouse models.

Resulting first year energy yield predictions are shown in Table 1.

Table 1: Year one energy yield for the system

Project	PR	Installed capacity (kWp)	Probability of exceedance	Specific yield (kWh/kWp)	1st year production (MWh)
140 kWp Pilot Project	82.8%	140	P50	1,573	220.9
			P75	1,505	211.0
			P90	1,443	203.0
18 MWp utility scale Project	81.7%	17,999	P50	1,553	27,960
			P75	1,486	26,740
			P90	1,425	25,650

When used to calculate output in subsequent years, a linear degradation of 0.4% should be applied. This energy yield study assumes 99% plant availability and 99% grid availability.

Technical inputs to financial analysis

We have estimated the Project cost considering the present market rate with ±10% uncertainty. The retrofitting jobs at the PoC as per project requirement has to be performed. The estimated project costs are INR 110 Lakhs and INR 10,368 Lakhs for 140 kWp pilot project and 18 MWp utility scale projects respectively. The annual O&M cost is estimated at INR 0.7 Lakh and INR 63 Lakh for pilot project and utility scale project respectively. The replacement of inverters once in 25 years of the Project life. The project cost and expected energy generation details are also given for utility scale ground mounted solar and wind projects for a comparative assessment. We have found that the solar project cost is at higher side due to higher PV module cost.

Permits and clearances

We have listed down the list of permits and clearances required at different stages of FSPV / ground mounted solar or wind project development. The Contractor has to fulfil all the required criteria of the CCMC to deploy manpower and perform the task in the lake premise. The Contractor shall contact CCMC's representative and understand the minimum permits and clearances and health, safety and environment (HSE) requirements to perform any task in the lake area.

Technical specification of pilot project

This specification defines the minimum requirements for the design engineering, procurement (manufacturing / supply), construction / erection, testing and commissioning of 140 kWp pilot FSPV project.

1 Introduction

1.1 Background

International Council for Local Environmental Initiatives (ICLEI) - Local Governments for Sustainability has been working closely with a regional network of local governments to achieve tangible improvements in regional and global sustainability through local initiatives. ICLEI – South Asia is working with over 70 cities in the region.

ICLEI – South Asia as a consortium partner is working in Capacity Building for Low Carbon and Climate Resilient City Development project (CapaCITIES) Phase II along with other implementing agency partners namely South Pole Group and econcept AG. CapaCITIES phase – II project is funded by the Swiss Agency for Development and Cooperation, with an objective to strengthen the capacities of Indian cities to plan and implement climate resilience actions, considering both climate change adaptation and mitigation measures in an integrated manner in key urban service sectors. As part of the CapaCITIES project, Ahmedabad and Coimbatore cities receive technical assistance from the project in preparation of the Climate Resilient City Action Plan addressing both climate change mitigation and adaptation aspects, and in identifying and implementing pilot demonstration projects and bankable projects.

Ahmedabad Municipal Corporation (AMC) and Coimbatore City Municipal Corporation (CCMC) have shown interest in deploying FSPV projects in the cities' water bodies to offset their energy consumption with technical support under the CapaCITIES Phase II project. Coimbatore city has proposed to consider one of the four lakes namely Periyakulam lake, Kumarswamy lake, Kuruchikulam lake, and Valankulam lake for FSPV project implementation. Ahmedabad city has proposed the FSPV project to be deployed either at Sabarmati river stretch passes through the city or few lakes in the AMC area. This assignment entails potential assessment and development of a technical feasibility study report for deployment of MW scale FSPV project in the two water bodies. It also includes identification of suitable location for deployment of a pilot project in Coimbatore, providing inputs to the bidding process and bid assessment for the pilot project.

ICLEI has appointed RINA Consulting Pvt. Ltd. ('RINA') and TruBoard Partners ('TruBoard') as consultants ('the Consultants') to assist for conducting following scope of services.

1.2 Scope of services

The scope of services for Coimbatore location are as follows:

- FSPV potential assessment;
- Technical feasibility study for MW scale project;
- Technical inputs to financial analysis; and
- Technical inputs to Request for Proposal (RfP) for pilot scale project.

This report includes the scope of services for Coimbatore location.

1.3 Basis of report

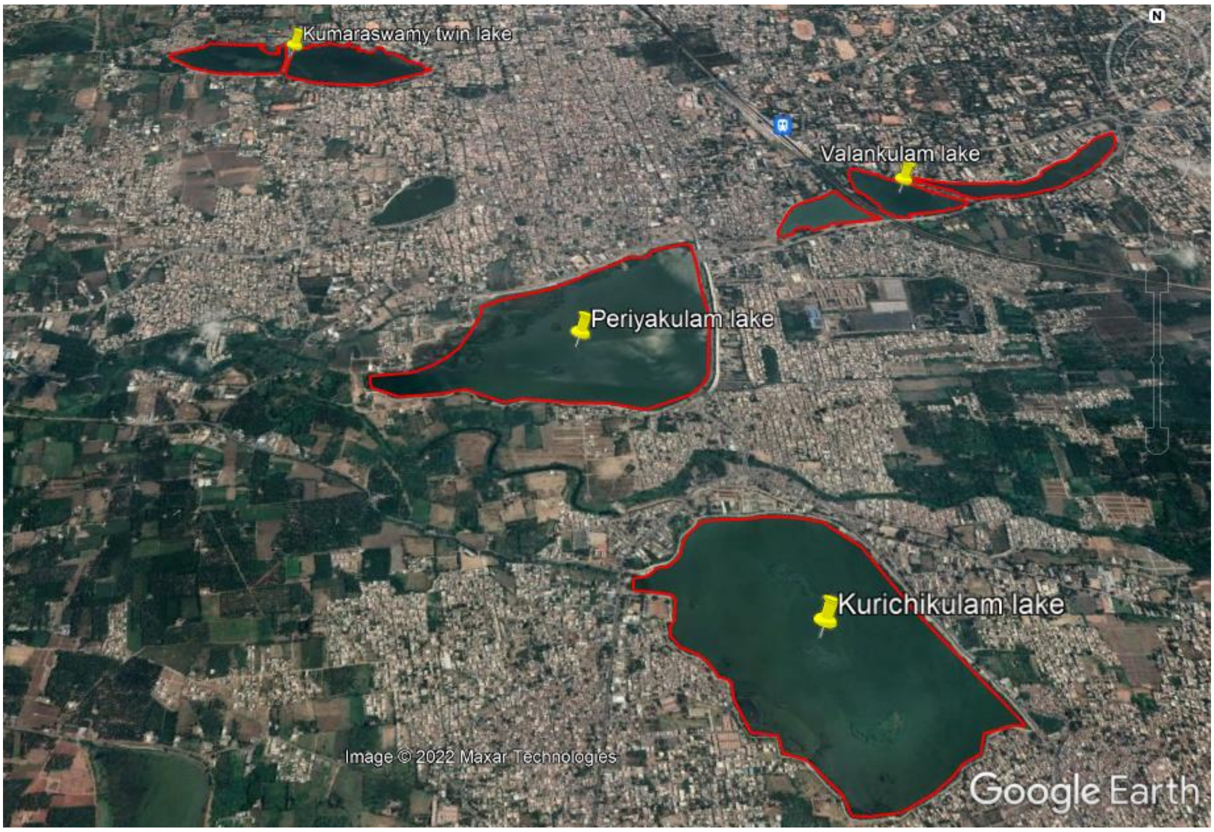
This report is based on the following key inputs received from ICLEI, CCMC and TANGEDCO;

- DPR for rejuvenation of waterbodies and rainwater harvesting for Kumaraswamy lake, Periyakulam lake and Valankulam lake;
- Layout of Kuruchikulam lake, Periyakulam lake, and Valankulam lake;
- List of substations in Coimbatore;
- CCMC energy consumption data;
- Inputs received from TANGEDCO on applicable charges;
- Single line diagram of Ukkadam substation;
- Inputs on power evacuation such as Point of Connection (PoC) and probable line / cable route;
- Climatic parameters from Meteonorm weather database;
- Software tools (PVsyst and AutoCAD);
- Site visit observations;
- The Consultant’s in-house database and tools; and
- Applicable policies and regulations.

2 Potential assessment and study area selection

CCMC is the civic body that governs the city of Coimbatore which is the second largest city in the state of Tamil Nadu located on the banks of the Noyyal River and surrounded by the Western Ghats. Coimbatore has several man-made lakes which are recently rejuvenated as part of the smart city mission under the purview of CCMC. As part of the CapaCITIES project, four lakes out of eight lakes, namely Periyakulam lake, Kurichikulam lake, Valankulam lake, and Kumaraswamy lake have been considered for evaluation of high level FSPV project capacity and study area selection for the feasibility study and pilot project implementation. Figure 1 shows the lakes in Coimbatore considered in this study.

Figure 1: Lakes in Coimbatore considered for the study



Periyakulam lake is the biggest lake in Coimbatore with water spread area of 347 acres followed by Kurichikulam lake of area 335 acres. Valankulam lake of water spread area 154 acres is divided in to three parts by a railway line and a road. Kumarswamy lake of water spread area 145 acres is a twin lake divided by a bund. All four lakes are situated within the premise of CCMC and are well connected by roads.

Figure 2: Study area selection criteria

Site feasibility

- Area occupied by transmission line, island, etc.
- Area allotted for recreational activities, and boating.
- Minimum water depth.
- Part of future development plan.
- Accessibility.
- Construction challenge.
- Operation challenge.
- Potential for project capacity scale up.
- Not affected by shading.
- Hydrographic parameters.
- Bathymetry and topography.
- Climatic parameters.

Power evacuation feasibility

- Available evacuation point nearby
- Voltage level
- Substation and line capacity
- Right of way
- Economics

E&S and H&S aspects

- Irrigation
- Domestic use of water
- Birds
- Flood
- Tree cutting
- Water depth
- Restricted zone due to bird sanctuary, defence use, archeological survey, etc.
- Safe to conduct construction works

2.1 Periyakulam lake

Periyakulam lake is being fed by Coimbatore anicut channel. The lake also receives surplus water from the Selvachinthamani lake located in the upstream (north-west). The lake is provided with the outlet connection to feed the Valankulam lake, which is located east side of the lake.

Figure 3 shows bathymetry map of Periyakulam lake. The bottom surface elevation varies in the range of 3 m. The maximum water depth is 5.4 m. North and West sides of lake reserved for recreational activities. Small islands present within the lake which are sitting place for birds. A 110 kV transmission line to Ukkadam substation is passing through the lake. Boat docking area is in North side and a large part of lake is used for boating. Estimated potential area for FSPV project is 47 acres out of 347 acres of total lake area.

The potential point of grid interconnection for pilot FSPV project shall be at 11 kV distribution line and distribution transformer present in the South-East corner of the Periyakulam lake. The potential point of grid interconnection for large scale FSPV project shall be at 11 kV voltage level of 110 kV / 11 kV, Selvapuram substation, which construction is yet to be started and is planned to be commissioned by 2nd quarter of 2023.

Figure 4 shows the potential area identified for FSPV project installation after taking out unusable area and area allocated for other usage. Both pilot project and MW scale project are feasible to install in Periyakulam lake.

Figure 3: Bathymetry map of Periyakulam lake

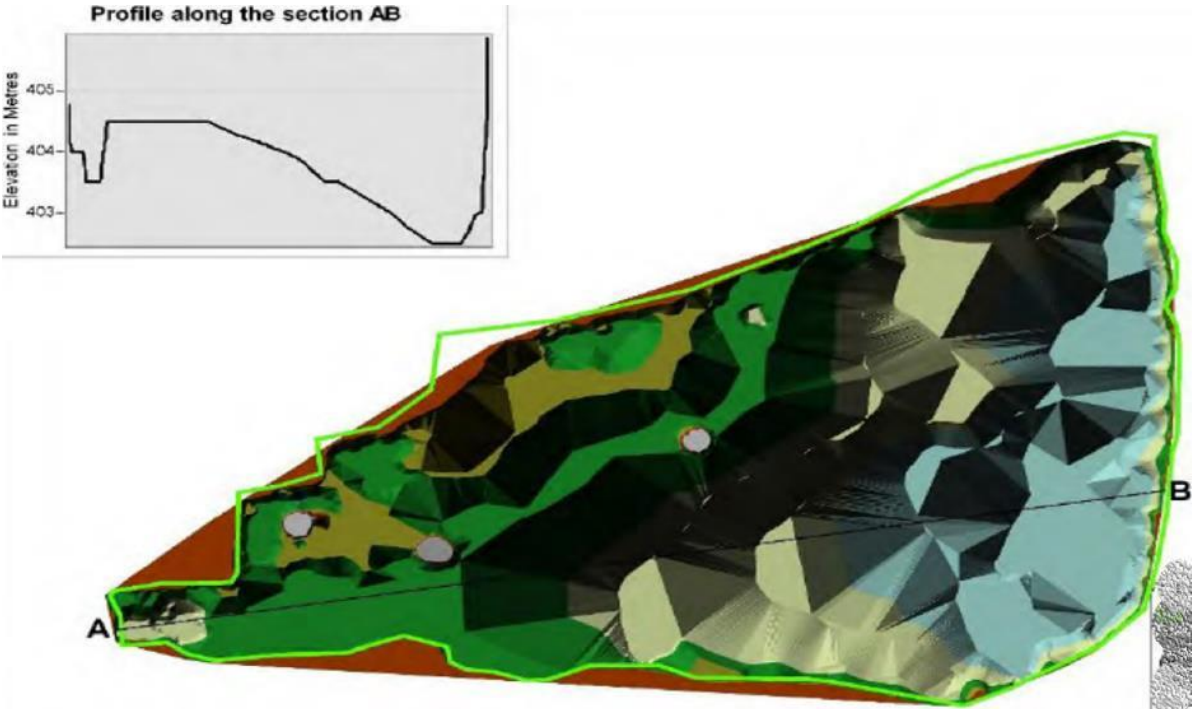
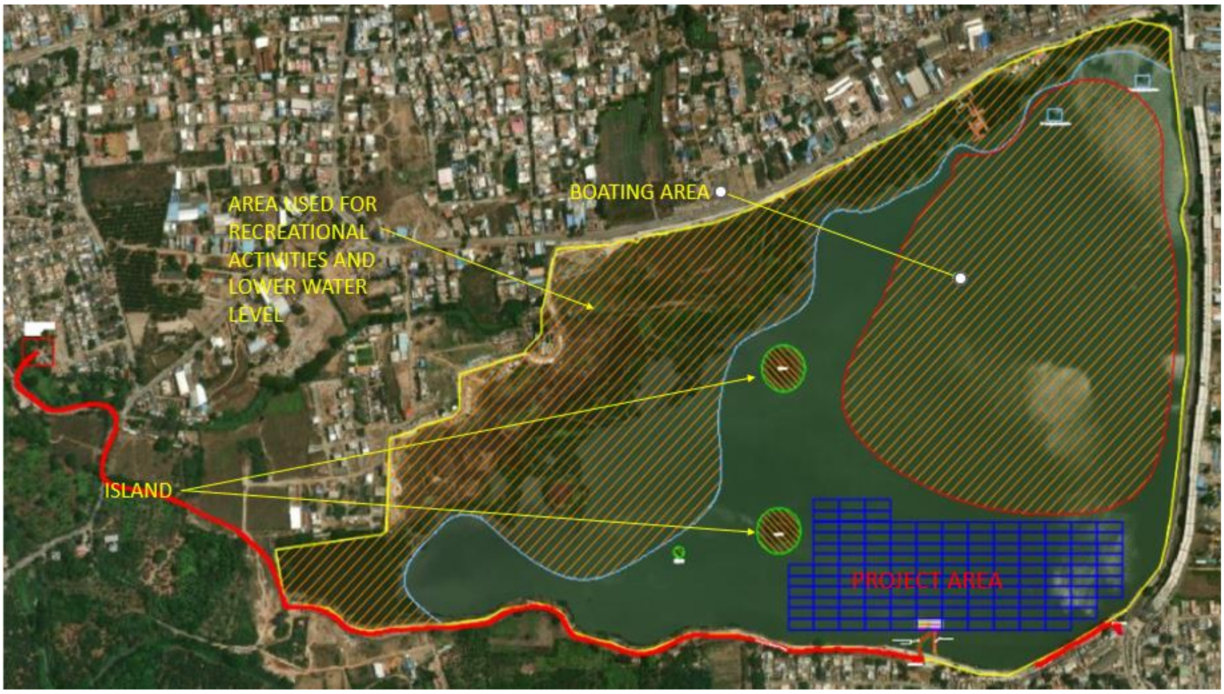


Figure 4: Potential area in Periyakulam lake



2.2 Kurichikulam lake

Kurichikulam lake receives water from Kurichi Anicut in the northwestern side. The excess water is connected to Vellalore lake in the eastern side.

Bathymetry map of Kurichikulam lake is not available. The maximum water depth is 3.3 m. There are large islands within the lake which are sitting place for birds. Water depth is lesser in West and South – West sides of lake. Estimated potential area for FSPV project is 171 acres out of 335 acres of total lake area.

Potential point of grid connection for pilot project shall be available nearest 22 kV line. Potential point of grid connection for large scale project shall be at Kuinamuthur substation at 110 kV.

Figure 5 shows the potential area identified for FSPV project installation after taking out area used for other purposes. There are environmental concerns related to birds habitat in the lake.

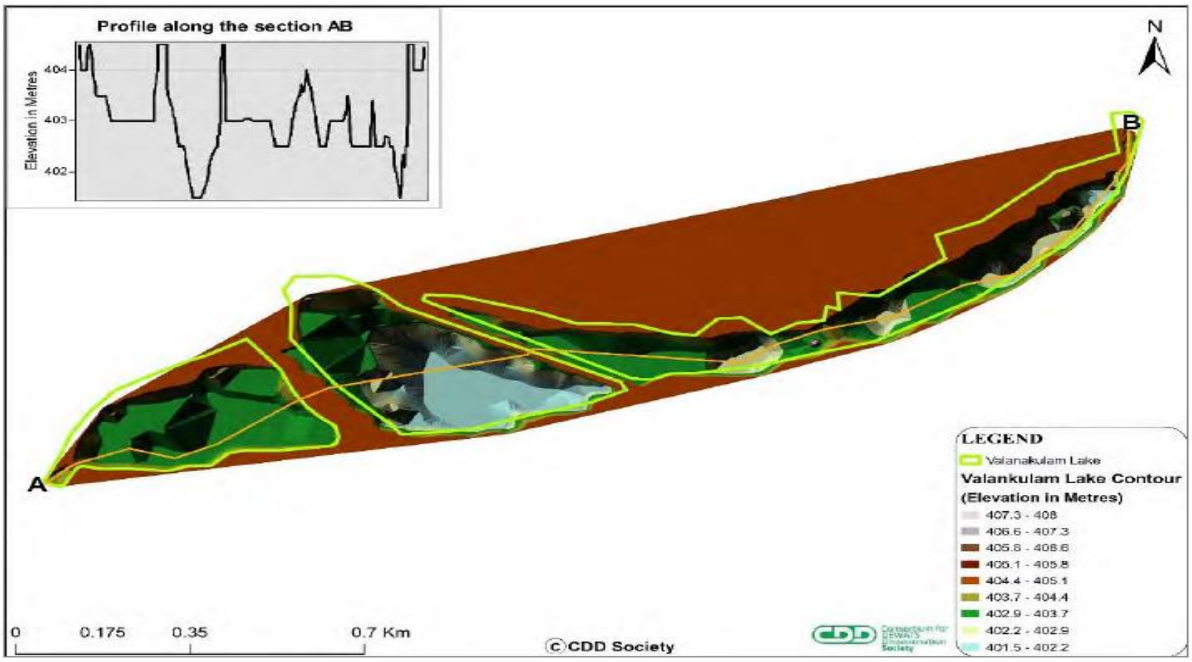
Figure 5: Potential area in Kurichikulam lake

2.3 Valankulam lake

Valankulam lake receives supply from the Coimbatore anicut channel through the Periyakulam lake and surplus into a stream, which falls into the Singanallur lake. Earlier the water used to reach Ammankulam but now it is diverted directly to the Sanganur pallam drain. At times of floods it acts as flood carrier for the city.

Figure 6 shows bathymetry map of Valankulam lake. The bottom surface elevation varies in the range of 3 m. Water depth is less in majority part of the lake. The maximum water depth is 3.8 m.

Figure 6: Bathymetry map of Valankulam lake



Southern part of Ukkadam Valankulam lake is used for boating and recreational activities. There are small islands within the lake. Estimated potential area for FSPV project is 16 acres out of 154 acres total lake area.

Figure 7: Potential area in Valankulam lake

Potential point of grid connection for pilot project as well as large scale project shall be at Ukkadam substation. Figure 7 shows the potential area identified for FSPV project installation after taking out area used for other purposes.

2.4 Kumaraswamy lake

Kumaraswamy lake depends on the surplus water of the adjoining lake Selvampati lake and Krishnampatti lake. It receives sewage water through many sewage inlets.

Figure 8 shows bathymetry map of Kumaraswamy lake. The bottom surface elevation varies in the range of 3 m. The maximum water depth is 3.4 m.

Figure 8: Bathymetry map of Kumaraswamy lake

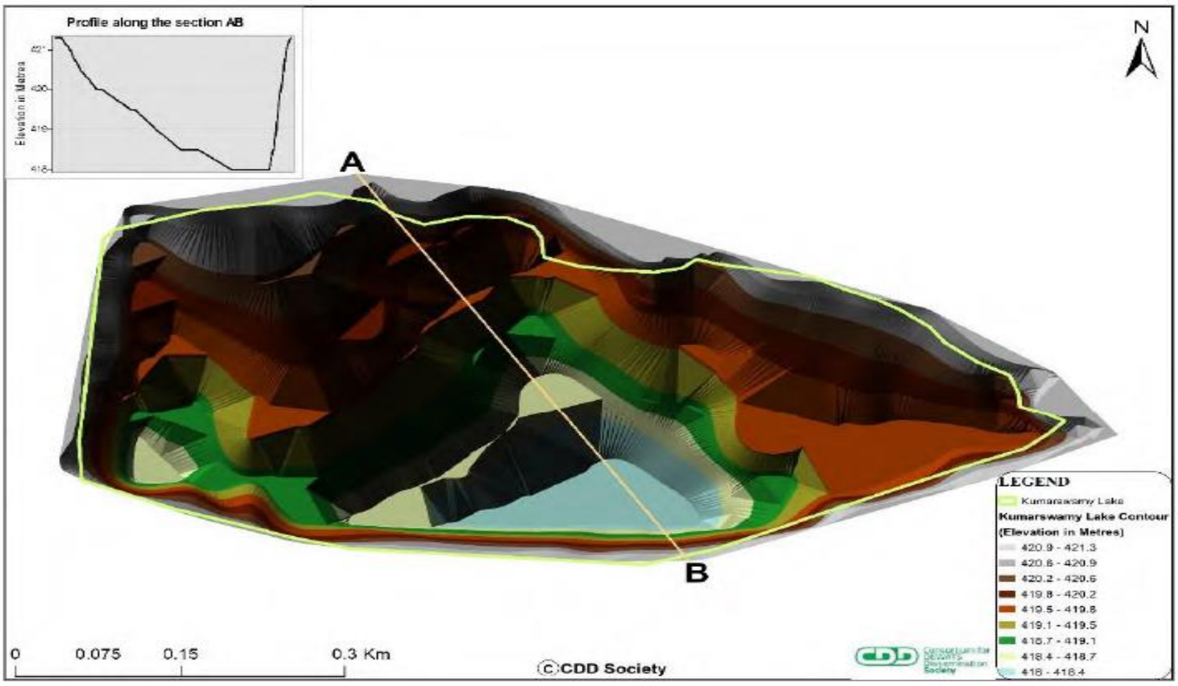


Figure 9: Potential area in Kumaraswamy lake

Lesser water depth in majority part of the lake. Small islands present within the lake. Estimated potential area for FSPV project is 35 acres out of 145 acres total lake area.

Potential point of grid connection for large scale project shall be at S N Palayam substation.

Figure 9 shows the potential area identified for FSPV project installation after taking out unusable area. However, after further consultation with CCMC on the identified area for FSPV project, CCMC raised social issue related to use of the identified area by local people for Vinayak idol immersion. Covering the area with FSPV project shall create a major social issue. Therefore, the FSPV project installation in Kumaraswamy lake is not feasible.

2.5 FSPV potential assessment

Table 2 shows preliminary estimation of FSPV capacity can be installed based on above mentioned factors.

Table 2: FSPV potential

Parameters	Periyakulam lake	Kurichikulam lake	Valankulam lake	Kumaraswamy lake
Total lake area	347 acres	335 acres	154 acres	145 acres
Potential area for FSPV project	47 acres	171 acres	0	25 acres
Approximate FSPV project capacity	• Pilot project: 140 kWp / 111 kW • MW scale project: 18 MWp / 12 MW	0	0	0
Remarks	• Suitable for 140 kWp / 111 kW pilot project from visibility point of view as major development are being constructed around this lake. • Suitable for 18 MWp / 12 MW, MW utility scale project.	• Not suitable for MW scale project due to existing bird's habitat.	• No potential area available for FSPV project.	• Not suitable for MW scale project installation because of local people use the identified area for Vinayak idol immersion.
Pilot Project	✓	×	×	×

Parameters	Periyakulam lake	Kurichikulam lake	Valankulam lake	Kumaraswamy lake
MW scale project	✓	×	×	×
Power evacuation point	• For Pilot project at 11 kV line of TNEB present in South-East corner of the lake. • For MW scale project at 11 kV in the upcoming 110 kV / 11 kV Selvapuram substation	-	-	-

2.6 Study area

The location selected for the development of both pilot as well as MW scale project i.e. 140 kWp (111 kW AC) and 18 MWp (12 MW AC) FSPV project respectively will be at the southern part of Periyakulam lake.

A technical specification of the 140 kWp pilot project is given in Chapter 10.

3 Site assessment

This section describes about Periyakulam lake which include accessibility, energy consumption, and climatic conditions.

3.1 Location

Periyakulam lake is situated in Coimbatore in the premise of CCMC.

Table 3: Site coordinates

Site name	Site coordinates
Periyakulam lake	10.982 °N, 76.957 °E

3.2 Site photographs

The photographs representing identified area, developments in and around Periyakulam lake and visible obstacles are shown below.

Figure 10: Aerial view of North side of lake

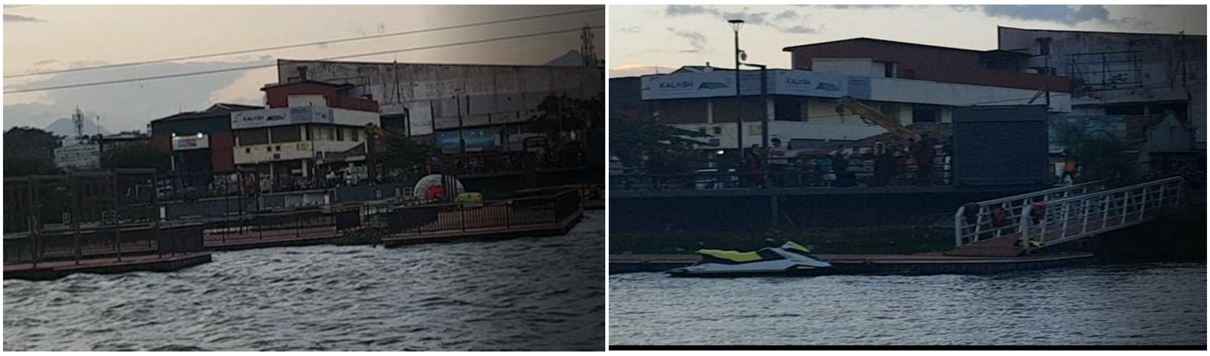
Figure 11: Recreational activities in North-West side of lake

Figure 12: South side of lake

Figure 13: Transmission tower

Figure 14: Proposed area for pilot project in South side

Figure 15: Boating area in North-West side of lake



3.3 Climate

The project site experiences moderate temperature throughout the year. In past, the maximum temperature in Summer reached up to 36 °C and minimum temperature in winter reached up to 22 °C. On an average day in the year, the temperatures are within 25 °C to 33 °C. The city had experienced a moderate humidity between 20% to 70% (except while raining). On any average day, the humidity lies in between 40% to 60%.

The city receives rain in between May and November due to both South-West and North-East monsoons. Table 4 shows the climatic parameters experienced at sites.

Table 4: Climatic parameters

Parameters	Values	Reference
Global Horizontal Irradiation (GHI)	1,875 kWh/m^2	Meteonorm weather data
Ambient temperature	26.5 °C	
Basic wind speed	39 m/s	IS 875 part - 3
Seismic zone	Zone – III	IS 1893 part - 1

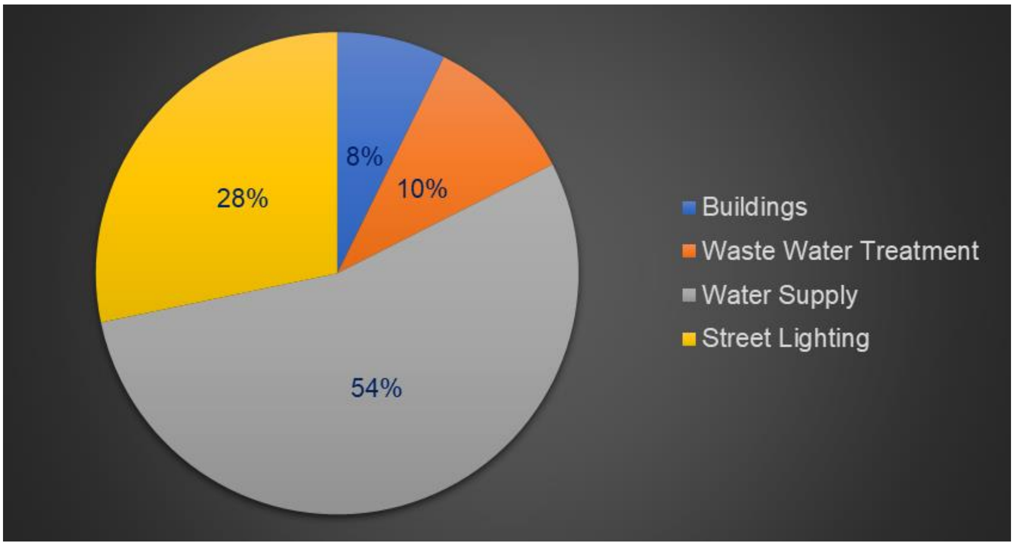
3.4 Accessibility

The Periyakulam lake is situated near to Ukkadam bus-stand. This lake is located North of the River Noyyal. The lake is being fed by Coimbatore Anicut channel from the Coimbatore Anicut on Noyyal River. The lake also receives surplus water from the Selvachinthamani Lake located in the upstream (north-west). The Periyakulam is well connected to Coimbatore and other major cities by road. The nearest railway station is Coimbatore Railway Junction, which is about 2 km from Periyakulam Lake. The nearest airport is Coimbatore International Airport, which is about 12 km away from it. The Periyakulam lake is comes in the Smart City plan powered by the Government of India in June month of 2020.

3.5 Energy demand

Electricity consumption in CCMC area is by domestic consumers, public lighting, educational institutions, industries, and commercial activities. Out of these, as per available data in FY 2019-20, total electricity consumption by the Coimbatore Corporation Facilities is 80 Million Units (MU). Figure 16 shows the breakup of total electricity consumption. Water supply consumes maximum electricity followed by street lighting. The solar PV project capacity of about 55 MWp shall be required to offset total energy consumption with renewable energy. At present, CCMC has 5.6 MWp solar PV project in operation. An additional capacity of more than 50 MWp solar shall be required considering future electricity demand.

Figure 16: Electricity consumption by Coimbatore Corporation facilities



4 Technology selection

FSPV plant is the PV plant that floats on water bodies. Floating solar projects have large potential to generate electricity without using valuable land or roof area. FSPV installation is a new opportunity for scaling up solar generation capacity, especially in countries with high population density and competing issues for use of available land area. They have certain advantages over ground mounted and rooftop PV installations, including utilization of existing electricity transmission infrastructure of hydropower sites if planned in the reservoir of a hydropower plant, and improved energy generation due to the potential cooling effects of water and the decreased presence of dust. Besides producing clean solar power, floating solar plants can help with water management. They reduce the loss of water to evaporation as they limit air circulation and block sunlight from the surface of the water. In addition, floating solar may prevent algae production, potential for lowering water treatment cost.

The key components of a FSPV plant are as follows:

- PV module;
- Float or pontoon;
- Anchoring and mooring;
- Inverter;
- Cable; and,
- Earthing and lightning protection.

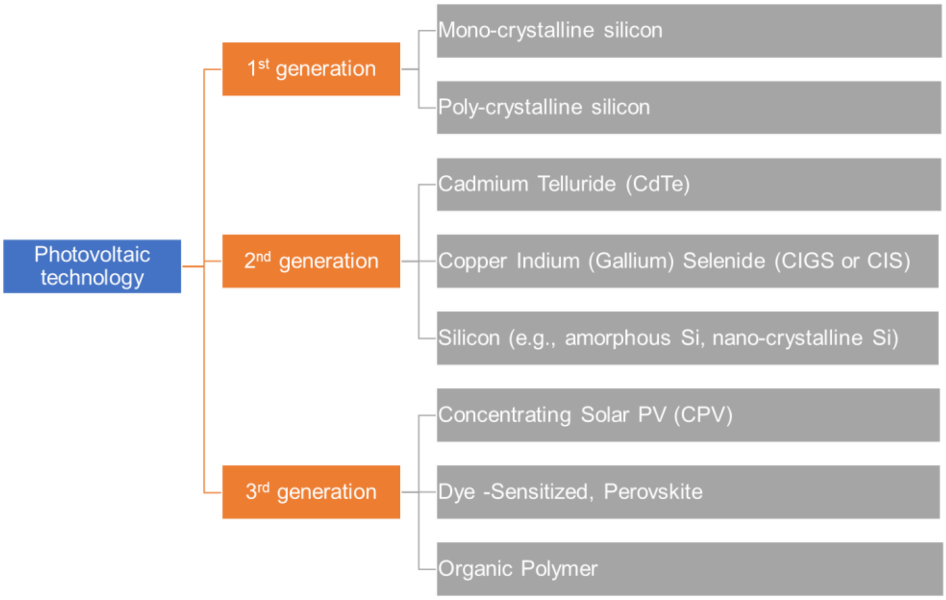
4.1 Technology type

The available technological options for different components of FSPV plants are described in this section.

4.1.2 PV modules

Traditionally, solar PV Modules are made using various forms of silicon, but technological advancements have resulted in manufacturing PV modules employing other semiconductor materials often referred to as thin-film technologies. Each of the various PV module technologies has unique performance characteristics and cost impacts that drive competition within the industry. Cost and performance can be further affected by the PV application and specific configuration of a PV system. Solar PV technologies are usually classified into three generations. Major technologies in each of these three generations depending upon material used and the level of maturity have been indicated in Figure 17.

Figure 17: PV module technologies

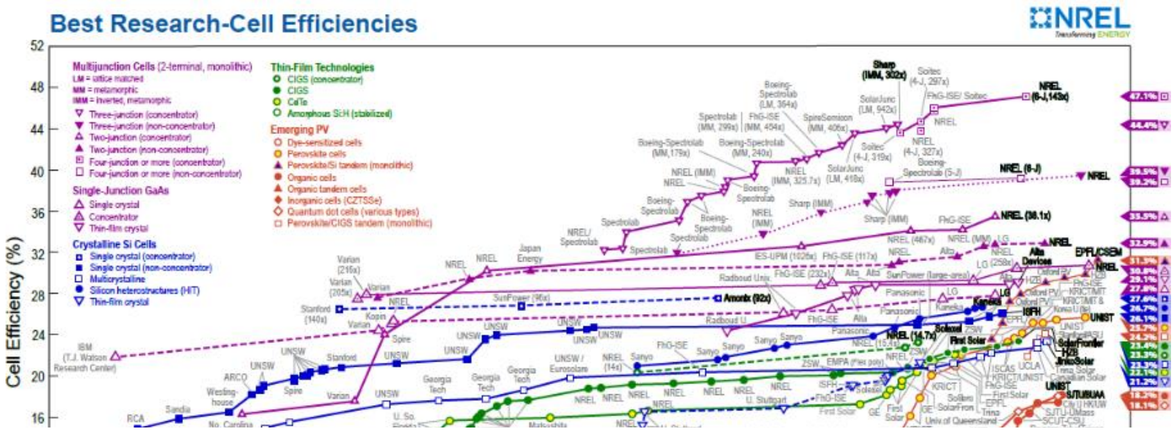


National Renewable Energy Laboratory (NREL) has developed a chart with all available technologies indicating the highest confirmed conversion efficiencies for research cells. This chart[1], for a range of photovoltaic technologies, plotted from 1976 to 2021 as shown in Figure 18. This chart indicates the cell efficiency results of 28 different subcategories by distinctive coloured symbols.

Figure 18: Cell efficiency of different PV technologies

range of photovoltaic technologies, plotted from 1976 to 2021 as shown in Figure 18. This chart indicates the cell efficiency results of 28 different subcategories by distinctive coloured symbols.

Figure 19: Cell efficiency of different PV technologies



[1] https://www.nrel.gov/pv/cell-efficiency.html

It is to be noted that there are cells with higher efficiencies available as indicated in Figure 18 but most of these higher efficiency cells are in the research scale only. These are neither available commercially nor proven in the utility-scale solar projects. Presently, out of the various PV technologies, the mono-crystalline / poly-crystalline silicon and the thin-film are the most commercially developed globally. Crystalline silicon technology dominates the global installed capacity of solar PV and accounts for approximately 95% followed by the thin-film technologies for the remaining 5%[2] capacity.

Constant innovations to boost energy generation have resulted in cutting edge crystalline silicon technologies. These innovations have resulted in further improved versions in this segment such as Passivated Emitter and Rear Cells (PERC), Half-Cut Cells and Bifacial Cells, Glass-Glass Modules etc. which are briefly described below.

PERC: PERC cells employs two different features which includes applying a passivation film on the rear surface of the cell and using chemicals to create tiny pockets in the film that absorb more light. The cell's front side receives direct sunlight while the rear side soaks up scattered and reflected light. These additional features boost energy generation in solar PERC cells compared to conventional ones.

Half-Cut Cells: Solar cells are cut into half the size of the conventional size. The half-cut cells generate half the current of a standard cell. There are several advantages to this technology, both in the performance and in the durability:

- Increase panel efficiencies (reduced resistive losses in the cell interconnection of solar modules leading to higher output);
- More resistant to cracking (smaller cell size); and
- Less affected by partial shading.

Bifacial Solar Cells: Bifacial solar cells have the capability to generate electricity by capturing irradiation on both sides and thus offer good potential to increase the yield of the PV power plants.

Glass-Glass Modules: A glass-glass PV module is employed with bifacial solar cells to allow capturing irradiation on both sides. If employing thin glass sheets on both sides, modules of thinner profile could be achieved, resulting in potential better heat management. Glass-glass modules have longer life compared to the glass- polymer back sheet modules for various reasons: glass is more durable than polymer, less delamination risk, better sealing, higher tensile strength. Glass-glass modules are also more resistant PID as they are more able to withstand high humid environment. Glass-glass modules allow for eliminating the use of frames, which is also a cost advantage.

We have assessed the commercially available technologies and considers recommending the PV module technology based on efficiency, ratings availability from tier-1 manufacturers at reasonable cost and suitable for FSPV installations. Table 5 represents a comparative assessment of commercially available PV technologies. We recommend mono crystalline Silicon (c-Si) PERC modules based on the comparative assessment given in Table 5.

[2] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf

Table 5: PV module technology comparison

S. N.	PV module technology	Manufacturer	Rating (Wp)	Efficiency (%)	Cost[3] (INR / Wp)	Suitability for roof mount	Availability
1	Mono c-Si	Jinko, JA, Canadian, Trina	355~415	19 ~ 20	21.1	Suitable	Moderate
2	Mono c-Si PERC		440~480, 530~550	20 ~ 22	22.6	Suitable	High
3	Mono c-Si PERC Bifacial		530~550	20 ~ 22	23.4	Bifacial gain is not significant for low roof clearance installations	Moderate
4	Poly c-Si		325 ~ 345	16 ~ 17	17.2	Suitable	Low
5	Poly c-Si PERC		345 ~ 390	18 ~ 19	18.7	Suitable	Moderate
6	Thin film (CdTe)	First Solar	420 - 450	17.0 – 18.2	-	Not suitable for string inverter due to short string size	Moderate

4.1.2.1 Selection of Solar PV Technologies for FSPV Projects

Crystalline-silicon technologies are the most deployed in global solar PV installations. Considering the maturity, long-term proven track record and availability of the crystalline silicon technology, crystalline silicon technology is the preferred one for the FSPV installations.

Bifacial modules would be beneficial in cases where the ground surface offers higher reflectivity (i.e., high albedo) and promote diffused radiation. Various studies published so far indicate employing bifacial modules on FSPV plants would not lead to possible gains, although many further studies are ongoing to explore this further.

Mono PERC / mono PERC Half-Cells are the advanced version of the crystalline silicon technologies which resulted in the higher efficiencies. Consequently, lower footprint area requirement will be the added advantage by way of reducing cost of floaters as well as the anchoring and mooring costs.

Beyond performance of the PV modules, failure modes should be considered when selecting PV modules for use in FSPV plants. FSPV plants encounter higher risks of exposure to moisture, mechanical stresses and potential induced degradation (PID Table 6 below provides several options available for improved reliability of PV modules used in FSPV plants.

Table 6: PV module failures and mitigation strategies for FSPV plants[4]

Environmental Stresses	Failure Mode	Mitigation Strategies
Moisture	• Corrosion; • Hydrolysis; • PID.	• Moisture resistance materials; • More durable encapsulant materials: olefin-based (TPO, POE), Ionomer; • Glass-glass instead of glass-back sheet;

[3] Cost data of few technologies are not available at the time of writing the report.

[4] source: Adapted from Harwood 2018 and World Bank floating solar handbook for practitioners

Environmental Stresses	Failure Mode	Mitigation Strategies
		• PID resistant cells; • System level PID compensation.
Mechanical stresses	• Interconnect fatigue; • Cell cracking.	• Increase module stiffness; • Cells and string on neutral axis; • Cut cells (for fatigue); • Lower modulus encapsulants; • Multi busbar/ wire interconnects.
Hotspot / shading	• Arcing; • Melting / cracking.	• Fewer cells per bypass diode; • Higher relative temperature index material; • Anti-soiling coatings.

Given the above circumstances and technology status, the following aspects should be considered in selecting PV modules for FSPV installations:

- Advanced solar PV modules technology such as mono PERC or mono PERC half cut cells is preferred;
- Glass-glass technology offers better hermetic seal to the inner components. On the other hand, glass-glass modules are heavier which would lead to higher demand both on buoyancy and mechanical mounting system. Moreover, if frameless glass-glass modules are chosen, the frameless design is less stiff which may lead to higher bending or vibration under dynamic load conditions. Also, there is a higher risk of moisture ingress if the application of edge sealant is ineffective. This can be addressed through proper quality control in module manufacturing process;
- Resistance to moisture and UV resistance could be further achieved with improved encapsulation; presently, the use of olefin-based encapsulants is preferred for modules on FSPV installations;
- In regard to mechanical stress, using modules with half-cut cells would address the risk better (reduces strain on ribbons). Manufacturers have also come up with multi-busbars in modules which would help in collecting the current even when the cells crack due to mechanical stresses;
- Majority of the solar PV module manufacturers are producing modules which are PID-resistant. This requirement should be part of a requirement for FSPV plants;
- To minimize maintenance costs, special coatings to minimize soiling accumulation on the modules which may help in reducing the effect of shading on the modules.

4.1.2.2 FSPV temperature cooling effect and field results

Studies have been and are being conducted by different experts around the world to better understand the thermal behaviour of PV modules in floating solar systems; the objective is to obtain a reliable method to quantify the cooling benefits from the operating environment; as this could strengthen the argument of one of the key benefits of floating solar (in addition to avoiding use of land, among others). The general conclusion is that the magnitude of the water evaporative cooling effect varies with the geometry of the floating solar system. Research studies on the temperature cooling effect of floating solar system conducted by experts from Japan and Korea have reported gains in energy yield beyond 10% when compared to the land system counterparts.

4.1.3 Floats

This section describes different type of floats available in the market and their pros and cons considering the project site conditions.

4.1.3.3 Modular pontoons

The mounting structure may be supported on a variety of different floating platforms which predominantly feature High Density Polyethylene (HDPE) components. All floating platforms will require anchoring solutions either utilising the reservoir's banks or underwater. The final design of the mooring system should be informed by the following:

- The recommendations of the reservoir's geotechnical survey, if available;
- The suitability of reservoir banks for anchor installation, if permitted; and,
- The cost of inspections and maintenance.

Below is a brief description of some of floating systems / suppliers with commercially available or development stage products at the time of writing. This is not intended to be an exhaustive list but rather provides some indication of the various system architectures available. Other suppliers may be available to support a project and should be assessed through competitive tender at the appropriate time. Manufacturers are understood to be willing to collaborate with developers to develop bespoke floating systems. We recommend that the following considerations are taken into account when selecting a supplier:

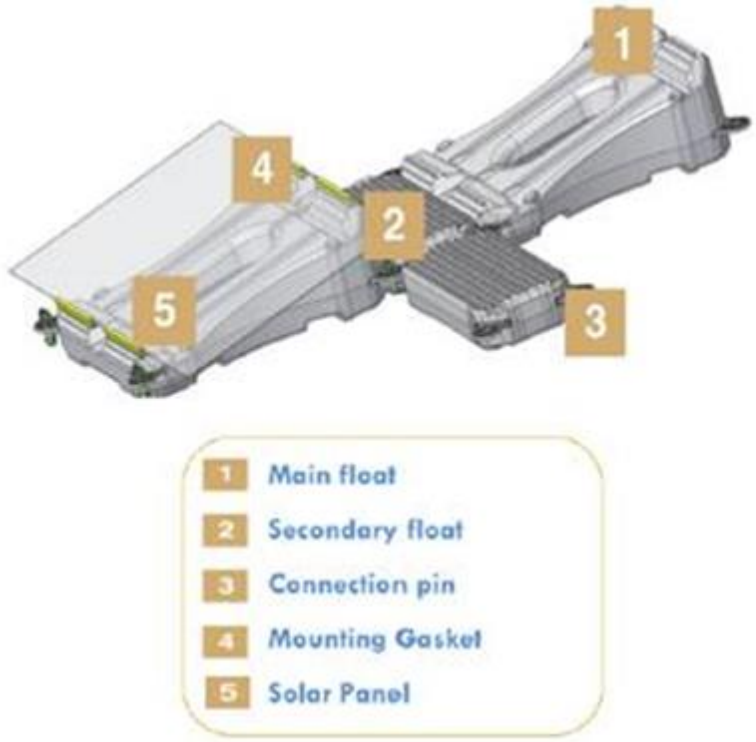
- Supplier track record;
- Floating technology track record;
- Buildability – ease of assembly and decommissioning;
- Provisions for O&M access;
- Costs; and
- Warranty.

Anchoring solutions are varied and are dependent on local soil characteristics and whether they are submerged or are installed on the banks of the reservoir. Typically, steel anchor heads are driven into the soil and connected to steel shackles and cables, which are in turn connected to the floating platform. Alternative solutions opt for concrete blocks that are placed on the bottom of the lake. Options not requiring under water deployment, making use of lake banks or anchoring on poles are generally cheaper to install, as well as more accessible for O&M personnel. An indicative selection of mounting systems available is provided below.

Example Technology: Ciel et Terre (C&T)

C&T claims extensive project involvement in over 120 FSPV projects. Figure 20 shows its standard floating platform system with one module per float. Figure 21 shows the typical arrangement involving the standard C&T primary and secondary floats.

Figure 20: Standard C&T primary and secondary floats

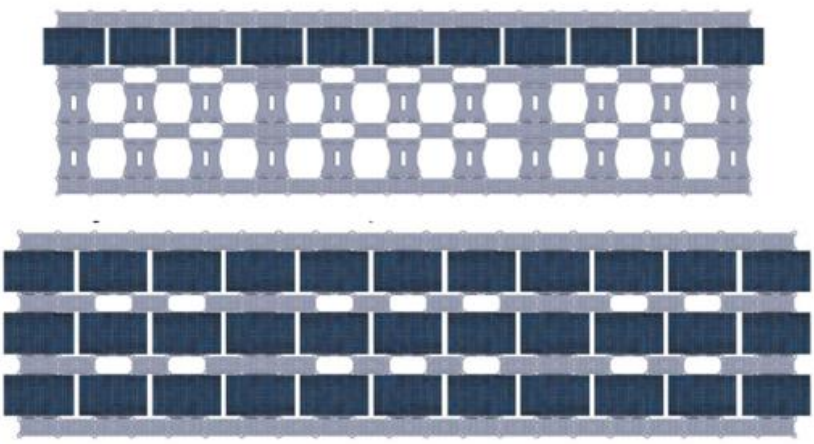


The floats are connected to each other to create an island, as shown in Figure 21.

This type of float can withstand the following conditions:

- Maximum water speed: 1 m/s;
- Wave height: up to 1 m;
- Temperature: between -10 and +50°C;
- Wind speed: specific to the anchoring system;
- Floats resistant to UV radiation and corrosion; and
- Maximum weight: 96 kg for main floats and 50 kg for secondary floats.

Figure 21: Typical layout for a floating platform made up of standard C&T floats



Example Technology: Sungrow

Originally an inverter manufacturer, Sungrow has quickly become a leading developer of FSPV systems and manufacturer of FSPV components. As of June 2019, Sungrow accounted for 60.94% of total installed FSPV capacity and 9.09% of the total number of FSPV projects installed within the top 200 FSPV projects internationally[5]. Most notably, Sungrow is listed as the FSPV system supplier for the 150 MWp plant in Guqiao Huainan, China, which currently ranks as the world's largest FSPV plant.

Sungrow manufactures and supplies the following floating pontoons which are similar in nature to other manufacturers, comprising:

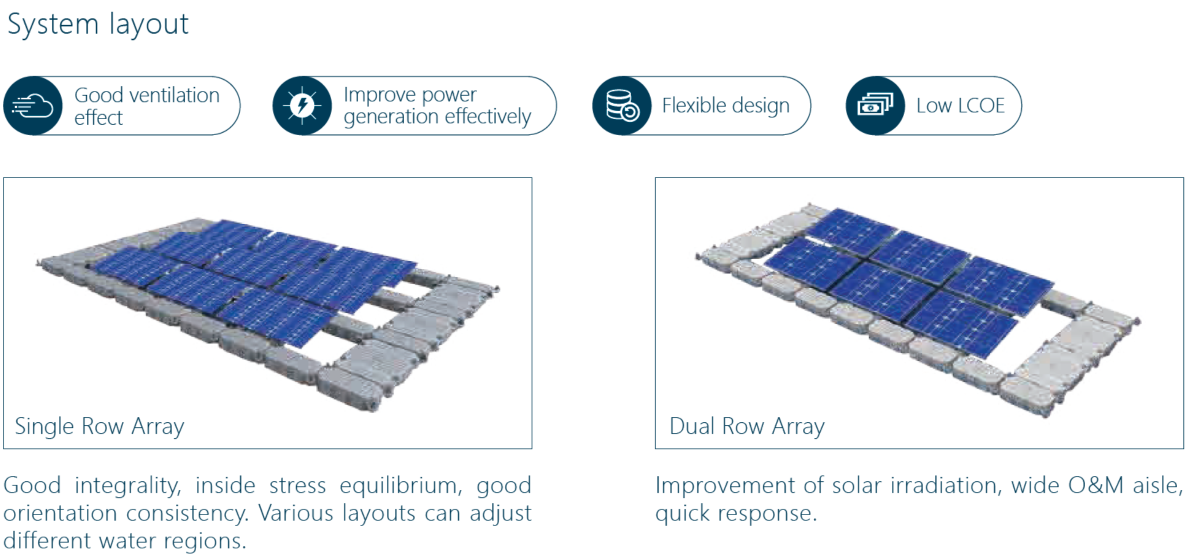
- Main floating bodies
- Aisle floating bodies
- Multifunction floating bodies for ancillary equipment

These components allow for arrays to be configured in virtually any manner as per site requirements. Figure 22 shows a typical float assembly. Figure 23 shows how the floats are configured into a floating platform.

Figure 22: Sungrow float assembly

5 Solarplaza, "A Comprehensive Overview of 200+ Global Floating Solar Plants", Solarplaza (2019) https://www.solarplaza.com/channels/future-grid/12067/200-global-floating-solar-plants/

Figure 23: Sungrow typical system configuration



Other notable manufacturers of floating pontoons include:

- Kyoraku (Japan);
- FloatPac (Australia);
- Isingenere (Spain); and
- ZNZC (China).

Example Technology: K2 Systems

A company with headquarter in Germany, K2 Systems supplies FSPV mounting systems with the following features:

- Allows for relatively high installable capacities due to panel/float arrangement; and
- East-West facing module installation.

RINA understands that K2 has limited experience in installed projects compared to C&T, at the time of writing. Figure 24 shows the basic K2 Systems mounting arrangement.

Figure 24: Basic K2 Systems float

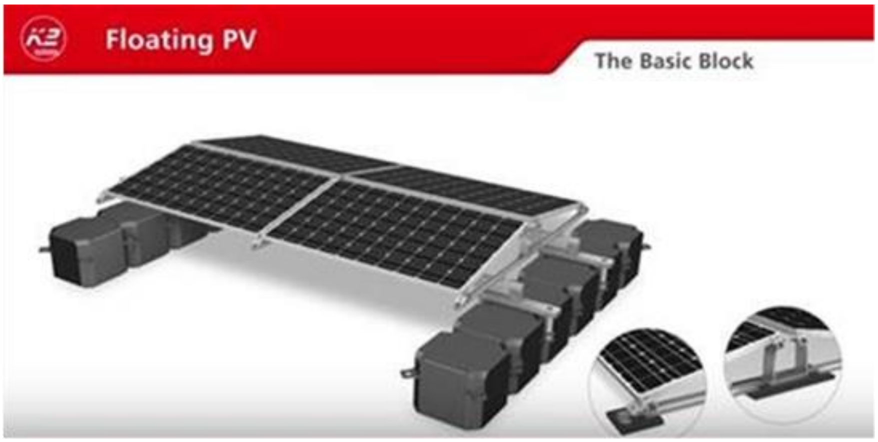
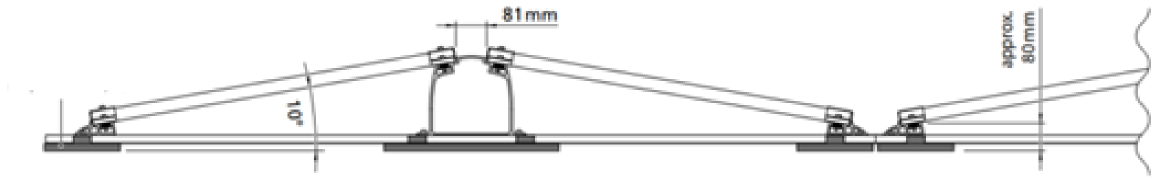


Figure 25: Basic K2 Systems mounting arrangement



4.1.3.4 Modular raft

An alternative to the floating pontoon design is to assemble a homogenous rigid metal frame and place it on top of a fixed floating structure to form a type of raft. The primary advantages of this design are the relative ease of sourcing and transporting the necessary components required. Additionally, there is added rigidity to the system which may relieve stress on PV module connections etc. However, this same rigidity can also result in mechanical stresses caused by water movement being concentrated on specific weak points.

Manufacturers of such systems include 4C Solar (Figure 26), Koine Multimedia (Figure 27), and Takiron Engineering (Figure 28).

Figure 26: 4C Solar floating raft

Figure 27: Koine Multimedia floating raft

Figure 28: Takiron Engineering floating raft

4.1.3.5 Ferrocement float

Ferrocement is a type of thin-wall reinforced concrete commonly constructed with hydraulic-cement mortar reinforced with closely spaced layers of continuous and relatively small wire mesh. The mesh may be made of metallic, plastic or other suitable materials. Ferrocement is a construction material that has been proven for qualities of crack control, impact resistance and toughness, largely due to close spacing and uniform dispersion of reinforcement within the material.

Manufacturers have used ferrocement based platforms for installing FSPV plants as shown in Figure 29.

Figure 29: Sample projects with ferrocement floats[6]

[6] https://adtechindia.com/

Advantages and disadvantages of ferrocement float design are listed in Table 7.

Table 7: Advantages and disadvantages of ferrocement float design

Advantages	Disadvantages
• Platforms with superstructure being in use for the last fifteen years for other applications like housing and resorts etc., and hence time tested. • Stability of the platform is much better due to greater self-weight and lower centre of gravity. • Higher safety due to larger number of watertight compartments. • Laminated ferrocement platforms will not corrode and need virtually no maintenance. • In the unlikely event of repair, its repair cost is very low. • Easy to fix the superstructure to the ferrocement base.	• Very limited manufacturers adopt this technology. • Relative higher cost when compared to other technologies adopted. • Not field proven as very limited projects have been deployed with this technology. • Not easy to install on water body.

4.1.3.6 Floating membrane

These systems have been developed based on Norwegian fish farming techniques and comprise an impermeable polymer membrane placed on top of the water and inside a floating HDPE circular floater pipe which secures it in place. Modules are fixed in aluminum rails that are attached to fixing points and fixed onto the membrane with keder tracks, placing them at a 0° tilt angle.

Table 8: Advantages and disadvantages of floating membrane

Advantages	Disadvantages
• The ability to withstand high wind speeds (modelled up to 275 km/h); and • Direct contact between PV modules and the water surface reduces module operating temperatures	• Rainwater has to be pumped out with a pump; • Requires special modules: double sided glass, frameless (currently higher costs than conventional framed modules); and • There have been soiling issues observed due to flat panels accumulating pollution without runoff.

4.1.3.7 Novel technologies

There are currently a number of further novel technologies being developed for FSPV electricity generation. These technologies are still in the theoretical or proof of concept phases and therefore not realistic options for project implementation.

4.1.3.7.1 Submerged FSPV

The premise underlying submerging PV modules directly beneath the water surface is that the advantages of module cooling will be realised, while also reducing the mechanical stresses applied to FSPV systems by wind and waves. Experimental plants have been developed (Figure 30)

Figure 30: Experimental submerged FSPV system[7]

4.1.3.7.2 High-wave offshore

While off-shore FSPV systems in the oceans present an immense opportunity in terms of available space and the number of major cities located in coastal regions, there are numerous challenges to be overcome for such systems to be realised. Most notably:

- Wind and waves present a more significant challenge due to their intensity in the ocean relative to inland water bodies
- Tidal movement and currents present additional challenges for mooring and anchoring
- The ocean marine environment is more conducive to corrosion
- Soiling due to bio-fouling is more likely

There are already some experimental plants in operation, but the industry body of knowledge needs to be further developed. Most recently, a consortium comprising Tractebel, Jan De Nul Group, DEME, Soltech and Ghent University have announced their intention to develop this technology further[8].

4.1.3.8 Fixed angle vs. Trackers

There are several other float systems available including one that attempts to permit the rotation of FSPV arrays in order to track the sun and increase yield. In this case it is claimed by its developers – Hanwha Q Cells and Solkiss – to be approximately 20% more efficient; which is in line with theoretical efficiency increase between fixed and trackers. However, we have not seen sufficient independent data nor field data to verify these claims.

Indications are that the intention is to rotate an entire FSPV island around the Z axis so as to track the Sun's azimuth angle. This may be achieved by mounting a single pile in the middle of the island and using cables, propellers, or other such actuators to induce rotation around this pile.

7 World Bank Group, ESMAP and SERIS. 2019. Where Sun Meets Water: Floating Solar Market Report. Washington, DC: World Bank.

8 https://tractebel-engie.com/files/attachments/.2318/PRESS-RELEASE-HIGH-WAVE-OFFSHORE-SOLAR-PANELS-SOON-A-REALITY.pdf

Figure 31: Azimuth tracking by cable[9]

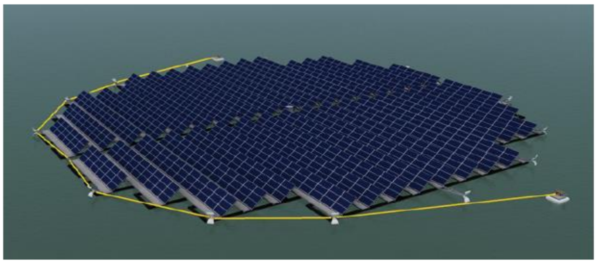
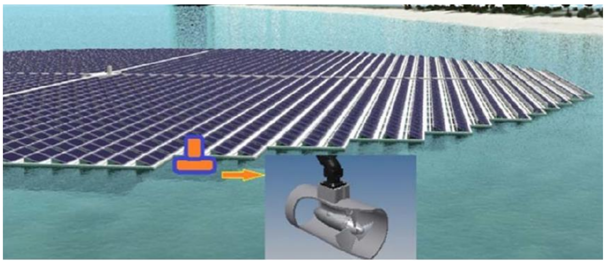


Figure 32: Azimuth tracking by propeller



4.1.3.9 Selection of Floats (Conclusions)

The majority of large scale FSPV plants deployed worldwide were carried out using HDPE floats where the solar PV modules are installed on pontoons above water. However, recent technological advancements have resulted in floating platforms with Basic K2 Systems float (with pontoons and metal frames) which offer higher air circulation to the modules. Both these float technologies have enough manufacturing base or can be manufactured locally.

HDPE floats and floats with combination of pontoons and metal frames can be explored for the FSPV plant considered in this study.

4.1.4 Anchoring and mooring

In order to fix the system on water, the following different anchoring systems can be considered:

- Fixed anchoring on shore;
- Deadweight anchoring on shore;
- Submerged anchor fixed to the bottom; and
- Deadweight submerged anchor.

9 Rosa-Clot, M. and Tina, G., The Floating PV Plant, (2018)

4.1.4.1 Fixed anchoring on shore

An example of the distribution of two anchorages on a part of a floating island is represented by the red lines in Figure 33.

Figure 33: Distribution of the anchoring system on the floating island – top view

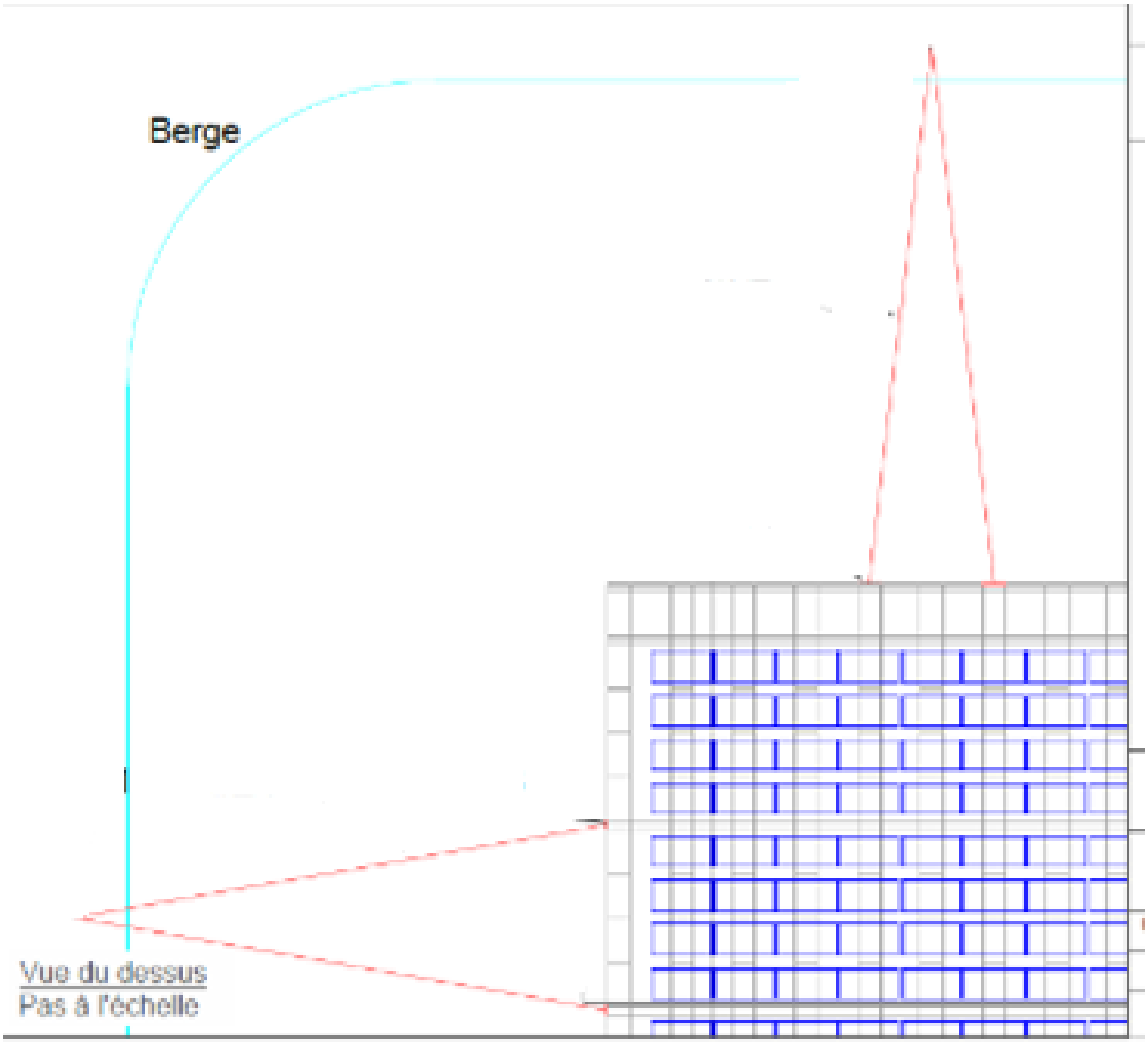


Figure 34: Side view of anchoring system

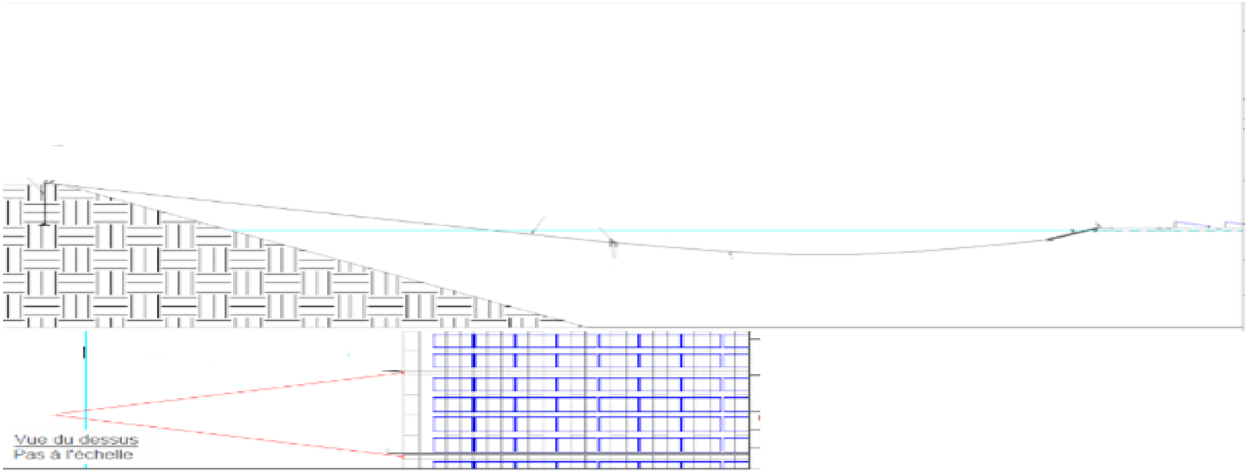
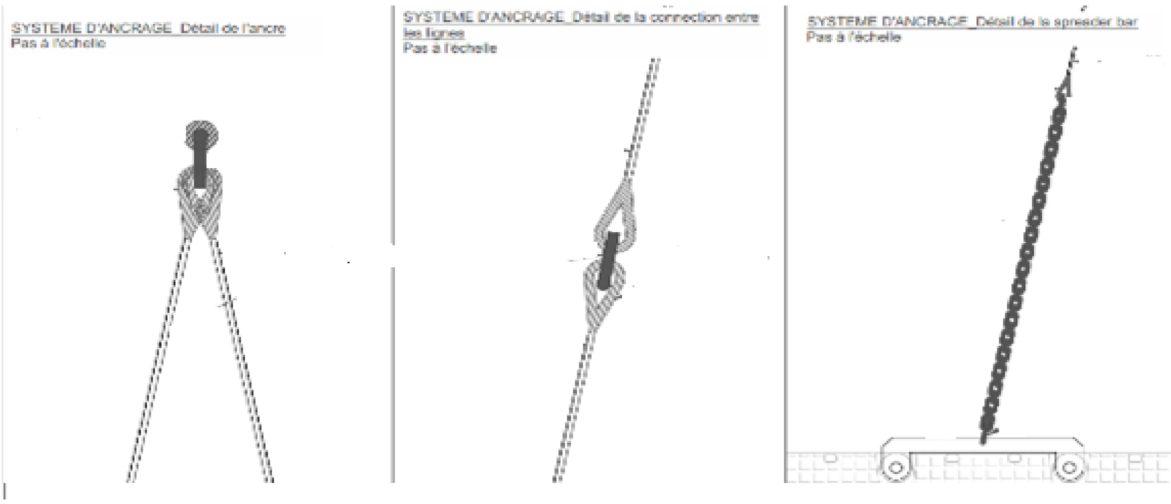


Figure 35: Anchor diagrams



The length of the anchoring system is calculated to take into account potential variations in water level. In this example, the anchor line is terminated by a chain at the FSPV island. The anchor cable is immersed over almost its entire length. On the shoreline, the visual impact of the anchor is minimal.

The figures below depict the anchoring system on the shoreline, island and its installation:

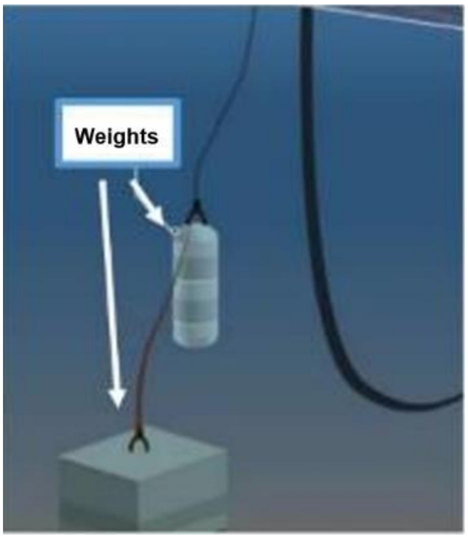
Figure 36: Shore-side anchoring system	Figure 37: Anchoring system fixed on the FSPV island side	Figure 38: Shore-side anchor installation
		

The main advantage of this anchoring solution is its robustness, the fact that it is non-intrusive in relation to the site and that maintenance does not require the intervention of divers.

4.1.4.2 Submerged anchoring system

An alternative solution can be the use of shoreline anchoring with a deadweight anchor. This system does not require ground penetration but has a much larger footprint. A schematic of such anchorage system is shown in Figure 39.

Figure 39: Submerged anchorage system

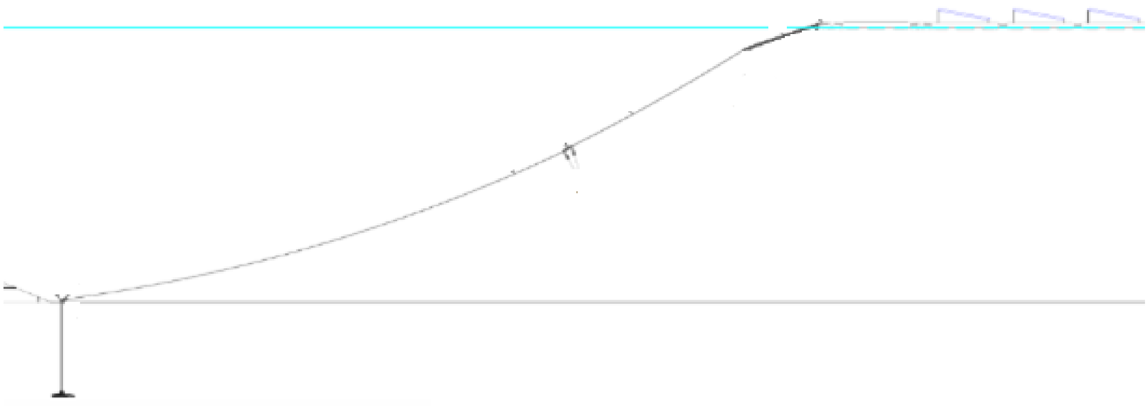


This system is the most commonly used anchoring system for the construction of floating solar plants.

4.1.4.3 Submerged anchorage system fixed to the bottom

For anchoring the FSPV platform when the shore is a large distance from the island, submerged anchoring is typically used. A schematic of such anchorage system is shown in Figure 40.

Figure 40: Submerged anchorage system fixed to the bottom



4.1.4.4 Comparison of different anchoring systems

A table summarizing the advantages and disadvantages of each option described above is shown in Table 9.

Table 9: Anchoring – Summary table

Technology	Advantages	Disadvantages
Anchoring on a fixed bank	• Non-intrusive with respect to the site • Robust • Easy maintenance	• Cost of installation • Not always suitable for all floats (e.g. large FSPV, due to distance/extension)
Submerged anchoring system	• No risk of piercing the bank • Easy maintenance	• Larger footprint • Dismantling costs
Immersed fixed anchoring	• No risk of piercing the bank or bottom	• Dismantling costs • Maintenance • Intrusive in relation to the site
Immersed ballast anchoring	• Non-intrusive with respect to the site	• Cost of installation • Dismantling costs • Maintenance

4.1.4.5 Mooring line

The proximity to the banks, the water depth and/ or the fluctuations in the water level will determine the type of the mooring layout of an FSPV system. Mooring systems may be specified as passive or active. Active mooring systems are those which counteract actively against the environmental forces to keep the floater in place, using for example, propellers or winches to give tension to the lines in function of the loading. This type of systems is not recommended for the Projects due to the complexity and the higher costs.

The mooring lines can be installed in a (multi-) catenary configuration or in taut configurations. The difference between (multi-) catenary systems and taut or semi-taut systems is that in the catenary system, the mooring restoring forces come from the weight of the line and the friction with the soil whereas in the taut system, the restoring forces are produced from the deformation of the tensioned line. Taut system requires a suitable anchor capable of withstanding the uplift forces.

In Table 10, potential spread mooring configurations applicable to a PV platform are given. This table does not include single mooring points nor active mooring.

Table 10: Potential spread moorings configurations applicable to a floating PV platform

Type of Mooring	Description	Comments
Catenary Mooring	Mooring lines have enough weight and length, so the restoring force comes mainly from the weight and the friction of the line at the bed. The mooring line is parallel to the lake bed.	• Relatively simple to install (depending on the anchoring). If drag anchors are used, then a settling distance is required to embed the anchor into the lake bed. • Not appropriate for standard floaters where the maximum capacity of the spread bar is assumed to be in order of 10 to 50kN; under these circumstances a heavy catenary is not required; instead, lighter configuration can be used. • It may be appropriate for floaters with a few connection points with higher resistance. • Requires space to accommodate the catenary and increases the mooring footprint. • It is not suitable to withstand vertical loads. An intermediate buoy can be used for that. • Wear at the lines in contact with the seabed. • Larger environmental footprint.
Multi-Catenary Mooring	Mooring lines are made up by different materials. Restoring forces may come from weight and/ or line deformation. The mooring line is at small angle with the lake bed.	• Complex to install (depending on the anchoring and the mooring lay out). • More suitable for floating PVs where a big number of connection points are available and maximum loads at connection points are limited. • A solution between chain and fibers may be used to provide the required restoring force. • Intermediate buoys can be used to absorb vertical movements. • Less environmental footprint. • Uplift forces start to turn important and a suitable anchor needs to be selected.
Taut	Restoring forces come from line deformation. Mooring lines arrive to an angle at the lake bed.	• Simple to install (depending on the anchoring system). Normally taut systems require a suitable anchor that is embedded in the lake bed by auxiliary mechanical machinery. • It is required to use a line with a higher stretchable property; for important fluctuations of water levels stretchers may be required. • Less environmental footprint. • Uplift forces are very important, drag anchors are not suitable for this solution.

If significant water level fluctuations are likely to occur, then a solution with taut lines and extensors, or a combination of catenary types equipped with intermediate buoys may be considered. These intermediate buoys will form a hybrid mooring system and they will move following water level fluctuations.

If no large vertical displacements of the water are expected, then a multi-catenary or taut configuration may be used. In this case, the mooring can be anchored to the banks or into the lake bed with catenary shape or semi-taut shape.

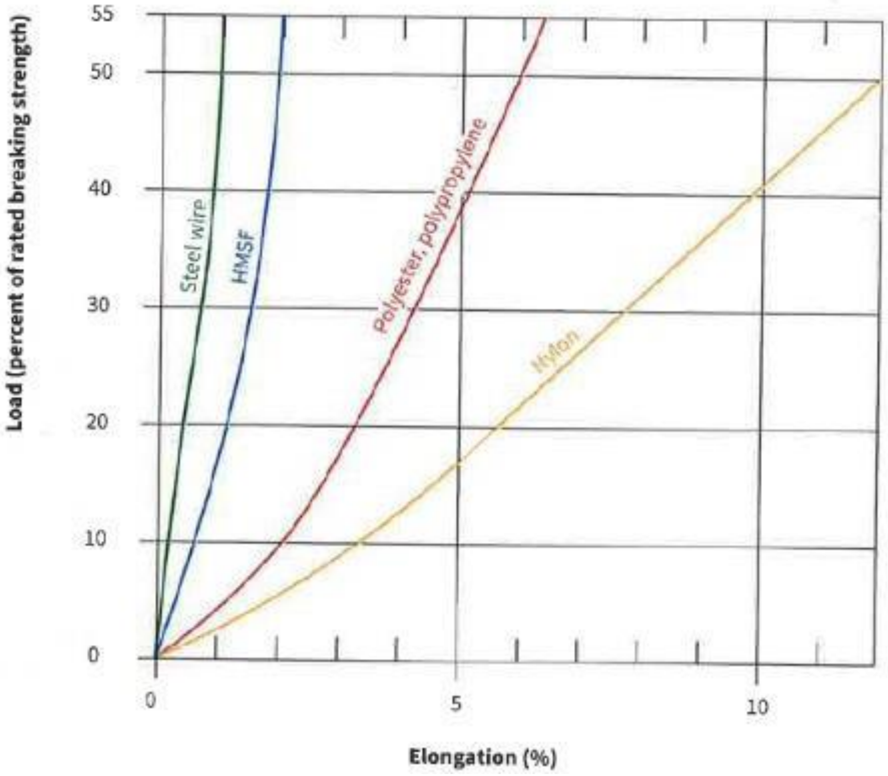
Mooring Make-up

Mooring lines are grouped in three different classes: chain, wire and synthetics. A mooring system can have hybrid mixture of the three types. For instance, in deep water, mooring chains are used at the sea bed to provide additional weight and friction resistance, whereas synthetics are used as stretcher.

The decision on the optimum mooring line should be made according to a standard process in which line manufacturer, line selector and floating PV platform developer interact with each other. It is not the purpose of this section to analyse that process. Instead some remarks based on previous experience are given for reference.

Steel wire ropes or High Modulus Synthetic Fibers (HSMF) seems very stiff according to Figure 41, these lines are indicated for applications in which very few movements are allowed. Normally some excursions may be allowed at the floating PV, in this sense, synthetics seems the most reasonable choice.

Figure 41: Typical load/extension stiffness characteristics of wire and synthetic fibres



Not only the stiffness of a mooring line is important. There are other factors that have influences on the mooring line performance such as external and internal abrasion, fatigue, creep, UV degradation, corrosion and many others. These should be analysed during the decision and design process. In Table 11, a comparison of the synthetic materials (without HSMF) is given.

Table 11: Comparison of mooring synthetic materials

Materials	Advantages / Disadvantages
Polyester	Most durable. Good Strength. High resistance against abrasion. Higher applicability on floating PV mooring.
Nylon	Lowest stiffness. It loses strength when wet. Higher applicability on floating PV mooring as stretcher.
Polypropylene	Similar properties as polyester but less abrasion resistance. Lower applicability on PV floater mooring.
Polyethylene	Same as Polypropylene.

Polyester stretchable ropes are proposed for the Projects under study due to their favourable properties.

4.1.5 Inverters

Inverters are required to convert the direct current (DC) electricity generated by the PV modules into alternating current (AC) which is suitable for exporting to the grid. The inverters also manage and optimise specific electrical parameters in order to maximise energy production and are a vital component in ensuring that power quality delivered meets the local grid code requirements.

Based on the power ratings, inverters are broadly classified as micro inverter, string inverter and central inverter. Each of these types of inverters differ in capacity, number of connected modules, type of installation etc.

The proposed solar PV project is with grid tied inverter. The grid tied inverter self-synchronises with the electrical grid when it finds the required power quality (mainly voltage and frequency) at the point of connection of each inverter.

4.1.5.1 String inverters

String inverters are smaller devices to which a small number of modules are connected. They are better able to optimise electrical parameters and maximise energy production in conditions where orientation or shading vary, particularly rooftops. However, the large number required for a utility scale application often results in higher installation and maintenance costs, including replacement over the plant lifetime.

4.1.5.2 Central inverters

Central inverters are larger devices with capacities of 1,000 kW or more which manage greater sections of the plant. They are generally not able to optimise energy production quite as efficiently as string inverters but are generally less resource intensive to maintain and can be more economical to purchase and install. Central inverters for utility scale installations are generally housed within weatherproof skid-mounted enclosures with similar dimensions to a shipping container but can also be installed in a masonry building with adequate ventilation. Alternatively, there are concepts whereby the inverters are situated on a floating platform housed within specialist containers (in which case a minimum ingress protection (IP) of 65 would be advisable). Such a solution would be applied where the benefit in terms of electrical cable losses outweigh the benefit of having easily accessible, land-based inverters.

4.1.5.3 Module based MPPT

Some manufacturers, such as Solar Edge, offer inverter systems with a DC-DC power converter and Maximum Power Point Tracking (MPPT) device located on each PV module or pair of modules. These devices allow for:

- High resolution monitoring of each panel of pair of panels for performance or technical failures
- Panel mismatch and soiling loss minimisation as each MPPT device controls its directly connected PV modules power output, with no effect on the string as a whole
- Added safety for O&M personnel with DC string voltages being kept to 30 V in the absence of a heartbeat signal from inverter

There are additional CAPEX costs involved with this technology, which may be offset by improved yields to some extent. This may be verified with desktop studies during the project feasibility stage

Central inverters are typically used in medium to large scale PV installations and string inverters are more dominant for smaller installations, although are available for all sizes of plant.

4.1.5.4 Inverter selection

Inverters should be sourced based on the following characteristics:

- Operational range (DC and AC);
- Efficiency;
- Power curve;
- Power factor;
- Degradation curve;
- Monitoring system;
- Protection devices;
- Allowed range of environmental conditions;
- Compliance with applicable quality standards; and
- Conformity with the relevant technical requirements of the Grid Code / Distribution Code.

We have assessed the commercially available inverter technologies and recommends a string inverter with 1000V or 1500V maximum DC voltage considering the comparative assessment made in Table 12 and the FSPV project requirements.

Table 12: Inverter technology comparison

S. N.	Inverter technology	Manufacturer	Rating at 50˚C (kW)	Efficiency (%)	# MPPT	Cost (INR/W)	Availability
1	String inverter 1000V	SunGrow, Huawei, Ingeteam	100	98.0 ~ 98.7	10	2.7	High
2	String inverter 1500V		200	98.0~99.0	9 - 12	1.8	High
3	String inverter with power optimizers	SolarEdge	120	98.6	1 per module or 1 for	4.5	Moderate

S. N.	Inverter technology	Manufacturer	Rating at 50˚C (kW)	Efficiency (%)	# MPPT	Cost (INR/W)	Availability
					every two modules		
4	Micro inverter	Enphase	0.235~ 0.440	97	1 per module	7.0	Moderate
5	Central inverter	SunGrow, Huawei, Ingeteam	2 MVA ~ 3.1 MVA	98.0~99.0	1 - 4	1.5	High

4.1.6 Balance of system

4.1.6.1 Cabling

The cables transport the energy produced by the modules to the inverters (DC cables) and from the inverters to the transformers and then to the delivery station (AC cables).

DC cables connect the modules to each other to form strings. These strings are then collected in combiner boxes that will be installed on the island in case of central inverter, otherwise strings are collected in string inverters. In case of central inverter, a junction box combines the output of several strings and connects them to the inverter. They also include several protection functions to ensure that defective strings do not affect the inverter. The DC cables are then all assembled to join the shoreline and the inverters.

After the inverters, the AC cables join the transformers. The cables are finally routed to the delivery station and grid connection point. The wiring principle is identical to the PV plants that are ground-mounted. The only difference is that the DC cables will have to cross the water.

Two other types of cables are installed in the plant:

- Communication cables - these allow the exchange of information between the inverters and the SCADA, located in the delivery station. An internet connection also allows remote access to this information.
- Grounding cable - necessary to comply with regulations and ground all metal components of the plant.

Two floating configurations are possible, as described below.

4.1.6.1.1 Floating cables

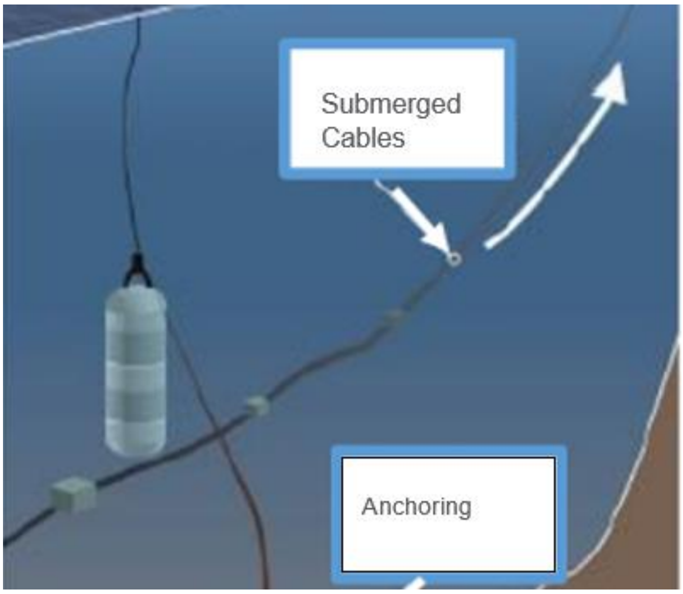
Cables are routed in a larger waterproof sheath fixed with fasteners. An example of floating system wiring is shown in Figure 42.

Figure 42: Example of DC floating cable

4.1.6.1.2 Submerged cables

In this configuration, the DC cables are routed from the island to the shoreline in an impermeable sheath. The system is shown in Figure 43.

Figure 43: Example of submerged DC wiring



A summary of cabling methods applicable for FSPV is given in Table 13.

Table 13: Summary table of wiring methods

Technology	Advantages	Disadvantages
Floating cables	• Economic • Easy installation • Easy maintenance	• Visual impact • May prevent boats from passing
Submerged cables	• Low visual impact	• Installation and maintenance more difficult and expensive

For reasons of convenience and price, cabling floating on a waterproof sheath fixed with fasteners is often considered.

4.1.6.2 Transformer

Transformers are required to modify the voltage by either stepping-up the medium AC voltage generated by inverters to feed into high voltage networks like a grid connection point, which require voltage ranges from 11 kV upwards, or stepping-down by reversing the process to produce lower voltage ranges. We recommends considering the transformer selection as per the IS/IEC/IEEE codes and standards for a photovoltaic project. The three-phase oil type transformers are most commonly utilised on utility scale PV projects. In utility scale PV installations, single multi-purpose units containing inverter/s, transformer (for example that step-up from low voltage to 11 kV, 22 kV or 33 kV) and switchgear are commonly specified. Designs of inverter and transformer installations for FSPV are shown in Figure 44.

Figure 44: Example of floating pontoon with inverter and transformer station (source: Sungrow)

In this case, considering the small capacity of the Project, it is recommended to place the transformer on the land area adjacent to FSPV island.

4.1.6.3 Switchgear

Switchgear is used to control the connection between the plant and the electricity distribution network. We recommend considering applicable IS/IEC/IEEE codes and standards for a photovoltaic project for switchgear selection in addition to. There are typically two sets of switchgear; one belonging to the local network operator and one belonging to the plant, which are housed in separate cabins, or switch rooms.

Switchgear and its components and accessories shall conform to relevant IS or IEC Standards amended up to date. Equivalent BIS Standards are also acceptable. The switchgear shall be indoor, metal clad, floor mounted, draw out type. Design and construction shall be such as to allow extension at either end. The switchgear shall be single front, metal enclosed, compartmentalised, fully draw-out type comprising of minimum 2.0 mm thick cold rolled, sheet steel units, assembled to form a rigid, free-standing structure. Vertical units shall be assembled to form a continuous line up of panels. The degree of protection of the switchgear enclosure shall confirm to IP42 for Indoor installation and weatherproof or IP65 for outdoor installation.

As per the standard engineering practices the switchgear shall be equipped with all relays, meters, switches and lamps shall be flush mounted on the respective cubicle door or on control cabinet built on the front of the cubicle. Controls and interlocks as required for the safe switching, operation and maintenance of the switchgear shall be provided. Mechanical interlocks shall be provided in addition to electrical wherever possible.

4.1.6.4 Other Components

Combiner or array boxes are installed between the PV modules and the inverter, but only for PV plants with central inverters as opposed to string inverters. Combiner boxes include wiring, switches and enclosures and they combine the output of several strings together and connect them with the inverter. They also include several protective features to ensure that faulty strings do not affect the inverter.

Other parts of FSPV plant specification will include cabling, security systems, fencing, lighting systems, earthing systems, firefighting and lightning protection, O&M and/or control buildings for work areas, parts and tool storage, access roads and some form of access to the floating arrays. The choice of some of these items may have a significant impact on the capital and operating costs and performance of the PV plant.

The final plant design should ensure that the chosen combiner boxes, cables and other electrical components have an appropriate IP rating and confirmation should be sought from manufacturers that their equipment is suitable for use over water.

4.1.6.5 SCADA and weather monitoring station

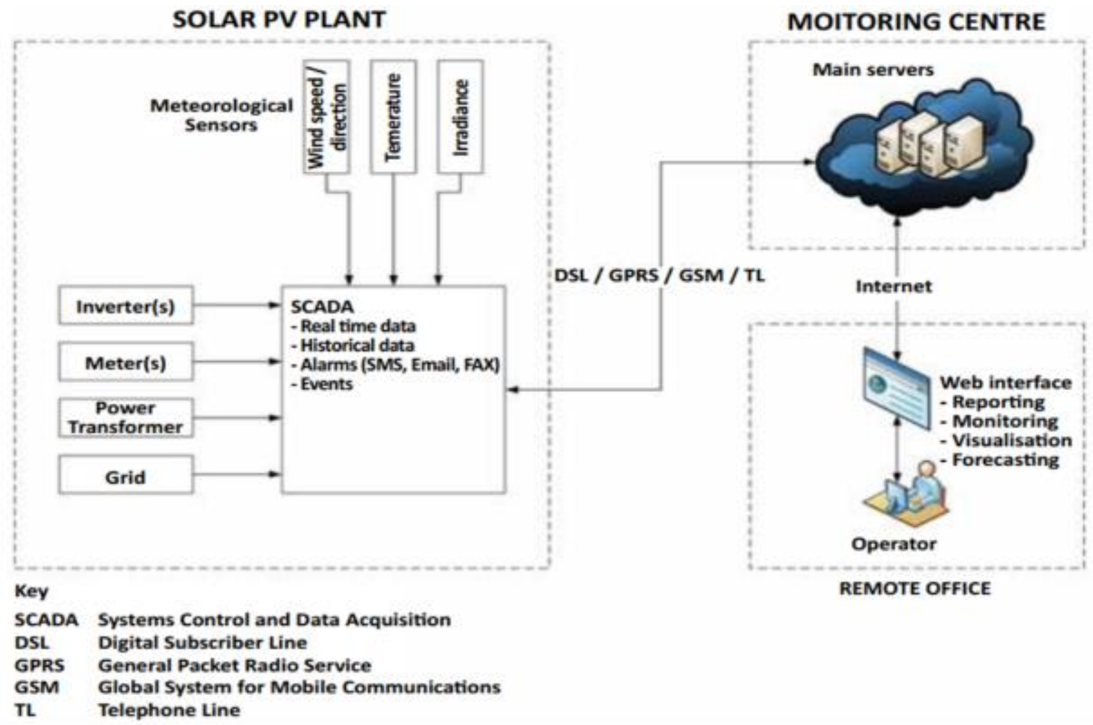
Weather stations in PV plants provide data on solar radiation, temperature, humidity, wind and rain. The data recorded by the weather station is important to assess plant performance and to identify instances of underperformance or opportunities in design or maintenance improvement. The data provided by the weather station as well as data from modules, inverters, transformers and plant meters are aggregated using a monitoring system platform. The monitoring system should allow remote access and control of the plant’s key equipment. The weather station should be located on the floating island and provide for the following weather parameters:

- Solar radiation;

- Module temperature;
- Ambient temperature;
- Relative humidity;
- Air pressure and air temperature;
- Wind speed and wind direction;
- Rainfall;
- Wave sensor;
- Obscape (wavedroid) sells buoy based on solid state sensors;
- Water temperature;
- IR camera.

In addition to the above environmental parameters, the monitoring system will also cover the operating conditions of the various electrical components of the PV system and will form part of the centralised plant SCADA system which enables the asset manager to operate the plant. The SCADA system shall be composed of an integrated operator human-machine interface (HMI), input/ (I/O), communication infrastructure and software. As per common industry practices an industrial Ethernet LAN and fibre optic network shall be distributed throughout the field for communication to field devices. An example of a PV monitoring system schematic is provided in Figure 45.

Figure 45: PV System Monitoring Schematic[10]



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[10] Utility-Scale Solar Photovoltaic Power Plants - A Project Developer's Guide – IFC (2015)

4.2 Key equipment manufacturer track record

There are Tier-1 manufacturers for PV module and reputed manufacturers for balance of plant components. The credentials of few manufacturers of key components are described in Table 14.

Table 14: Key equipment manufacturer experience and track record

Component	Make	Manufacturer experience and track record
PV module	Jinko	Jinko Solar Co., Ltd ('Jinko Solar') was founded in 2006 and is headquartered in Shanghai, China. As of December 2019, Jinko Solar had an annual capacity of 11.5 GW for mono silicon wafers, 10.6 GW for solar cells, and 16 GW for solar modules. Jinko Solar had delivered more than 52GW of solar modules worldwide as of December 2019 and employs more than 15,000 personnel worldwide. In year 2020, Jinko Solar ranked as a "Top Performer" in the PVEL PV module reliability scorecard, for six consecutive years. Jinko solar was listed in the Q4 2020 Bloomberg New Energy Finance Tier 1 PV module manufacturers list, which provides a good indication of bankability and market acceptance of the brand. Based on the above-mentioned information, and have previous experience, we consider Jinko Solar to be a suitable module manufacturer. We consider Jinko solar PV modules to have suitable technical characteristics and certifications that are in line with market standards.
	Trina	Trina Solar Limited ('Trina Solar') is a Chinese manufacturer of photovoltaic modules, which was founded in 1997 as a system installation company. Trina Solar modules provide electric power components for residential, commercial, industrial and other applications worldwide. Trina Solar is a vertically integrated manufacturer for the supply chain from the production of monocrystalline ingots, wafers and cells to the assembly of modules. The company is a global player in the PV market, with significant market presence and an established track record in the UK. Trina Solar claims it has delivered more than 66 GW of solar modules worldwide as of June 2021. The company employs approximately over 15,000 people worldwide and has connected over 5 GW of solar power plants to the grid. Trina Solar was listed in the 2020 Q3 Bloomberg New Energy Finance Tier 1 PV module manufacturers list, which provides a good indication of bankability and market acceptance of the brand. Based on the above information, and our previous experience with Trina Solar modules, We consider Trina Solar to be a suitable module manufacturer.
	Canadian Solar	Canadian Solar Inc. ('Canadian Solar') was established in 2001 and is headquartered in Ontario, Canada, with manufacturing facilities in Canada and China. Canadian Solar provides vertically integrated

Component	Make	Manufacturer experience and track record
		solar solutions i.e., components manufacture includes ingots, wafers, solar cells, and solar modules. Canadian Solar has delivered more than 52GW of solar modules worldwide as of year 2020 and employs more than 13,000 personnel worldwide. In year 2020, Canadian Solar has been recognized as No. 1 top bankable manufacturer rated by Bloomberg New Energy Finance (NEF). Canadian solar was listed in the Q4 2020 Bloomberg NEF Tier 1 PV module manufacturers list, which provides a good indication of bankability and market acceptance of the brand. Based on our experience and the information highlighted above, we consider Canadian Solar to be a well-established module manufacturer.
Inverter	Huawei	Huawei, founded in 1987, is a multinational company headquartered in Shenzhen, China. Huawei is a leading global provider of information and communications technology (ICT) infrastructure and smart devices. The company has integrated solutions across four key domains – telecom networks, IT, smart devices, and cloud services. Huawei has approximately 197,000 employees and operate in over 170 countries and regions. Huawei offers grid tied string inverters in the range of 12 kW to 200 kW for utility scale and commercial consumers, and 2 kW to 10 kW for residential consumers respectively. Huawei has delivered more than 118 GW inverter power solutions across the globe by the end of 2019. Based on our experience and the information highlighted above, we consider Huawei to be a well-established inverter manufacturer.
	Sungrow	Sungrow Power Supply Co. Ltd. was established in China in 1997. Sungrow manufactures inverters for residential, commercial and utility scale projects with power ranging from 2 kW to 5.0 MW. Its shipment of inverters to date stands at over 154 GW globally. At present production capacity of Sungrow stands at 90 GW globally. In 2019 & 2020, for two consecutive years Sungrow was the declared 100% bankable by Bloomberg NEF. Based on our experience and the information highlighted above, we consider Sungrow to be a well-established inverter manufacturer.
	SMA	SMA Solar Technology AG (SMA) develops, produces and sells solar inverters, transformers and monitoring systems for photovoltaic applications. SMA claims to be the world's largest producer of inverters in this sector. SMA was founded in 1981, headquartered in Niestetal, near Kassel, Germany, and is represented by sales and service subsidiaries on four continents in 18 countries and has more than 3,000 employees worldwide. Since 2008, SMA Solar Technology AG has been listed on the Prime Standard of the Frankfurt Stock Exchange (S92) and is listed in the SDAX index.

Component	Make	Manufacturer experience and track record
		Based on our previous experience and the information highlighted above, we consider SMA to be a well-established inverter manufacturer.
Float	Ciel & Terre France	Ciel & Terre was established in 2006 and is headquartered in France. Since its inception, C&T was in the business of developing rooftop PV and ground mounted PV systems in France. C&T ventured into floater manufacturing in 2011. As of year 2020, C&T has delivered more than 520 MW of floater solutions globally for 225 projects and more than 170 collaborators worldwide. C&T has presence in 30 countries across the globe having more than 40 manufacturing lines. We consider Ciel & Terre an experienced floater supplier for solar PV projects.
	Sungrow China	Sungrow FSPV is a wholly-owned subsidiary of Sungrow Group, which has 24 years R&D and production experience in PV industry area. Sungrow have an experienced in floating body, anchor system, inverter & booster floating platform, system O&M and leads Chinese floating photovoltaic (FSPV) technology standards. Sungrow has delivered more than 1.4 GW floating system solution globally. Based on our previous experience and the information highlighted above, we consider Sungrow to be a well-established floater manufacturer.
	ISIGENERE, Spain	ISIGENERE was founded in 2008 headquartered in Beneixama, Alicante Spain. ISIGENERE is specialist in floating body, anchor system, inverter & booster floating platform. The company stands in the top 5 floater suppliers globally having a market share ~5% after C&T and Sungrow. Based on our previous experience and the information highlighted above, we consider ISIGENERE to be a well-established floater manufacturer.
	NRG, Italy	NRG was founded in 2010 headquartered in Italy. NRG is specialist in floating body, anchor system, inverter & booster floating platform. The company stands in top 5 floater suppliers globally have market share ~5% after C&T and Sungrow. We considers NRG to be a well-established floater manufacturer based on the information highlighted above.

The Client wishes to have maximum PV array capacity. Therefore, we have assessed the commercially available technologies and considers recommending the PV module technology based on efficiency, ratings availability from tier-1 manufacturers and comes under updated Approved List of Models and Manufacturers (ALMM) list of Ministry of New and Renewable energy (MNRE) at reasonable cost and suitable for FSPV installation. Table 5 represents a comparative assessment of commercially available PV technologies. we recommend mono crystalline Silicon (c-Si) Passivated Emitter and Rear Cell (PERC) modules based on the comparative assessment given in Table 5. During the detailed design phase, the mounting system specifications should be aligned with the manuals and instructions from the solar PV module supplier.

5 Project conceptualization

A number of key considerations apply to FSPV project installation which are assessed in the conceptualization of the Project below.

5.1 Shadow analysis

While there is little or no effect of topographic shadow within the lake premises, however there is shadow impact caused by transmission line, transmission tower, trees and elevated structures built around the lake. Except transmission tower and line, shadow of other objects does not penetrate on the water surface. Figure 46 shows the affected area due to transmission tower shadow.

Figure 46: Transmission tower shadow in Periyakulam lake

The pattern of shadow is essentially governed by position of earth-sun angle with respect to a location. It is apparent that the shadow is most effective on 21st December due to highest solar declination angle at the project site, which causes lowest day length as well. Hence, it can be safely inferred that the shadow will be the longest one on 21st December. However, the impact of shadow on roof area was also assessed for the remaining days of the year. The intensity of the solar radiation at the project site is maximum during 11:00 AM to 3:00 PM. A conservative assessment is performed, and the roof area affected by shadow during 10:00 AM to 3:00 PM is not considered for installation of PV modules.

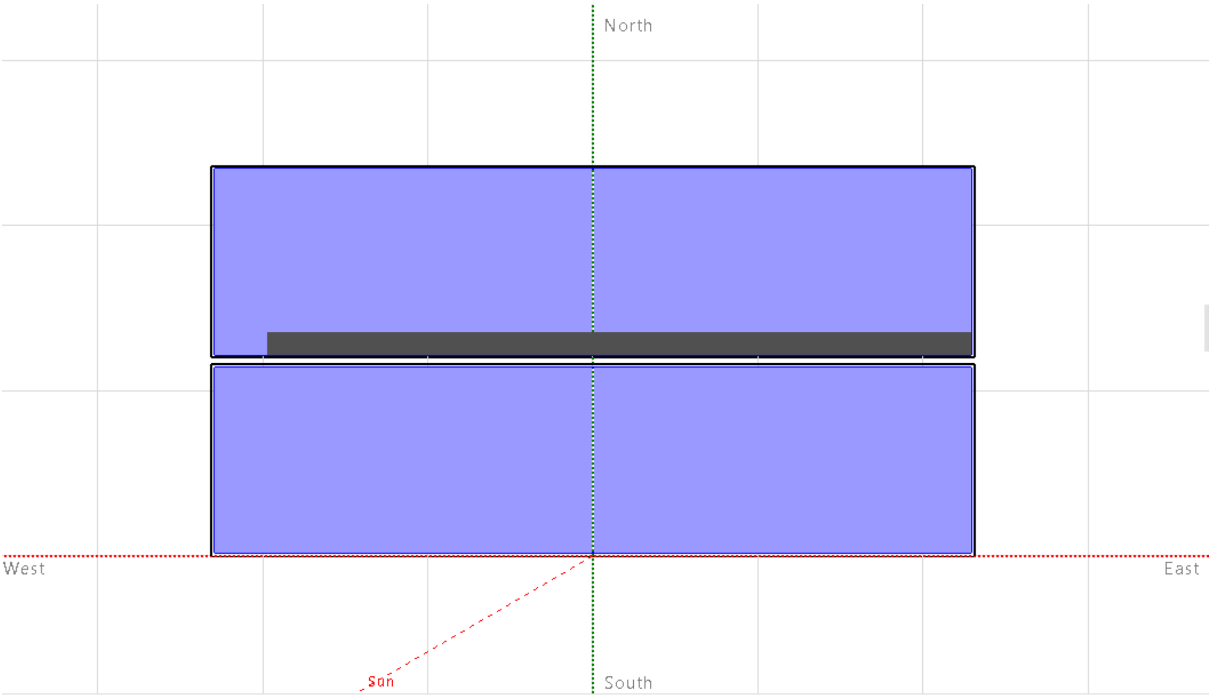
5.2 Tilt-pitch optimization

The tilt and pitch have major role in generation. Optimum tilt helps in receiving maximum solar radiation on collector surface where adequate pitch helps in minimizing generation loss due to inter row shadow.

In FSPV projects, due to design constraints related to wind load on the floating island and HDPE pontoon type available in the market, either 5 degree or 8 degree tilt angle with inter row spacing of 0.2m to 0.3m selected. We have analysed the energy figures and observed that there is 0.5%

difference in final energy output. As the energy gain is not significant, we recommend to consider either of the tilt angle considering both techno-commercial aspects. Figure 47 shows a representative image of inter row shadow.

Figure 47: Inter row shadow



5.3 Orientation

India is situated in the northern hemisphere and receives maximum solar radiation from South direction. Therefore, the optimum orientation for PV module installation at fixed tilt is South. We recommend installing PV modules facing south (i.e., azimuth 0˚).

5.4 Layout

The Project layout is given in Appendix A includes following:

- Area occupied by other usage;
- Potential area available for FSPV project installation at Periyakulam lake for both pilot as well as MW scale project;
- Cable route;
- Accessibility; and
- Power evacuation point.

5.4.2 PV array capacity

The PV array capacity in the area free from shadow and utilities is calculated. The commercially available mono PERC PV module technology of rating 540 Wp is considered for calculation of PV array capacity or DC capacity. The calculated DC capacity for pilot project is 140 kWp and for MW scale project, is 18 MWp at Periyakulam lake. The commercially available string inverters allow DC overloading of up to 1.5 times of inverter rating at 50˚C. We have considered 1.28 and 1.4 DC overloading for both pilot project and MW scale project respectively for calculation of inverter capacity or AC capacity of the Project.

5.4.3 Equipment layout

PV module, string inverter, solar string cable, weather monitoring system, PV array earthing system, lightning protection system for PV array and AC cable are recommended to be mounted and laid on the floats with suitable clamping arrangements. LV/MV switchgear, transformer and other AC side balance of system components including power evacuation equipment shall be installed on ground adjacent to the floating island.

5.5 Grid interconnection

Both the pilot project and MW scale project will be at Periyakulam lake. The generated power will be proposed to be connected to the 11 kV line and distribution transformer present in South-East corner of the lake for the pilot project. The MW scale project shall be connected at 11 kV to the upcoming 110 kV / 11 kV Selvapuram substation in the west of Periyakulam lake.

Considering, the pilot project location at South side, the Experience centre and Sewage Treatment Plant (STP) at west side of the lake will not be suitable option for power evacuation considering the minimum cable route length requirement of 2 km where the cost of cable estimated to be half of standard total project cost to limit the voltage drop within 2%. Therefore, we recommend to step up to 11 kV and evacuate power to TNEB grid.

On the other hand, for MW scale project, the nearby available power evacuation point shall be at 11 kV to the upcoming Selvapuram substation TNEB substation which is located approximately 2.1 km away from the FSPV project.

5.6 Single Line Diagram (SLD)

The SLD includes both DC side and AC side electrical components of the PV system is shown in Appendix B.

5.6.2 DC configuration

For pilot project, considering the design parameters (minimum and maximum design temperature are 0º and 70º respectively), 540 Wp mono PERC PV module and 1500 V maximum DC voltage, 26 modules form a string. There are total 10 strings.

For MW scale project, considering the design parameters (minimum and maximum design temperature are 0º and 70º respectively), 540 Wp mono PERC PV module and 1500 V maximum DC voltage, 26 modules form a string. There are total 1,282 strings.

The DC configuration of the Projects is shown in Table 15.

Table 15: DC configuration

Project	Site location	Inverters (kW)	# PV modules	#Modules / String	#Strings
Pilot project	Periyakulam Lake	111 kW – 1 no.	260	26	10
MW scale project		295 kW – 41 nos.	33,332	26	1,282

1C x 6 mm^2 Cu, XLPO, DC cable is selected to limit the DC Ohmic loss within 0.7%, accordingly the position of string inverters selected. At DC side, there should be minimum overcurrent, and type-II overvoltage protections.

5.6.3 AC side

5.6.3.1 Pilot Project

The AC cable size is selected based on the power, voltage rating, route length and laying pattern. The generated power from the FSPV plant shall be evacuated to the point of connection (PoC) via above ground cable tray. The distance between the inverter and PoC is within 100 m for the pilot project.

The AC output of the single inverter is directly connected to inverter duty transformer which shall step-up power from 540 V to 11 kV. There shall be an In-Coming and Out-Going (ICOG) Vacuum Circuit Breaker (VCB) panel at 11 kV before termination at the outdoor existing 11 kV transmission line.

At inverters output end, there should be minimum overcurrent, type-II overvoltage, under/over frequency, insulation fault monitor and anti-island protections. The fault current contribution by the inverters is usually limited by the inverter control circuit and this should be based on IEC 61727 or IEEE 1547 and the typical range of short circuit current is between 100% and 200% of the rated inverter current. Additionally, in ICOG panel, there shall be over current, over voltage, earth fault protections. The Multi-Function Meter (MFM) or bidirectional meter with suitable accuracy level is recommended as per applicable Central Electricity Authority (CEA) standard and guideline of Tamil Nadu Generation and Distribution Company (TANGEDCO) for metering considering the selected mode of electricity consumption either captive or net-metering. The AC side configuration of the Project is shown in Table 16. We recommend that the integration of the Project into the existing configuration at PoC is appropriately assessed during the detail design stage.

Table 16: AC configuration

Project	Inverter	Transformer	HV switchgear	PoC
Pilot project	1 x 111kW	Inverter Duty Transformer 150 kVA, 0.540 kV / 11 kV, ONAN	Qty. – 1 no., ICOG panel, 11 kV 630 A VCB, relay and metering panel	One PoC at the existing 11 kV transmission line

5.6.3.2 MW Scale project

The AC cable sizes are selected based on the power, voltage rating, route length and laying pattern. The generated power from the FSPV shall be evacuated to the point of connection (PoC) at the substation via underground cable trenches. The cumulative distance between the FSPV plant to the Selvapuram substation is about 2.1 km.

The AC output of each inverter is connected to AC Combiner Box (ACCB). There are a total of 41 inverters of 295 kW each connected to 4 ACCBs. The inverter output is at 800 Vac. Therefore, the LV system shall be designed at 800 Vac. The collected power from 4 ACCBs shall be step up via 2 numbers of 3 winding 6 MVA, 0.8-0.8/11 kV, ONAN Inverter Duty Transformer (IDT) from 800 V to 11 kV. Further the step-up power at 11 kV combined at outdoor rated 11 kV switchgear panel of 2 in and 1 out configuration. The 11 kV switchgear panel shall have all protection and metering arrangement. The output of the 11 kV switchgear panel further evacuated to upcoming Selvapuram substation via 3 runs of 3C x 300 mm^2 XLPE Al armoured of 11 kV underground cable.

At inverters output end, there should be minimum overcurrent, type-II overvoltage, under/over frequency, insulation fault monitor and anti-island protections. The fault current contribution by the inverters is usually limited by the inverter control circuit and this should be based on IEC 61727 or IEEE 1547 and the typical range of short circuit current is between 100% and 200% of the rated inverter current. Additionally, in ACCBs and 11 kV switchgear panel, there should be over current, over voltage, earth fault protections. Additionally, the transformer protections shall be inbuilt to the ICOG panel. The Multi-Function Meter (MFM) is recommended at 11 kV switchgear panel. The AC side configuration of the Project is shown in Table 17. We recommend that the integration of the Project into the Client's existing supply configuration is appropriately assessed during the detail design stage.

Table 17: AC configuration

Project	Inverter	ACCB	Transformer	HV switchgear	PoC
MW Scale Project	41 x 295 kW	Qty. – 4 no., 3 nos. are of 10 in – 1 out, 600V, In – 10 x 360 A MCCB, Out – 1 x 3000 A VCB 1 no of 11 in – 1 out, 800V, In – 11 x 360 A MCCB, Out – 1 x 3000 A VCB	Inverter Duty Transformer – 2 nos. 6 MVA, 0.8-0.8/11 kV, ONAN	Qty. – 1 no., 2 in – 1 out, 11 kV, In – 2 x 630 A VCB, Out – 1 x 1250 A VCB, relay and metering panel	One PoC at 11 kV of Selvapuram substation

5.6.4 Earthing and Lightning

As per IEC 62548, there are two forms of equipotential bonding to be established in the floating body: main equipotential bonding, and supplementary equipotential bonding. Main equipotential bonding is the connection of exposed conductive parts to the main earthing network, which is directly connected to the earth. These conductors are termed as main equipotential bonding. Depending on the required cable length, equipotential bonding is achieved with copper (Cu) cables of suitable size ranges generally in between 2.5 mm^2 to 70 mm^2.

The resistivity of water is lower than soil. Hence, one option can be earthing in the reservoir water directly. Alternative option is, earthing network established on the floats and earth cables routed to shore from floating islands and grounded at the onshore earth pits. Acceptable earth resistance at the main earth busbar typically ranges from 1 Ω to 5 Ω, or as specified in the standards. We recommend conducting a soil resistivity study and use the actual soil resistivity values for design of earthing system for the project.

All string inverters shall have distinct connections with main earth network for equipotential bonding through suitably sized earthing cables as per the manufacturer's recommendations.

The purpose of a lightning protection system (LPS) is to protect PV installations from direct lightning strikes and possible fires caused by lightning-induced currents. In general, LPS should be implemented at FSPV sites. This includes the onshore LV & HT panel for off-taking power from FSPV project, which should be protected with an LPS. LPS III according to IEC 62305-3 (EN 62305-3) is recommended. In principle, a risk analysis as per IEC 62305-2 (EN 62305-2) standard should be performed. The reference from local meteorological service records should be taken into consideration to determine the frequency of lightning strikes and deployment of appropriate LPS. Considering the project size of about 140 kWp and 18 MWp, the installation of LPS shall be on both ground as well as in lake shall be accessed during project implementing phase.

5.6.5 Module cleaning system

The water required for the module cleaning is available in the reservoir subject to the required Total Dissolved Solid (TDS) level of water as recommended by the module manufacturer. Typically, the TDS required for module cleaning is about 200 ppm.

There are various types of module cleaning available in the market. The selection of module cleaning system shall be based on the project size and the system should be economically viable. We recommend a sprinkler system of 5 m range with piping network for both 140 kWp and 18 MWp pilot project and MW scale project. The sprinkler system shall be operated at a designated time before generation hour for approximately 5 minutes with the help of a programmable timer which will start and stop the water pump. The size of the water pump shall be decided based on water pressure requirement as recommended by the module manufacturer. The manpower engaged for Operation and Maintenance (O&M) shall make a periodic visit to wipe out and remove the dirt sticking to modules. Figure 48 shows a representative image of sprinkler based module cleaning system.

Figure 48: Sprinkler based module cleaning system

6 Bill of Materials (BoM)

6.1 Pilot Project

A tentative BoM and a list of recommended makes is given in Table 18. A detail technical specification of the 140 kWp pilot project is given in Chapter 10.

Table 18: BOM and recommended makes for 140 kWp FSPV pilot project

Items	Item description	UoM	Qty	Recommended make
PV module	Mono c-Si PERC, 540 Wp, 1500 V	no.	260	Tier-1 and Approved List of Models and Manufacturers (ALMM) by MNRE
Inverter	Grid-tied string inverter, 111 kW, 1500 V DC, 540 V AC, 3-ph, 50 Hz, multiple MPPTs, SPD type-II (DC and AC)	no.	1	SunGrow/Huawei/SMA/ reputed make
Float – Module	Thermoplastic, HDPE material with UV stabilizer	no.	260	Ciel & Terre/ SunGrow / ISIGENERE/ NRG
Float –Walkway	Thermoplastic, HDPE material with UV stabilizer	Lot	1	Ciel & Terre/ SunGrow / ISIGENERE/ NRG
Float – Equipment mounting	Thermoplastic, HDPE material with UV stabilizer	Lot	1	Ciel & Terre/ SunGrow / ISIGENERE/ NRG
Module Mounting accessories	Al or SS of suitable grade	Lot	1	Reputed make
DC cable	1Cx6 mm^2, Cu, XLPO, 1.5 kV grade	km	1	Leoni/Lapp
MC4 connectors	IP67	pair	30	Staubli/Leoni/MC
AC cable (Inverters to Transformer)	3Cx150 mm^2 Al, 1.9/3.3 kV kV grade, XLPE, FRLS AR	m	50	Polycab/Seichem/RR Kabel
Transformer	Inverter duty transformer 150 kVA, 0.540 kV / 11 kV	no.	1	VoltAmp / Essener / reputed make
AC cable (Transformer / HT panel / PoC Termination)	3Cx300mm^2, Al, 11 kV grade, XLPE, FRLS AR	m	500	Polycab/Seichem/RR Kabel
ICOG panel work in existing panel)	11 kV, 40 kA, 630 A VCB and relay panel with transformer protection, energy meter, Weatherproof and outdoor rated.	no.	1	L&T make VCB / reputed make panel

Items	Item description	UoM	Qty	Recommended make
Data logger and Weather Monitoring System (WMS)	Data logger for monitoring of MFM, pyranometer, ambient and module temperature sensors, and anemometer.	set	1	Datalogger – iPLON /Webdyn/ reputed make Pyranometer - Kipp&Zonen/ reputed make Others – reputed make
Control cable	Shielded RS485 (4 twisted pair x 0.5sqmm)	m	120	Belden/reputed make
Earth pit	17.2 mm diameter and 3 m long Cu bonded rod, maintenance free earth enhanced material, cast iron pit cover and accessories. Quantity shall be as per detailed design requirements.	Lot	1	Reputed make
Earthing cable	Module and MMS - 1Cx2.5mm^2, Cu cable PVC	m	200	Polycab / Seichem / RR Kabel / Reputed make
	Module and MMS - 1Cx16mm^2, Cu cable PVC	m	500	
Lightning Protection System	As per design requirements	Lot	1	Reputed make
Cable tray	PosMAC of suitable size, with cover	Lot	1	Reputed make
Inverter mounting support on float	Al or SS brackets and fasteners with AL or HDG clamps suitable designed considering mounting position recommended by the manufacturer	Lot	1	Reputed make
Fire extinguisher	Class E or CO_2 type	Lot	1	Reputed make
Signage	Photo luminescent & Weatherproof	Lot	1	Reputed make
Miscellaneous	Lugs, thimbles, sleeves, cable identification tags, wall anchors, conduits	Lot	1	Reputed make

The above tentative BoM is prepared based on the preliminary layout and SLD developed for Periyakulam lake.

6.2 MW Scale Project

A tentative BoM and a list of recommended makes are given in Table 19.

Table 19: BoM and recommended makes for 18 MWp FSPV project

Items	Item description	UoM	Qty	Recommended make
PV module	Mono c-Si PERC, 540 Wp, 1,500 V	No.	33,332	Tier-1 and ALMM by MNRE
Inverter	Grid-tied string inverter, 295 kW, 1,500 V DC, 800 V AC, 3-ph, 50 Hz, multiple MPPTs, SPD type-II (DC and AC)	No.	41	SunGrow/Huawei/SMA/ reputed make
Float – Module	Thermoplastic, HDPE material with UV stabilizer	no.	33,332	Ciel & Terre/ SunGrow / ISIGENERE/ NRG
Float –Walkway	Thermoplastic, HDPE material with UV stabilizer	Lot	1	Ciel & Terre/ SunGrow / ISIGENERE/ NRG
Float – Equipment mounting	Thermoplastic, HDPE material with UV stabilizer	Lot	1	Ciel & Terre/ SunGrow / ISIGENERE/ NRG
Module Mounting accessories	Al or SS of suitable grade	Lot	1	Reputed make
DC cable	1Cx6mm^2, Cu, XLPO, 1.5 kV grade	km	95	Leoni/Lapp
MC4 connectors	IP67	pair	2,700	Staubli/Leoni/MC
AC cable (Inverters to ACCB)	3Cx240mm^2, Al, 1.9/3.3kV grade, XLPE, FRLS AR	km	12	Polycab/Seichem/RR Kabel
ACCB	10x360A, 1x3000A, 36kA MCCB, 800V, type-II AC SPD, earth fault protection, Red-Yellow-Blue (RYB) indicators, IP 65, Suitable for Outdoor Installation	no.	3	ABB/L&T/Siemens / reputed make panel
	11x360A, 1x3000A, 36kA MCCB, 800V, type-II AC SPD, earth fault protection, Red-Yellow-Blue (RYB) indicators, IP 65, Suitable for Outdoor Installation	no.	1	ABB/L&T/Siemens / reputed make panel
AC cable (ACCB to Transformer)	3Cx400mm^2, Al, 1.9/3.3kV grade, XLPE, FRLS AR, with SANS stamps	km	4	Polycab/Seichem/RR Kabel / Aberdare South Africa company
Transformer	Inverter duty transformer 6 MVA, 0.8-0.8/11 kV, ONAN	no.	2	Reputed make

Items	Item description	UoM	Qty	Recommended make
11 kV Switchgear panel	2 x 630 A VCB IN – 1 x 1,250 A VCB Out, 11 kV Switchgear and relay panel with transformer protection, energy meter, IP55, as per applicable codes and standards.	no.	1	Reputed make
AC cable (Transformer to 11 kV Switchgear panel to Substation)	3Cx300mm^2, Al, 6.35/11kV grade, XLPE, FRLS AR, with SANS stamps	km	7	Polycab/Seichem/RR Kabel / Aberdare South Africa company
Data logger and Weather Monitoring System (WMS) along with PPC	Data logger for data monitoring of MFMs, pyranometer, ambient and module temperature sensors, and anemometer. With Power Plant Controller (PPC)	set	1	Datalogger & PPC – iPLON /Webdyn/ reputed make Pyranometer - Kipp&Zonen/ reputed make Others – reputed make
Control cable	Shielded RS485 (4 twisted pair x 0.5sqmm)	Lot	1	Belden/reputed make
Earth pit	17.2 mm diameter and 3m long Cu bonded rod, maintenance free earth enhanced material, cast iron pit cover and accessories. Quantity shall be as per detailed design requirements.	Lot	1	Reputed make
Earthing cable	Module and MMS - 1Cx2.5mm^2, Cu cable PVC	km	80	Polycab / Seichem / RR Kabel / Reputed make
	String inverter - 1Cx16mm^2, Cu cable PVC	Lot	1	
Lightning Protection System	As per design requirements	Lot	1	Reputed make
Cable tray for installation on ground	PosMAC of suitable size, with cover	Lot	1	Reputed make
Inverter mounting support on float	Al or SS brackets and fasteners with AL or HDG clamps suitable designed considering mounting position recommended by the manufacturer	set	1	Reputed make
Fire extinguisher	Class E or CO_2 type	Lot	1	Reputed make

Items	Item description	UoM	Qty	Recommended make
Signage	Photo luminescent & Weatherproof	Lot	1	Reputed make
Miscellaneous	Lugs, thimbles, sleeves, cable identification tags, wall anchors, conduits	Lot	1	Reputed make

The above tentative BoM is prepared based on the preliminary layout and SLD developed for MW scale project at Periyakulam lake.

7 Irradiation and Energy Yield

An energy yield assessment was undertaken for the 140 kWp pilot project and 18 MWp utility scale project at Periyakulam lake.

We have taken following steps to establish the energy yield for the Project:

- Acquired and analysed Global Horizontal Irradiation (GHI) and Diffused Horizontal Irradiation (DHI) data from Meteonorm database;
- Modelled the system configuration performance ratio and resultant first year specific yield estimate;
- Calculated combined uncertainties to give long term specific yield estimates at various probabilities of exceedance.

Each step is described in the following sections.

7.1 Irradiation

7.1.2 Global and Diffuse Horizontal Irradiation

The global irradiance is the measure of the solar electromagnetic power in watts passing through a surface of area 1 m^2, expressed in W/m^2, and is composed of both direct and diffuse (scattered) sources. Global Horizontal Irradiation (GHI) is a measure of total energy incident on a horizontal plane, or the irradiance (W/m^2) incident for a period of time and is expressed in watt hours per unit area (Wh/m^2). Diffuse Horizontal Irradiation (DHI) is a similar measure, representing the energy that did not arrive directly from the sun but that had been scattered on its path before hitting the plane.

The irradiation is the energy source for a solar project and as such it is important that sufficient data is collected for the sites in question. A location at the centre of the site was selected as the point of interest for the irradiation assessment. There are several representative databases available for the Subproject location that use information from either satellite (along with other observations and models) or ground measurements to estimate long-term average GHI and DHI values. The Consultant has taken GHI and DHI values from Meteonorm database included in Table 20.

Table 20: Annual GHI from various sources

Project	Period	Spatial resolution (km)	GHI (kWh/m^2)	DHI (kWh/m^2)
140 kWp Pilot project and 18 MWp project at Periyakulam lake	1991-2010	8	1,875	880

7.1.3 Global Inclined Irradiation

GHI and DHI values have been uplifted to GII using the industry standard Perez model. For the site in question, we understand there to be one module orientation of 5° tilt and 0° azimuth. Monthly and yearly inclined irradiations shown for the selected orientation can be expected as shown in Table 21.

Table 21: Monthly and yearly incident irradiation

Month	GHI (kWh/m²)	DHI (kWh/m²)	GII (kWh/m²)
January	169.3	55.5	178.8
February	165.3	61.4	171.5
March	185.4	76.5	188.4
April	178.6	78.4	177.9
May	174.1	84.1	171.1
June	145.7	83.2	142.7
July	138.9	84.3	136.4
August	136.0	79.3	134.8
September	151.0	75.0	152.1
October	146.9	77.6	150.0
November	137.9	58.5	143.7
December	145.9	66.8	153.5
Total	**1,875**	**880**	**1,901**

We would consider that an inclined irradiation of 1,901 kWh/m²/year for Periyakulam due to the impact of the selected orientation can legitimately be applied to the site and these figures have been carried forward in the analysis.

7.2 System Design

7.2.2 Modelled system design and approach

There are a number of losses associated with the harvesting of sunlight for the generation of DC power and there are further losses in the conversion of DC power from the modules to the useful AC power that feeds to the grid, the cumulative loss of which defines a project's Performance Ratio (PR).

These specific losses are dependent on the system design and key plant components. For this Subproject, the modelled system design characteristics were based on communication with and information provided by the Client.

Each individual loss has been modelled taking into account the plant configuration conceptualised (and considered sufficient) and industry best practices.

Some specific losses are influenced by factors which cannot always be quantified at an early stage of a project. However, these should be considered in order to accurately determine the performance of the project. Should specific information be provided regarding those losses, then this can be reviewed, and the figures adjusted accordingly. Below is a non-exhaustive list describing some of these factors:

- Variation in performance and efficiencies under real operating conditions;
- Characteristics that vary due to the manufacturing and sorting process of PV modules;
- Performance measurements that are not identified on standard data sheets;

- Current technology in the PV industry;
- Quality of design and installation method;
- Power Factor different from unity or grid maximum export limitation.

In consideration of the above, the following assumptions have been made in relation to the expected system design and installation:

- Standard quality of the executed installation method;
- General design and sizing criteria in line with quality standards. Quality standards include cable voltage drop limits, panel heating and ventilation, control and protection settings etc.;
- Final configuration of Project equipment to be completed using a standard approach;
- For the purpose of this yield we have assumed a Power Factor of unity (PF=1) at the inverter level. There is likely to be a small amount of power factor required to overcome the inductive losses of the electrical transmission from the inverters to obtain unity at the connection point. A detailed review to obtain this figure is outside of the scope of this report. We have modelled the most likely occurring power factor experienced on similar sites. The inverters are capable of operating in the range of 0.8 leading to 0.8 lagging, however running the site constantly at a PF 0.8 will make a significant difference in the losses. It should be noted that in the event the grid operator requires the Plant to operate within this range, the yield should be updated. This power factor may also impact the under-sizing loss for the higher DC:AC ratios.

For the energy yield assessment, PVsyst software (v7.2) is used.

The yield is based on the site layout developed by us, which connects strings comprising of 20 modules along the length of the row. This configuration has been modelled accordingly in PVsyst.

7.2.3 String sizing

Modules are connected in strings (a number of panels connected in series). A number of strings may then be connected in parallel to an inverter. String and panel arrangements are determined by the following factors:

- The MPP voltage range of the inverter;
- The highest MPP current capacity of the inverter; and
- The maximum system voltage of the panels.

For this, the electrical characteristics of the strings and array are calculated for 70˚C and 0˚C[11] module temperature and compared against the above parameters in order to ensure that the project is suitably designed.

A summary of the string configuration, power ratio, voltage and current compatibility of the string arrangement are detailed in Table 22.

11 We have reviewed long term site temperature data and consider a minimum temperature assumption of 0°C to be appropriate for this calculation for the Project location.

Table 22: System configuration

Array size (kWp)	String configuration	No. of inverters	Power ratio (AC:DC)	Module	Max. voltage compatible	Max. current compatible
140	10 strings of 26 modules per Sungrow SG111-HV inverter	1	1:1.26	JA solar JAM72-S30-540-MR	✓	✓
17,999	1,282 strings of 26 modules per Sungrow SG320HX-20A inverter	41	1:1.49	JA solar JAM72-S30-540-MR	✓	✓

The AC:DC ratio is based on the nominal inverter power (111 kVA at 50°C and 125 kVA at 40ºC) and (295 kVA at 50°C and 320 kVA at 40ºC), which is in line with project requirements.

The maximum voltage and current expected to be produced by the PV array have been calculated considering the climatic conditions at the site and was not found to exceed the operational limits of each inverter. As such we consider the system configuration to be suitable.

7.3 Detailed Performance Ratio Calculations

7.3.2 PR Calculations

The PR has been estimated following the process outlined in the previous section and a breakdown can be seen in Table 23.

Table 23: PR Calculations

Description	Loss	
	140 kWp Pilot Project	18 MWp Project
Far shadings	0.0%	0.0%
Near shadings: irradiance loss	0.0%	0.0%
Spectral	0.0%	0.0%
Angular / IAM	3.0%	3.0%
Soiling cover	1.0%	1.0%
Low irradiance performance	0.6%	0.6%
Light Induced Degradation (LID)	1.2%	1.2%
Module quality / power tolerance	-0.4%	-0.4%
Module temperature losses	7.3%	7.3%
Near shadings: Electrical effect	0.0%	0.0%
Mismatch	0.4%	0.4%
Ohmics, DC wiring	0.7%	0.8%

Description	Loss	
	140 kWp Pilot Project	18 MWp Project
Inverter efficiency	1.2%	1.5%
Undersizing of the inverter	0.5%	0.5%
MPPT performance	0.0%	0.0%
Ohmics, AC LV wiring	0.5%	0.6%
LV-MV transformer	1.1%	1.2%
Ohmics, AC MV wiring	0.0%	0.6%
Self-consumption	0.2%	0.3%
Module degradation	0.2%	0.2%
Plant and Grid availability	98.8%	98.8%
PR at PF=1	**82.8%**	**81.7%**

All subsequent yield calculations in this report are based on the PR modelled at the PoC located at the PoC. LV and MV line losses have been computed based on the assumption of power evacuation line up to PoC.

The Consultant has applied a soiling loss of 1.0% to the model considering FSPV project. Based on our experience of FSPV projects, we recommend that the modules are cleaned about 20 times a year. A degradation rate of 0.4%/year is considered to be an appropriate assumption for inclusion in the Project financial model.

For year one, we take the average degradation of 0% at the starting point and 0.4% at the end of year 1. Therefore, for the purposes of modelling first year PR numbers a value of 0.2% has been used.

7.3.3 Availability assumptions

This energy yield study assumes 99.4% plant availability and 99.4% grid availability.

7.3.4 Yield estimations

Specific yield is a measure of the output of a PV system per unit of installed capacity (kWh/kWp). It is a function of the irradiance experienced by a system, and its PR. Year one specific yield calculations for the projects are shown in Table 24.

Table 24: Year one energy yield for the system

Project	PR	Installed capacity (kWp)	Probability of exceedance	Specific yield (kWh/kWp)	1st year production (MWh)
140 kWp Pilot Project	82.8%	140	P50	1,573	220.9
			P75	1,505	211.0
			P90	1,443	203.0
18 MWp utility scale Project	81.7%	17,999	P50	1,553	27,960
			P75	1,486	26,740

Project	PR	Installed capacity (kWp)	Probability of exceedance	Specific yield (kWh/kWp)	1st year production (MWh)
			P90	1,425	25,650

Plant and grid availability have been included in our year one specific yield figures in Table 24. The figures in Table 24 already contain an allowance for the first year's degradation. For future years' output we recommend that a linear degradation of 0.4% be applied. P75, and P90 numbers are based on an uncertainty analysis. Table 25 shows the annual energy production for 25 years.

Table 25: 25 years energy yield

Year	Annual production (MWh) at P50	
	140 kWp	18 MWp
Year 1	220.9	27,960.0
Year 2	220.0	27,848.2
Year 3	219.1	27,736.8
Year 4	218.3	27,625.8
Year 5	217.4	27,515.3
Year 6	216.5	27,405.3
Year 7	215.7	27,295.6
Year 8	214.8	27,186.5
Year 9	213.9	27,077.7
Year 10	213.1	26,969.4
Year 11	212.2	26,861.5
Year 12	211.4	26,754.1
Year 13	210.5	26,647.1
Year 14	209.7	26,540.5
Year 15	208.8	26,434.3
Year 16	208.0	26,328.6
Year 17	207.2	26,223.3
Year 18	206.3	26,118.4
Year 19	205.5	26,013.9
Year 20	204.7	25,909.8
Year 21	203.9	25,806.2
Year 22	203.1	25,703.0
Year 23	202.3	25,600.2
Year 24	201.4	25,497.8
Year 25	200.6	25,395.8

8 Technical inputs to financial analysis

This section provides an overview of the project cost, O&M cost and CUF considering suitable assumptions. Table 26 shows the Project cost estimated considering the present market rate with ±10% uncertainty.

Table 26: FSPV project cost

Items	Cost (Lakh INR)	
	140 kWp	18 MWp
PV module	43.9	5,346.0
Inverter	3.5	320.4
Floater-module, walkway, equipment mounting and cable laying and anchoring & mooring system	12.6	1,080.0
Balance of System (BOS)	14.0	1,260.0
Power evacuation	12.0	108.0
Installation and commissioning	6.3	540.0
Total hard cost without tax	*92.3*	*8,654.4*
Applicable tax (12% on 70% of total project cost and 18% on 30% of total project cost)	12.7	1,194.3
Total hard cost with tax	*105.0*	*9,848.7*
Soft cost (Financing/ IDC/Insurance/Stamp Duty/Mortgage/Working Capital + Contingency)	4.9	519.3
Total	**109.9**	**10,368.0**

Other technical inputs to the financial model are given in Table 27.

Table 27: Technical inputs to financial model for FSPV project

Items	UoM	Value		Reference
		140 kWp	18 MWp	
Annual energy generation (1st year)	Lakh units	2.21	279.6	Energy yield estimated at P50
Capacity Utilization Factor (CUF)	%	18.0	17.7	CUF estimated at P50
Year-on-Year (Y-o-Y) degradation	%	0.4	0.4	Consultant's assumption
Useful life	Years	25	25	Market standard
Project cost	Lakh INR	110	10,368	Table 26
O&M cost	Lakh INR	0.7	63	Market rate
O&M cost escalation rate	%	4	3	Market rate
Inverter replacement year	Year	13th	13th	Market standard

The project cost and key technical inputs for the financial analysis for development of utility scale ground mounted solar PV project are shown in Table 28 and Table 29.

Table 28: Ground mounted solar PV project cost

Items	Cost (Lakh INR/MWp)
PV module	297.0
Inverter	17.8
Module mounting structure	40.0
Balance of System (BOS)	70.0
Power evacuation	6.0
Installation and commissioning	20.0
Land	12.0
Total hard cost without tax	462.8
Applicable tax (12% on 70% of total project cost and 18% on 30% of total project cost)	*63.9*
Total hard cost with tax	*526.7*
Soft cost (Financing/ IDC/Insurance/Stamp Duty/Mortgage/Working Capital + Contingency)	27.8
Total	**554.4**

Table 29: Technical inputs to financial model for ground mounted solar PV project

Items	UoM	Value	Reference
Project capacity	kWp	1,000	Project layout
Annual energy generation (1st year)	Lakh units	15.6	Energy yield estimated at P50
Capacity Utilization Factor (CUF)	%	17.8	CUF estimated at P50
Year-on-Year (Y-o-Y) degradation	%	0.4	Consultant's assumption
Useful life	Years	25	Market standard
Project cost	Lakh INR	554.4	Table 28
O&M cost	Lakh INR	3.5	Market rate
O&M cost escalation rate	%	4	Market rate
Inverter replacement year	Year	13th	Market standard

The project cost and key technical inputs for the financial analysis for development of wind power project are shown in Table 30 and Table 31.

Table 30: Wind power project cost

Items	Cost (Lakh INR/MW)
WTG supply	525.0
Unit substation and internal transmission line	77.0
Power evacuation till GSS	12.0
Installation and commissioning	15.0

Items	**Cost (Lakh INR/MW)**
Land	104.0
Total without tax	*733.0*
Applicable tax (12% on 70% of total project cost and 18% on 30% of total project cost)	95.9
Total with tax	*828.9*
Soft cost (Financing/ IDC/Insurance/Stamp Duty/Mortgage/Working Capital + Contingency)	44.0
Total	**872.9**

Table 31: Technical inputs to financial model for wind power project

Items	UoM	Value	Reference
Project capacity	kW	1,000	Project layout
Annual average energy generation	Lakh units	28.91	Energy yield estimated at P90
Capacity Utilization Factor (CUF)	%	33.00	CUF estimated at P90
Year-on-Year (Y-o-Y) degradation	%	0.05% (2nd to 20th year) 0% (21st to 25th year)	Consultant's assumption
Useful life	Years	25	Market standard
Project cost	Lakh INR	872.88	Table 30
O&M cost	Lakh INR	9.0	Market rate
O&M cost escalation rate	%	5	Market rate
Inverter replacement year	Year	13th	Market standard

9 Permits and clearances

The permits and clearances required at different stages of FSPV / ground mounted solar or wind project development have been presented in Table 32.

Table 32: Permits and clearances

List of Consents	Authority	Approval Stage
Project registration	Tamil Nadu Energy Development Agency (TEDA) / Non-Conventional Energy Sources (NCES) department of TANGEDCO	Prior to Construction
Labour registration, workman compensation policy, ESIC	Labour Ministry and other Relevant Authorities	Prior to Construction
Erection All Risk Insurance	Relevant Authorities	Prior to Construction
Consent to Establish (CTE)	Tamil Nadu state Pollution Control Board	Prior to Construction
Consent to Operate (CTO)	Tamil Nadu state Pollution Control Board	Prior to start of operation
Evacuation /connectivity approval and approval of drawing and documents	Electrical Inspectorate of TANGEDCO	Prior to Commissioning
Land sale / lease deed	Revenue department	For ground mounted project only
No Objection Certificate (NOC)	Gram panchayat / CCMC	
Road crossing of transmission line/cable	High-way authority	If required
Chief Electrical Inspector to Government (CEIG) approval	TANGEDCO	Prior to Commissioning
Wheeling and Banking permission	TANGEDCO	Prior to Commissioning, for open access project
Long Term Open Access (LTOA) or Medium Term Open Access (MTOA)	TANGEDCO	
Commissioning Certificates	TANGEDCO	Post Commissioning

In addition to above, the Contractor has to fulfil all the required criteria of the CCMC to deploy manpower and perform the task in the lake premise. The Contractor shall contact CCMC's representative and understand the minimum permits and clearances and health, safety and environment (HSE) requirements to perform any task in the lake area. The Contractor shall be allowed to perform works at project site in the day-time only i.e. sunrise to sunset due to safety reasons.

10 Technical Specification of Pilot Project

This specification defines the minimum requirements for the design engineering, procurement (manufacturing / supply), construction / erection, testing and commissioning of FSPV project.

10.1 Environmental Conditions

Following site conditions shall be considered while conducting detailed engineering of the project:

- All equipment shall be designed for 50˚C ambient temperature.
- Project location falls under Wind Zone- II, where the basic wind speed is 39 m/sec (140.4 kmph) as per IS-875:1987 (Part-3). All structures and floating island shall be designed for the minimum wind speed of 39 m/sec.
- The seismic zone shall be zone-III as per IS 1893 part -1.
- Relative humidity shall be considered 90%.

10.2 PV module

- The total solar PV array capacity should not be less than allocated capacity (140 kWp) and shall comprise of mono c-Si PERC solar PV modules of minimum 540 Wp and above wattage.
- The glass shall be minimum 3.2 mm thickness with anti-reflection coating, high transmission, low iron tampered glass.
- The frame shall be minimum 35 mm height and made up of anodized aluminium alloy.
- Protective devices against surges at the PV module shall be provided. Low voltage drop bypass diodes shall be provided.
- PV modules must be in Ministry of New and Renewable Energy (MNRE)'s Approved List of Models and Manufacturers (ALMM) and in Bloomber New Energy Finance (NEF)'s Tier-1 list, tested and approved by one of the IEC authorized test centres, NABL accredited laboratories and as per guidelines of MNRE.
- The module frame shall be made of corrosion resistant materials, preferably having anodized aluminium.
- The bidder shall carefully design & accommodate requisite numbers of PV modules to achieve the rated power.
- Other general requirement for the PV modules and subsystems shall be the Following:
  - The rated output power of any supplied module shall have positive tolerance in range of 5 Wp or above.
  - The peak-power point voltage and the peak-power point current of any supplied module and/or any module string (series connected modules) shall not vary by more than 2% (two per cent) from the respective arithmetic means for all modules and/or for all module strings, as the case may be.
  - The module shall be provided with a junction box with either provision of external screw terminal connection or sealed type and with arrangement for provision of by-pass diode. The box shall have hinged, weatherproof lid with captive screws and cable gland entry points or may be of sealed type and IP-65 or higher rated.
  - I-V curves at STC should be provided by the Contractor.
- Modules deployed must use a RF identification tag laminated within the PV module and suitable to remain intact for the life of the PV module. The following information must be mentioned in the RFID used on each module. This should be inside the laminate only.

- Name of the manufacturer of the PV module.
- Name of the manufacturer of Solar Cells.
- Month & year of the manufacture (separate for solar cells and modules).
- Country of origin (separately for solar cells and module).
- I-V curve for the module Wattage, Im, Vm and 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 per ISO 9001 and ISO 14001.

- The Bidder shall provide RFID reader suitable for reading RFID tag of modules.

10.2.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 33.

Table 33: Applicable Indian and international Standards for PV module

Standard	Description
IEC 61215/ IS 14286	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) modules
IEC 61701	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1/ IS 16170: Part 1	PV module performance testing and energy rating - Irradiance and temperature performance measurements, and power Rating
IEC 62716	PV modules – Ammonia (NH_3) Corrosion Testing (As per the site condition like dairies, toilets)
IEC 61730-1,2	PV module Safety Qualification – Part 1: Requirements for Construction, Part 2: Requirements for Testing

10.2.3 Warranties

PV modules are having both product and performance warranties. Product warranty is defined as the manufacturer should warranty the PV modules to be free from the defects and/or failures specified below for a period not less than 10 years from the date of sale to the original customer or from the date of CoD whichever is later:

- Defects and/or failures due to manufacturing;
- Defects and/or failures due to quality of materials; and
- Non-conformity to specifications due to faulty manufacturing and/or inspection processes. If the PV modules fail to conform to this warranty, the manufacturer will repair or replace the modules.

As per the performance warranty, the predicted annual degradation of power generated not exceeding 2% in 1st year and not more than 0.55% from 2nd year to 25th year.

10.3 Equipment Mounting Floats

- The PV module floater design shall be appropriate and innovative. It must follow the existing water profile.

- The floater units shall be prefabricated and designed for simple on-site installation. There shall be minimum requirement of masonry or use of complex machinery at the installation site. The floatation unit shall be modular in nature to facilitate the ease of assembly / disassembling and provision to be scaled up. Each module / combination of maximum two modules should support at least one solar panel. All modules should be standardized and independently created. Walk way should be provided to access the flotation device.
- The flotation device should be manufactured from HDPE with UV stabilizer. The design of the floatation device should have satisfactory rigidity, flexural strength (ASTM D790, ISO 178), tensile strength (ASTM D638, ISO 527) and compressive strength (ASTM D695, ISO 604) while loaded with maximum load under extreme environmental conditions.
- The grade of thermoplastic used should be tested under extreme weather conditions if sunlight, UV, heat, air, and water (ASTM D2565, ASTM D4329, ASTMG7/G7M-11), good environmental stress crack resistance and a combination of hardness and impact strength (ASTM D5397, ASTM D1693). The thermoplastic used should be safe for use when in contact with water. (Above points to be confirmed by Manufacturer's data sheet and test certificates).
- Stability of floating device should be maintained. No colour variation after UV exposure equivalent to 10 years under 150 kilo-Langley / Year irradiation. Third party testing or witness is required by purchaser.
- The flotation device shall have minimum strength at ambient temperature of the site location or minimum range of (+) 50 to (-) 10 ^{o}C, while it shall be designed to have safety factor of minimum 1.15 on extreme conditions.
- The flotation device should be passed the Full notch creep test (ISO16770).
- The floater vendor should have proven experience and the agency should have supplied floater to any project in MW range, which is working successfully at least for a period of one (02) years.
- PV module installation system shall be of proven design and subjected to Mechanical test to withstand unit failure conditions under static and fatigue conditions for wind speeds to withstand the maximum wind speed 39 m/s of the area.
- The materials used shall be halogen, silicon free conforming to RoHS directive 2002/95/EC. (Same to be confirmed by Manufacturer's data sheet and test certificates).
- The floatation device should be chemically resistant to acid, lye, petrol and mineral oil and partially resistant to benzene.
- The floatation device should pass the different HDPE material test from Central Institute of Plastics Engineering & Technology (CIPET) or reputed labs from India with may be inspected by the purchaser.
- The floatation device used should be safe for use when in contact with drinking water and meet requirements stipulated in standard IS 15410:2003.
- The min. thickness of thermoplastic used for floatation device should be 4 mm.
- The floatation device, when installed in the raw water reservoir, should not restrict the process of gas exchange across the air water interface. More specifically, the water plane area (WPA) does not allow the transmission of sunlight into the water and the transfer oxygen across the air-water interface. In order to facilitate this, the design of the floatation device should be such that appropriate voids, greater than at least 30% of all area covered by the floatation device.
- The floatation device should be designed such that it arrests evaporation and facilitates in evaporation loss mitigation. Vendor should provide appropriate cover by flotation device and solar panel and total coverage of water body should not more than 70% of the Raw Water Pond and water body. Appropriate vapour escape vents should be provided for each floatation device and solar panel assembly for the purpose of maintaining BOD of the water body.

- The design of the flotation device should incorporate appropriately sized walking platform for regular maintenance and inspection. The row alleys platform should be for both column and row alleys.
- The design of the floating device should incorporate appropriately sized walking platform for regular maintenance and inspection. The walking platform should have a continuous uninterrupted surface with the minimum width of at least 400 mm excluding cable laying arrangement. Walkable floater pathway shall be provided after consecutive two strings of modules. The complete floating system shall have at least 400 mm walking corridor all along the periphery comprising of module floaters and / or walkway floater to prevent water splash.
- In order to increase longevity and prevent unexpected loss of buoyancy, the floating unit shall have a minimum material thickness of 4 mm, with moisture retention of less than 5%. (Detailed buoyancy calculation to be submitted along with the drawings at the time of drawing approval).
- Float system should be designed to withstand the maximum wind speed (140.4 km/hr) and shall be able to withstand the weight of one O&M personal carrying tools, equipment etc with minimum weight of 100 kg.

10.3.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 34.

Table 34: Applicable Standards for floaters

Standard	Description
ASTM D1693	Test for Environmental Stress Cracking of HDPE
ISO16770	Stress cracking resistance of HDPE
IS 15410:2003	Test for drinking water compatibility, Material safe for drinking water
RoHS directive 2002/ 95/EC	Test for Restriction of Hazardous Substances
ASTM D5397	Standard Test Method for Evaluation of Stress Crack Resistance
IS875: Part-3	Code of practice for Buildings & structures-Wind Loads
IS1893:2002	Criteria for earthquake resistant design of structures-General Provisions and buildings
ASTM D790, ISO 178	Standard Test methods for Flexural properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D638, ISO 527	Standard test method for Tensile Properties of Plastics
ASTM D695, ISO 604	Standard test method for compressive strength properties of 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 G7/G7M-11	Standard practice for atmospheric environmental exposure testing of non-metallic

10.4 Anchoring and Mooring System

- The water level variation and prevailing wind speed are the primary safety considerations, to be taken into account, while designing the plant such that the plant has no impact on the reservoir. The mooring system thus needs to be designed that it not only restricts the lateral movement of the proposed plant but also accommodates the water level variability. In addition, the mooring system should also have minimal impact on the overall ecosystem of the reservoir.
- Flexible mooring system shall be designed to keep the platform position to adopt waves, wind and water level variation.
- The array structure should be so designed that it will occupy minimum space without sacrificing the output from PV panels.
- For string inverter mounted on floaters, bidder to take into consideration the load of string inverter during design of floaters and suitable supporting arrangement for mounting the inverter on floaters as per manufacturer recommendation.
- The floatation modules once assembled together should form an integrated structure and relative alignment of the flotation modules subsequent to complete installation (installing module mounting structure and solar PV modules) shall not misalign the solar panels and adversely affect their power generation capability.
- In order to address the proper handling of panel mounting system during the severe weather conditions, floating vendor should have proper expansion capability for panel mounting system.
- The floatation device should be re-processable and recyclable at the end of its useful life.
- Each floatation module should have its appropriate drainage facility such that there is no water logging on the floating module.
- Big wind tunnel test for the structures in all wind directions (real scale, real angle) for at least 2x4 configurations to be done.
- The clearance between lowest part of the module structure and the water level shall normally not be more than 250 mm.
- The module alignment and tilt angle, in case of floating SPV power plant, shall be between 1 degree to 18 degrees. It shall be mounted facing south and tilted to an angle within the range of 1 degree to 18 degrees for optimum performance and appropriate wind resistance that must be mentioned in engineering drawing for approval of Client with documentary proof.
- Mountability of solar panel by the floatation device should be maximum 2 panels per unit.
- The flotation device should balance the thermal expansion so that PV panel not stretched by thermal expansion.
- Min. guaranteed life of the floatation device/ unit floater should be 25 years.
- The design of complete system, including CFD modeling, comprising of Floating unit, MMS and anchoring and mooring system, shall be verified by suitable third party NABL accredited agency/ reputed institutions like IITs and submitted for employer's approval.
- The flotation device should be manufactured locally (in India) only, to ensure safe work practice, genuine process is followed & transparent quality checks by Client at manufacturing premises any time.
- The array structure shall be so design that it will occupy minimum space without sacrificing the output from SPV panels.
- The structure shall be designed to allow easy replacement of any module by authorized personnel and shall be in line with the site requirements.
- The array structure for metallic structure (if used) shall be made of anodized aluminium (aluminium alloys) / SS 304 or SS better grade, of suitable thickness size. (Same to be confirmed by suitable test report and material composition report) having sufficient strength and

suitable size to mount/ support all the PV panel/ accessories/ equipment required for the plant. (To be supported by structural analysis report). All design shall be submitted during drawing approval with suitable test reports.

- The complete support structure, design shall normally be designed to withstand wind speed up to 140.4 km/hr (to be confirmed by suitable third party test report).
- The complete plant is to be designed with proper anchorage system so as to withstand the wind pressure at maximum 140.4 km/hr.
- In general bolts, nuts, shims and other hardwires should be Zinc plated. Fasteners visible outside shall be of stainless steel SS 304. The generally applicable engineering principle will be the fasteners shall be equal to or of greater corrosion resistance than the most corrosion resistance metals being fastened.
- Dedicated floating approach walkways to be provided from the end of the water body to each block of the plant with suitable railing on both sides. The block size of the floating system depends on the array layout optimization. The same shall be finalized during detailed engineering.
- The water level variation and prevailing wind speed are the primary safety consideration, to be taken into account, while designing the plant such that the plant has no impact on the reservoir. The mooring system thus needs to be designed that it not only restricts the lateral movement of the proposed plant but also accommodates the water level variability. In addition the mooring system should also have minimal impact on the overall ecosystem of the reservoir.
- The minimum life of the Anchoring system shall be 25 years.
- The materials used in the anchoring system shall not contaminate the water of or affect the aquatic life.
- The design of mooring system shall permit minimal lateral movement of the plant in case of maximum wind loads (As per IS 875-3). Anchoring design report for the project showing that the system could support the maximum wind load on site shall be submitted to employer.
- Placement of Plant: The placement of the plant in the water body shall be decided during detail engineering after conducting bathymetric survey, topographical survey, hydro graphic and hydrological studies and geo-technical assessment of the site.
- Prevailing wind load: The mooring system should be designed for worst case scenario; for a wind load of 140.4 km/hr. The design of the mooring should prevent the lateral movement of the plant in case of maximum wind loads.
- Water variability: The mooring system should accommodate fluctuations in water level. Further the orientation of the plant needs to be maintained; hence fluctuations in water level should not result in lateral movement of the plant.
- The mooring system should minimize its impact on the reservoir and thus as far as possible pilings or movement of mooring system of the reservoir bed should be avoided.
- Suitable wind breakers should be provided.
- The manufacturer should warrant the solar PV module floaters and Anchoring system to be free from the defects and/or failures specified below for a period of 25 years from the date of sale to the original customer (i.e. EPC Contractor).
  - Defects and/or failures due to manufacturing
  - Defects and/or failures due to quality of materials
  - Non conformity to specifications due to faulty manufacturing and/or inspection processes.
- If the solar PV module floaters and Anchoring system fails to confirm to this warranty, the manufacturer will repair or replace the solar PV module floaters and Anchoring system, at the Purchaser's sole option. The contractor shall be responsible to contact with the supplier if any of the above-mentioned cases occurred.

10.4.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 35.

Table 35: Applicable standards for anchoring and mooring system

Standard	Description
RoHS directive 2002/ 95/EC	Test for Restriction of Hazardous Substances
ASTM D5397	Standard Test Method for Evaluation of Stress Crack Resistance
IS3043:1987	Grounding of mounting structures
IS800:1984	Code of practice for general construction of steel
IS875: Part 2	Code of practice for Buildings & structure
IS875: Part-3	Code of practice for Buildings & structures-Wind Loads
IS1893:2002	Criteria for earthquake resistant design of structures-General Provisions and buildings
IS 4759	Hot dip Zinc coating on structural steel and other allied products.
IS4736	Hot dip Zinc coating on mild steel tubes
IS2062	Hot Rolled Medium and High Tensile structure steel.

10.5 Inverters

As PV array produce direct current electricity, it is necessary to convert this direct current into alternating current and adjust the voltage levels to match the grid voltage. Conversion shall be achieved using an electronic Inverter and the associated control and protection devices. All these components of the system are termed the “Power Conditioning Unit (PCU)”. In addition, the PCU shall also house MPPT (Maximum Power Point Tracker), an interface between Solar PV array & the Inverter, to the power conditioning unit/inverter should also be DG set interactive. If necessary. Inverter output should be compatible with the grid frequency. Typical technical features of the inverter shall be as follows:

Table 36: Inverter General Technical Particulars

Parameters	Description
Switching devices	IGBT/MOSFET
Control	Microprocessor /DSP
Rated capacity	111 kW
Maximum DC voltage	1500 V
MPPT	Multiple
Nominal AC output voltage and frequency	540 V, 3 Phase, 50 Hz
Output frequency	50 Hz
Grid Frequency Synchronization range	+/- 5 Hz
Ambient temperature considered	-20˚C to 50˚C
Humidity	95% non-condensing

Parameters	Description
Protection of enclosure	IP-65 and outdoor
Grid Frequency Tolerance range	+/- 5 Hz
Grid Voltage tolerance	-20% to +15%
No-load losses	Less than 1% of rated power
Inverter efficiency (minimum)	>97% (without in-built galvanic isolation)
THD	< 3%
PF	0.8 lag ~ 0.8 lead
Protections	Over current and over voltage protections at both DC and AC sides of Inverter. Minimum type-II SPD or higher shall be acceptable.

- PCU/inverter shall be capable of complete automatic operation including wake-up, synchronization & shutdown;
- The output of power factor of PCU inverter is suitable for all voltage ranges or sink of reactive power, inverter should have internal protection arrangement against any sustainable fault in feeder line and against the lightning on feeder;
- Built-in meter and data logger to monitor plant performance through external computer shall be provided;
- Anti-islanding (protection against islanding of grid): The PCU shall have anti islanding protection in conformity to IEEE 1547/UL 1741/ IEC 62116 or equivalent BIS standard;
- The Contractor shall be responsible for limiting DC injection into the grid and load as per the CEA/state regulations;
- The PCU/ inverter generated harmonics, flicker, DC injection limits, Voltage Range, Frequency Range and Anti-Islanding measures at the point of connection to the utility services should follow the latest CEA (Technical Standards for Connectivity Distribution Generation Resources) Guidelines;
- The power conditioning units / inverters should comply with applicable IEC/ equivalent BIS standard for efficiency measurements and environmental tests as per standard codes IEC 61683/IS 61683 and IEC 60068-2 (1,2,14,30)/ Equivalent BIS Std;
- The MPPT units environmental testing should qualify IEC 60068-2 (1, 2, 14, 30)/ Equivalent BIS std. The junction boxes/ enclosures should be IP 65 (for outdoor)/ IP 54 (indoor) and as per IEC 529 specifications;
- The PCU/ inverters should be tested from the MNRE approved test centres/ NABL/ BIS/ IEC accredited testing- calibration laboratories. In case of imported power conditioning units, these should be approved by international test houses.

10.5.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 37.

Table 37: Applicable Indian and international Standards for Inverters

Standard	Description
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems: Part 1: General requirements, and Safety of power converters for use in photovoltaic power systems

Standard	Description
	Part 2: Particular requirements for inverters. Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC/IS 61683 (as applicable)	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions)
IEC 62116/ UL 1741/ IEEE 1547 (as applicable)	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures
IEC 60255-27	Measuring relays and protection equipment – Part 27: Product safety requirements
IEC 60068-2 / IEC 62093 (as applicable)	Environmental Testing of PV System – Power Conditioners and Inverters
Fuses	
IS/IEC 60947 (Part 1, 2 & 3), EN 50521	General safety requirements for connectors, switches, circuit breakers (AC/DC): • Low-voltage Switchgear and Control-gear, Part 1: General rules • Low-Voltage Switchgear and Control-gear, Part 2: Circuit Breakers • Low-voltage switchgear and Control-gear, Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units • EN 50521: Connectors for photovoltaic systems – Safety requirements and tests
IEC 60269-6	Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

10.6 HV Switchgear

- The general construction of the MV Switchboards shall be factory assembled with fabrication processed on CNC type or equivalent machines.
- The switch boards shall be dead front totally enclosed, cubicle type suitable for floor mounted free standing outdoor installations. The design shall be totally dust - tight damp-proof and vermin proof offering degree of protection not less than IP-42 for indoor applications and IP-65 for outdoor applications.
- Switchboards shall be in compliance to form 4 as per IEC. Separate segregated compartments shall be provided for breakers, Isolators, bus bars, cable box, voltage Transformers, wire ways, relays, and instrument and control devices. Switchboard shall be compartmentalised design and shall be provided with hinged doors in front and back with facility for padlocking doors.
- Circuit breakers shall be drawing out type, motor operated with independent closing and shunt tripping from a suitable DC supply source. Breaker truck front panel shall house mechanical ON/OFF push actuators, manual & motorised mechanism, spring charge status, operation counter and any other provision as required to carry out safe operation.
- 11 kV switchgear panel shall be equipped with metering and protection relays as indicated in drawings. All relays shall be numeric type with multifunctional meter having an accuracy class of 1.0s.

- Circuit breakers shall be equipped with manual spring charge facility for closing the breaker as an alternative to motorized operation.
- Breaker panels shall be compact in construction and metal enclosed with sheet steel of suitable thickness.
- All the metallic parts shall be suitably thick and shall use high tensile steel which shall be suitably treated & painted.
- 11 kV Switchgear and panels shall be equipped with all the protections as required to complete the commissioning and for safe operations. 33kV surge arrestors shall also be provided at the outgoing feeder.
- 11 kV bus shall be constructed in such a way that by operating one breaker preferably or as mutually agreed during detailed engineering (bus coupler) all inverters can be switched off during non-generating hours with the auxiliary system operational. The parties shall jointly discuss with the Original Manufacturers in case Supplier is unable to seek the relevant Warranties as agreed in the Contract.
- All breakers should have same rating so that interchangeability is possible, one Spare feeder shall be provided.
- The bus bars shall be of high conductivity electrolytic copper, air insulated and housed in a separate compartment segregated from all other compartments supported by epoxy insulators. Busbars should have uniform cross sections with suitable capacity for carrying rated current continuously and short circuit current for specific time duration without overheating. All the bus bars shall be provided with colour coded heat shrinkable sleeves.
- Instrument Transformers shall be suitable for measuring and protection. Appropriate error limits, burden shall be selected for specified class of instrument Transformers. The CT and PT design and construction shall withstand system thermal and dynamic overloads.
- The switchboard shall be provided at the bottom throughout its entire length with adequately sized copper earth bus to carry the fault current for the same duration as short time rating of the circuit breaker. Earth bus shall have two earthing connection facility at its both ends of earthing conductor.
- All the Incoming and outgoing feeders shall be provided with multifunctional meter, which shall have an accuracy class of 1.0s with provision of measuring Import and export of energy. All relays shall be numeric type.
- Each breaker vertical shall be equipped with local/remote selector switch, emergency stop, TNC switch, indicating lamps showing breaker ON, OFF, TRIP, spring charge, trip circuit healthy, breaker in TEST/SERVICE position, gas pressure low. Additionally, annunciation window with hooter shall also be provided.
- Space heaters shall be provided with each breaker vertical.
- The Contractor shall submit all relevant calculations and drawings/ data sheets/ guaranteed parameters of the 11 kV Switchgear to the Purchaser for approval prior to commencement of manufacture.
- The Contractor shall ensure that all spare cable entry holes inside the cubicle be sealed with proper size rubber grommets.
- A continuous 50mm x 6mm copper (tinned) earth bus shall be provided running along the full lengths of the panels.
- Suitable arrangement shall be provided at the two ends for connection to the Plant earthing system.
- Each panel and the equipment mounted on each panel shall be securely connected to the earth bus.

- For this purpose, the earth wire shall be looped from equipment to equipment and both ends of the earth wire shall be connected to the earth bus.
- Busbar shall be constructed from hard drawn, high conductivity, tin plated electrolytic copper of 99% purity with high pressure bolted type connection.
- Busbar shall be fully insulated and of uniform cross-section and shall run the full length of the switch board. Bus bar ends shall be ready with drilled and finished for future extension for both ends.
- Insulation shall comply with the type of air insulated bus bars. The insulation shall be continued as far as practicable into the circuit breaker/starter compartments.
- Bus Bars shall be adequately braced to withstand the thermal and magnetic short circuit current of 40 kA and stresses imposed on the electrical system for 1 Sec.
- Busbar including all joints shall be insulated and their spacing, regardless of Busbar shall be arranged and supported so that under no circumstances (including short-circuit conditions) shall the clearances from earthed metal work or other phase conductor shall be less than the distances specified in IEC 60071.
- Stand-off insulators and bus bar supports and inserts shall be made of porcelain or cycloaliphatic epoxy material and shall comply with requirement of IEC 60071.
- All insulating material shall be flame resistant, non-hygroscopic and non-tracking in the presence of corona. Tapered Bus Bars are not acceptable.
- Busbar compartment shall be fully independent of other compartments and be provided with insulated barriers between panels to contain flashover. No other wiring shall be included in this compartment except the connections between vertical bus bars and main bars by solid bars.
- The Busbar spout and circuit spout covers shall be operated independently of each other.
- Phase identification of Busbar shall be done be coloured heat resisting non shrinkable PVC sleeving or non-flammable painting material.
- Phase of bus-bars and other main circuit conductors including the connection terminals shall be identified as follows, at one end or other place along the length.

10.6.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 38

Table 38: Applicable Standards for HT switchgear

Standard	Description
IS 2516	Circuit Breakers.
IS 2705	Current Transformers
IS 3156	Potential Transformers
IS 13118	HV Circuit Breakers

10.7 Inverter Duty Transformer

- The inverter duty transformer, 150 kVA, 11/0.540 kV rating shall be considered.
- The inverter duty transformer should be provided with separate galvanically isolated low-voltage windings for each Inverter. These shall be of converter duty and suitable for operation with pulsed Inverter.

- The inverter duty transformer should be rated for a maximum temperature rise of 50°C by oil temperature and 55°C by winding temperature with a daily average ambient temperature of 50°C.
- The inverter duty transformer shall have ONAN type cooling arrangement.
- The inverter duty transformer shall have off circuit tap changer with suitable numbers of taps
- The inverter duty transformer bushing shall be of solid porcelain.
- The Contractor shall submit all relevant calculations and drawings/ data sheets/ guaranteed parameters of the inverter duty transformer to the Purchaser for approval prior to commencement of manufacture.
- The inverter duty transformer tank should provide rigidity and dynamic ability to withstand pressure due to short circuit current. It should be capable of bearing all stresses during transportation and operation without any deformation.
- Low carbon steel grade plates that have been stiffened and reinforced may be used. Oil tight welds and joints shall be provided and measures should be taken to prevent internal corrosion of plates.
- Pressure Test: Fully assembled transformer with its radiators, conservator and other fittings shall be capable of withstanding a pressure equivalent to twice the normal head of liquid or 35 kN/m^2 in addition to the normal pressure, for one hour and measured from the base of the tank.
- Inspection opening and cover must be provided with handling equipment for easy access to bushing connections.
- The cover design shall avoid stagnant water and facilitate easy flow of gas bubbles towards the Buchholz relay.
- Design of magnetic shall be such as to avoid static discharge development of short circuit within itself or in earthed clamped structure.
- Core shall be of non-aging, high grade and low loss Cold Rolled Grain Oriented (CRGO) Silicon steel.
- The maximum permissible flux density for the laminations under the specified at rated or normal voltage and frequency condition shall not exceed 1.7 tesla.
- 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 to combined voltage and frequency fluctuations:
  - 110% for continuous rating.
  - 125% for at least one minute.
  - 140% for at least five seconds.
  - Bidder shall furnish over fluxing characteristic up to 150%
- Winding conductor should be electrolytic grade copper, free from scales and burrs.
- To avoid shrinkage during operation, windings shall be subjected to shrinkage treatment.
- The winding assembly should be full vacuum dried and then impregnated immediately in transformer oil.
- Oil will be pure hydrocarbon mineral oil, clean, free from moisture, and have uniform quality throughout.
- For the first oil filling of each Transformer, 10% extra oil of total quantity of oil in non -returnable shall be supplied.
- Sufficient number of radiators shall be made to meet the requirement of temperature rise.
- Radiators shall be detachable type directly mounted or separately mounted. Flanged, gasketed and bolted connections shall be used for connecting the radiators to the tank.
- Radiators shall be individually tested for leakage and pressure test etc. before connecting to tank.

- Each radiator shall have top and bottom shut off valves, top filling plug, bottom drain plug, lifting lugs, thermometer pockets at inlet and outlet pipes, air release devices, earthing provisions, filter valves and all other necessary accessories required.
- Radiator valves must indicate open and close direction clearly.
- Marshalling box fabricated using cold rolled sheet of at least 1.6 mm thickness shall be tank mounted, with a sloping roof. The box shall be tank protection of IP 65 as per IS: 2147.
- All the incoming cables shall enter the marshalling box from bottom.
- All outgoing connections from the transformer shall be connected to the marshalling box. It shall be enclosed in a metal casing and be weather and dust proof with a minimum of IP 65 certification.
- The temperature indicators shall be mounted at about 1600mm from ground level.
- Conservator with oil level gauge and plain silica gel breathing device shall be mounted integral with the tank in such a manner that the lowest oil level bushings remain under the head of liquid under all times.
- Volume of the conservator shall meet the requirement of expansion of total oil in Transformer and cooling equipment from minimum ambient to oil temperature of 90ºC.
- The oil filling hole shall have a cap and suitable drainage valve to completely drain the oil.
- One end of conservator shall be bolted to facilitate cleaning.
- Breathers shall be mounted at approximately 1400 mm above ground level.
- Pressure release devices operating at a static pressure below the hydraulic pressure of the tank shall be provided at all appropriate locations. The device shall also be equipped with potential free contact for alarm/trip and connected to the marshalling box.
- To avoid discharge spraying from the pressure release devices on the tank, the discharge shall be taken through pipes away from the Transformer.
- The Buchholz Relay shall be a double float relay as per IS 3637 with shut off valves on either side.
- Pot cocks at the top and bottom of the relay drain plug. An inspection window and calibrated scale for measurement, terminal box with oil tight double compression type brass gland.
- The angle of inclination should be between 3° and 7°.
- All valves shall be of gun metal only and of sluice type provided with hand wheels. The valves shall have padlocking facility in closed and open condition.
- Open and closed position shall clearly be mentioned on the valves.
- They shall be provided with blanking plates or screwed plugs.
- 150 mm dial type thermometers and 150 mm diameter dial type indicator shall be provided for oil and winding respectively. Minimum two potential free contacts for alarm and trip signals shall be provided. Temperature sensing equipment shall be connected through capillary tube.
- Temperature indicator dials shall have linear gradations to clearly read at least every 2ºC with ±1.5% accuracy or better.
- As per CEA this shall be ensure that the transformers of 10 MVA and above rating or in case of oil filled transformers with oil capacity of more than 2000 liters are provided with firefighting system its per IS - 3034: 1993 or with Nitrogen Injection Fire Protection system (NIFPS).

10.7.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 39

Table 39: Applicable standards for inverter duty transformer

Standard	Description
IS 2026	Power Transformers
IEC 61378 -1	Converter duty Transformers
IS 3639	Fittings and Accessories for Power Transformers
IS 2099	Specification of HV Porcelain Bushing
IS 7421	Specification of LV Porcelain Bushing
IS 10028	Practice for selection, installation & maintenance of Transformers
IS 335	New Insulating oils
CBIP12	Manual on Transformers
IS 3637	Buchholz Relay
IS 5561	Specification for terminal connector
IS 6600	Specification for overloading of Transformers
IS: 2147	Marshalling Box

10.8 Data Acquisition System / Plant Monitoring

- Data Logging Provision for plant control and monitoring, time and date stamped system data logs for analysis with the high quality, suitable PC. Metering and Instrumentation for display of systems parameters and status indication to be provided.
- Data logger shall be with Zero export feature and a control loop to ensure that the plant is switched-OFF when the main supply is OFF and back-up generator is ON.
- **Solar Irradiance:** An integrating pyranometer / solar cell based irradiation sensor (along with calibration certificate) provided, with the sensor mounted in the plane of the array. Readout integrated with data logging system.
- **Temperature**: Temperature probes for recording the Solar panel temperature and/or ambient temperature to be provided complete with readouts integrated with the data logging system
- The following parameters are accessible via the operating interface display in real time separately for solar power plant:
  - AC Voltage.
  - AC Output current.
  - Output Power
  - Power factor.
  - DC Input Voltage.
  - DC Input Current.
  - Time Active.
  - Time disabled.
  - Time Idle.
  - Power produced
  - Protective function limits (Viz-AC Over voltage, AC Under voltage, Over frequency, Under frequency ground fault, PV starting voltage, PV stopping voltage.

[12] CBIP-Central Board of Irrigation and Power,

- All major parameters available on the digital bus and logging facility for energy auditing through the internal microprocessor and read on the digital front panel at any time and logging facility (the current values, previous values for up to a month and the average values) should be made available for energy auditing through the internal microprocessor and should be read on the digital front panel.
- PV array energy production: Digital Tri Vector Energy Meters to log the actual value of AC/ DC voltage, Current & Energy generated by the PV system provided. The Metering arrangement shall be as per Central Electricity Authority (Installation and Operation of Meters) (Amendment) Regulations, 2019. The Energy meter along with CT/PT should be of 0.2s accuracy class.
- Computerized DC String/Array monitoring and AC output monitoring shall be provided as part of the inverter and/or string/array combiner box or separately.
- String and array DC Voltage, Current and Power, Inverter AC output voltage and current (All 3 phases and lines), AC power (Active, Reactive and Apparent), Power Factor and AC energy (All 3 phases and cumulative) and frequency shall be monitored.
- Computerized AC energy monitoring shall be in addition to the digital AC energy meter.
- The data shall be recorded in a common work sheet chronologically date wise. The data file shall be MS Excel compatible. The data shall be represented in both tabular and graphical form.
- All instantaneous data shall be shown on the computer screen.
- Software shall be provided for USB download and analysis of DC and AC parametric data for individual plant.
- Provision for instantaneous Internet monitoring and download of historical data shall be also incorporated.
- Remote Server and Software for centralized Internet monitoring system shall be also provided for download and analysis of cumulative data of all the plants and the data of the solar radiation and temperature monitoring system.
- Ambient / Solar PV module back surface temperature shall be also monitored on continuous basis.
- Simultaneous monitoring of DC and AC electrical voltage, current, power, energy and other data of the plant for correlation with solar and environment data shall be provided.
- Remote Monitoring and data acquisition through Remote Monitoring System software at the Client location with latest software/hardware configuration and service connectivity for online / real time data monitoring / control complete to be supplied and operation and maintenance / control to be ensured by the bidder.

10.9 Metering

The multi-function energy meter (0.2s class) or required as per TANGEDCO / CEA guidelines shall be installed for the measurement of import / export energy.

10.9.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 40.

Table 40: Applicable Indian and international Standards for Energy Meters

Standard	Description
IS 16444 or as specified by the DISCOMs	A.C. Static direct connected watt-hour Smart Meter Class 1 and 2 — Specification (with Import & Export/Net energy measurements)

Standard	Description
CEA regulations	CEA regulation for Installation and Operation of Meters and the amendments thereafter

10.10 Protections

The system should be provided with all necessary protections such as over current, over voltage protections, earthing, Lightning, and grid islanding and not less than the requirements mentioned below:

10.10.2 Lightning protection

The SPV power plants shall be provided with lightning & overvoltage protection. The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances etc. The entire space occupying the PV array (DC side) and balance of system components (includes AC side components) shall be suitably protected against lightning by deploying required number of lightning arrestors. Lightning protection should be provided as per NFC 17-102:2011 standard. The protection against induced high voltages shall be provided by the use of SPD type II and suitable earthing such that induced transients find an alternate route to earth.

10.10.3 Surge protection

Internal surge protection shall consist of SPD type II, surge-arrestors connected from +ve and -ve terminals to earth (via Y arrangement).

10.10.4 Earthing protection

Each array structure of the PV yard should be grounded/ earthed properly as per IS:3043-1987. In addition, the lighting arrester/masts should also be earthed inside the array field. Earth Resistance shall be tested in presence of the representative of Department as and when required after earthing by calibrated earth tester. PCU, ACDB and DCDB should also be earthed properly.

Earth resistance shall not be more than 5 ohms. It shall be ensured that all the earthing points are bonded together to make them at the same potential

10.10.5 Grid Islanding

In the event of a power failure on the electric grid, it is required that any independent power-producing inverters attached to the grid turn off in a short period of time. This prevents the DC-to-AC inverters from continuing to feed power into small sections of the grid, known as “Islands.” Powered Islands present a risk to workers who may expect the area to be unpowered, and they may also damage grid-tied equipment. The FSPVP shall be equipped with islanding protection. In addition to disconnection from the grid (due to islanding protection) disconnection due to under and over voltage conditions shall also be provided.

A manual disconnect 4-pole isolation switch beside automatic disconnection to grid would have to be provided at utility end to isolate the grid connection by the utility personnel to carry out any maintenance. This switch shall be locked by the utility personnel.

10.10.6 Codes and Standards

In addition to the technical specifications mentioned above, the Project shall conform to the applicable, codes, standards and certifications but not limited to the list shown in Table 41.

Table 41: Applicable Indian and international standards for system protection

Standard	Description
IEC 62561 Series (Chemical earthing) (as applicable)	IEC 62561-1: Lightning protection system components (LPSC) - Part 1: Requirements for connection components IEC 62561-2: Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes IEC 62561-7: Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds
IS:3043-1987	Code of practice for Earthing
NFC 17-102:2011	Protection against lightning - Early streamer emission lightning protection systems
BFC 17-102:2011	Lightening Protection Standard
IEC 60364-5-53/ IS 15086-5 (SPD)	Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control
IEC 61643-11:2011	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods

10.11 AC and DC Cables

- Cables of appropriate size to be used in the system shall have the following characteristics:
  - Shall meet IEC 60227/IS 694, IEC 60502/IS1554 standards
  - Temp. Range: –10°C to +80˚C
  - Voltage rating:
    - DC side – 1.5 kV
    - LV AC side – 1.9/3.3 kV
    - HV AC side – 11 kV
  - Excellent resistance to heat, cold, water, oil, abrasion, UV radiation Flexible
  - Sizes of cables between array interconnections, array to junction boxes, junction boxes to Inverter etc. shall be so selected to keep the voltage drop (power loss) of the entire solar system to the minimum (2%)
  - For the DC cabling, XLPO insulated and sheathed, FRLS, UV-stabilized single core multi-stranded flexible copper cables shall be used; multi-core cables shall not be used.
  - For the AC cabling, XLPE, FRLS & armoured single or, multi-core multi-stranded flexible copper/Aluminium cables shall be used; Outdoor AC cables shall have a UV-stabilized outer sheath.
  - The cables (as per IS) should be insulated with a special grade PVC/XLPE compound formulated for outdoor use. Outer sheath of cables shall be electron beam cross-linked XLPO type and black in colour.
  - The DC cables from the SPV module array shall run through a UV-stabilized PVC conduit pipe of adequate diameter with a minimum wall thickness of 1.5 mm.

- Cables and wires used for the interconnection of solar PV modules shall be provided with solar PV connectors (MC4) and couplers
- All cables and conduit pipes shall be clamped to the rooftop, walls and ceilings with thermo-plastic clamps at intervals not exceeding 50 cm; the minimum DC cable size shall be 6 mm^2 copper. In three phase systems, the size of the neutral wire size shall be equal or half to the size of the phase wires.
- Cable Routing/ Marking: All cable/wires are to be routed in a GI cable tray and suitably tagged and marked with proper manner by good quality ferule or by other means so that the cable easily identified. In addition, cable drum no. / Batch no. to be embossed/ printed at every one meter.
- Cable Jacket should also be electron beam cross-linked XLPO, flame retardant, UV resistant and black in colour.
- All cables and connectors for use for installation of solar field must be of solar grade which can withstand harsh environment conditions including High temperatures, UV radiation, rain, humidity, dirt, salt, burial and attack by moss and microbes for 25 years and voltages as per latest IEC standards. DC cables used from solar modules to array junction box shall be solar grade copper (Cu) with XLPO insulation and rated for required voltage level as per relevant standards only.
- The ratings given are approximate. Bidder to indicate size and length as per system design requirement. All the cables required for the plant shall be provided by the bidder. Any change in cabling sizes if desired by the bidder shall be approved after citing appropriate reasons. All cable schedules/ layout drawings shall be approved prior to installation.
- Multi Strand, Annealed high conductivity copper conductor PVC type ‘A’ pressure extruded insulation or XLPE insulation. Overall PVC/XLPE insulation for UV protection Armoured cable for underground laying. All cable trays including covers to be provided. All cables conform to latest edition of IEC/ equivalent BIS Standards as specified below:
- BoS item / component Standard Description Standard Number Cables General Test and Measuring Methods, PVC/XLPE insulated cables for working Voltage up to and including (1.5kV DC / 3.3kV AC / 11kV AC), UV resistant for outdoor installation IS /IEC 69947.
- The total voltage drop on the cable segments from the solar PV modules to the inverter shall not exceed 2.0%.
- The total voltage drop on the cable segments from the solar grid inverter to the PoC building distribution board shall not exceed 3.0%.

10.11.2 Codes and Standards

The Project shall conform to the relevant standards and certifications shown in Table 42.

Table 42: Applicable Indian and international Standards for Cables

Standard	Description
IEC 60227/IS 694, IEC 60502/IS 7098-1 & 2/IS 8130 / IEC69947 (as applicable)	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation)
BS EN 50618	Electric cables for photovoltaic systems (BT(DE/NOT)258), mainly for DC Cables

10.12 Tools and Tackles and Spares

Within one (1) month of Provisional Plant Acceptance, the Contractor shall free issue agreed spares and necessary tools and tackles. List of spares and tools and tackles to be supplied by the bidder for approval of specifications and make from owner during bidding.

A list of requisite spares in case of PCU/inverter comprising of a set of control logic cards, IGBT driver cards etc. Fuses, MOVs / arrestors, MCCBs etc along with spare set of PV modules be indicated, which shall be supplied along with the equipment. A minimum set of spares shall be maintained in the plant itself for the entire period of warranty and Operation & Maintenance which upon its use shall be replenished.

10.13 Danger Boards and Signages

Danger boards should be provided as and where necessary as per IE Act. /IE rules as amended up to date. Three signage shall be provided at all key installation areas. Text of the signage may be finalized in consultation with Owner.

10.14 Fire Extinguishers

The firefighting system for the proposed power plant for fire protection shall be consisting of:

- Portable fire extinguishers for fire caused by electrical short circuits
- Sand buckets
- The installation of Fire Extinguishers should confirm to TAC regulations and BIS standards.

10.15 Solar PV Module Cleaning System

Suitable arrangement has to be made for wet cleaning of PV modules using the water quality recommended by the module manufacturer. The piping line and valves of adequate quantity for availing portable water at desired pressure at the PV array location suitable for PV module cleaning. The required tools for module cleaning such as wiper, hose pipe, soft cotton cloth etc. has also to be provided. A sprinkler-based system of 5 m range with piping network is recommended. The sprinkler system shall be operated at a designated time before generation hour for approximately 5 minutes with the help of a programmable timer which will start and stop the water pump. The size of the water pump shall be decided based on water pressure requirement as recommended by the module manufacturer. The manpower engaged for O&M shall make a periodic visit to wipe out and remove the dirt sticking to modules

10.16 Drawings & manuals

- Two sets of Engineering, electrical drawings and Installation and O&M manuals are to be supplied. Bidders shall provide complete technical data sheets for each equipment giving details of the specifications along with make/makes in their bid along with basic design of the power plant and power evacuation, synchronization along with protection equipment.
- Approved ISI and reputed makes for equipment be used.
- For complete electro-mechanical works, bidders shall supply complete design, details and drawings for approval to Owner before progressing with the installation work

10.17 Planning and designing

- The bidder should carry out Shadow Analysis at the site and accordingly design strings & arrays layout considering optimal usage of space, material and labour. The bidder should submit the array layout drawings along with Shadow Analysis Report to Owner for approval.
- The Owner reserves the right to modify the landscaping design, Layout and specification of sub-systems and components at any stage as per local site conditions/requirements.
- The bidder shall submit preliminary drawing for approval & based on any modification or recommendation, if any. The bidder submits three sets and soft copy in CD of final drawing for formal approval to proceed with construction work

10.18 Drawings to be furnished by bidder after award of contract

The Contractor shall prepare list of documents as per Technical Specifications and furnish for approval of the same and review of work schedule. Any part of the facilities covered by or related to the documents to be approved by CCMC or appointed consultant shall be executed only after the CCMC's approval thereof. The Contractor shall furnish the following drawings award/Intent but not limited to and obtain approval:

- General arrangement and dimensioned layout of floating island / PV array area;
- Single line diagram;
- Schematic drawing showing the requirement of PV panel, Power conditioning Unit(s)/ inverter, Junction Boxes, AC and DC Distribution Boards, meters etc.;
- Structural drawing along with foundation details for the structure;
- Itemized bill of material for complete plant covering all the components and associated accessories;
- Shadow analysis;
- Cable loss calculation and route layout;
- Equipment datasheet;
- Any other document / drawing not listed above but required for the successful completion of the project.

10.19 Safety measures

The bidder shall take entire responsibility for electrical safety of the installation(s) including connectivity with the grid and follow all the safety rules & regulations applicable as per Electricity Act, 2003 and CEA guidelines etc.

10.20 Display Board

The bidder has to display a board at the project site mentioning the following:

- Plant Name, Capacity, Location, Date of commissioning, estimated Power generation.
- The size and type of board and display shall be approved by Engineer-in-charge before site inspection.

10.21 Site Preparation

Site preparation shall cover all work as required for installation of a floating solar PV plant as per standard industry practices and shall include but not limited to the following activities:

- Preparation of assembly and launching pad cleaning of bank area e.g. removal of debris, temporary herbs and bushes, anu structure or fully removed during design stage etc.
- Power and water arrangement for construction.
- For material storage, adequate platforms shall be provided on Site for module floaters. PV modules and all other materials/ equipment shall be stored in compliance with manufacturer's guideline as required.
- Clearing area identified for cable routing, earthing conductor routing, and earth pit.

10.22 Civil Infrastructure

All relevant Standards required for civil works shall be strictly adhered to. Civil works required for construction of Main Control Building shall include, but not limited to the following:

- All outdoor MS structures to be used shall be galvanised with proper zinc coating having a minimum thickness of 80 microns for thickness more than 5 mm and 60 microns for thickness less than 5 mm. The Contractor shall ensure that all such structures are properly aligned and levelled.
- No rusted nuts/ bolts/ washers are used for fastening of members.
- In cases, where use of black metal is permitted by the Purchaser, no structural member shall be used without application of proper primer and paint.

10.23 Miscellaneous

In addition to all the standard equipment following supporting systems shall also be provided as required to complete the job.

- Power factor shall be maintained at the interconnection point as required by the State Utility. Although Inverters may operate at wide range of power factor, the Contractor shall provide capacitors / reactors if required by Grid regulations.
- Liasioning with State Electricity Board and the Purchaser.
- Supply and installation of cable trays as required.
- Firefighting equipment as per local standards.

Appendices

A. Layout

The plant layout for both 140 kWp pilot FSPV project and 18 MWp FSPV project at Periyakulam lake are available as separate attachments to this report.

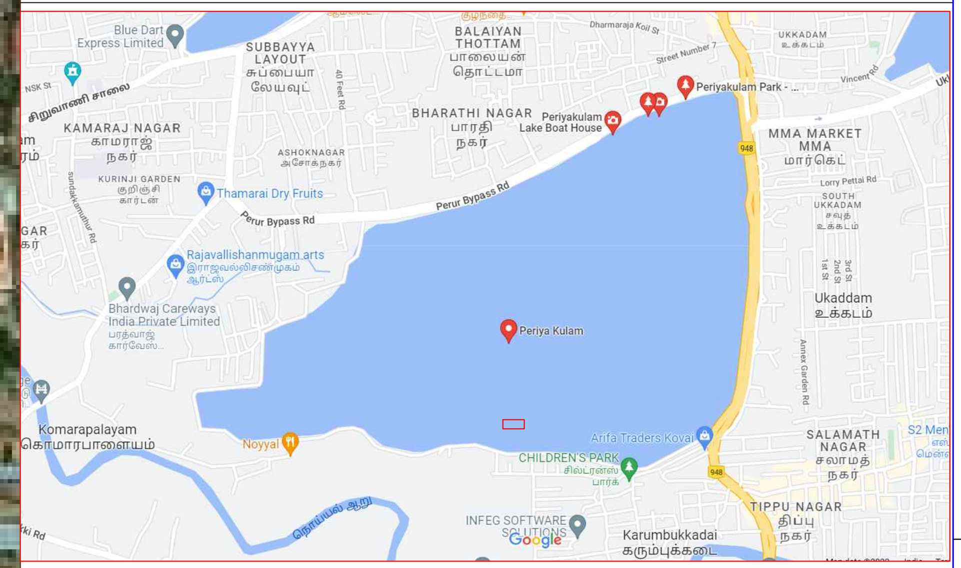
B. SLD

The SLD for both 140 kWp pilot FSPV project and 18 MWp FSPV project at Periyakulam lake are available as separate attachments to this report.

RINA Consulting Private Limited
507, K M Trade Tower,
Kaushambi, Ghaziabad,
Uttar Pradesh - 201010, India

TruBoard Credit Monitoring Services Private Limited
Emaar Digital Greens,
Tower B, 374,
Golf Course Road Underpass,
Baharampur Naya,
Sector 61, Gurugram,
Haryana – 122102.

LOCATION MAP - SCALE : 1:50,000



SYSTEM SUMMARY :

ELECTRICAL CONFIGURATION:

TOTAL PV PLANT CAPACITY (DC): 140 kWp
TOTAL INVERTER CAPACITY (AC): 111 kW
MODULES PER STRING: 26
STRING QUANTITY: 10
PV MODULE:MONO CRYSTALLINE PERC, 540 Wp
MODULE QUANTITY: 260 NOS.
STRING INVERTER: 1 NO., 111 KW, 1500 V
FLOATING ISLAND: HDPE PONTOON SUPPORTED BY ANCHORING AND MOORING SYSTEM
POWER EVACUATION POINT: EXISTING 11KV TRANSMISSION LINE
EVACUATION VOLTAGE: 11 KV

SITE COORDINATES:
10.9787 °N, 76.9550 °E

NOTES :

1. ALL DIMENSIONS ARE INDICATIVE.
2. DESIGN BASED ON SITE BOUNDARIES PROVIDED WITHIN REFERENCE DOCUMENTS FROM THE CLIENT.
3. LOCATION OF THE PV ARRAYS, ANCILLARY BUILDINGS, SECURITY FENCE AND TRANSFORMER STATIONS ARE INDICATIVE AND MAY CHANGE DURING THE DETAILED DESIGN PHASE.
4. THE CABLE ROUTE CONNECTING THE PROPOSED PV PLANT TO EXISTING INFRASTRUCTURE IS INDICATIVE AND IS SUBJECT TO CHANGE AT THE DETAILED DESIGN PHASE AND ACCORDING TO THE GRID CONNECTION AGREEMENT.
5. SETBACKS CONSIDERED IN LAYOUT ARE INDICATIVE AND SUBJECT TO CHANGE DURING THE DETAILED DESIGN PHASE.
6. THE PREPOSED AREA FOR THE FLOATING SOLAR PV PROJECT IS 0.5 ACRES

REV	DESCRIPTION	DRN BY	CKD BY	APPV. BY	DATE
0	FINAL ISSUE TO CLIENT	HM	SSU	PD	18-11-2022
A	INITIAL ISSUE TO CLIENT	HM	SSU	PD	05-10-2022

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New Delhi – 110016

south pole group
1A & 1B, Block - B, Vatika first India Place, near MG road metro station, MG Road, Sector - 28, Gurugram - 122002, Haryana, India

RINA
B-607/608, Everest Chambers, Andheri – Kurla Road, Andheri East, Mumbai – 400059, Maharashtra, India

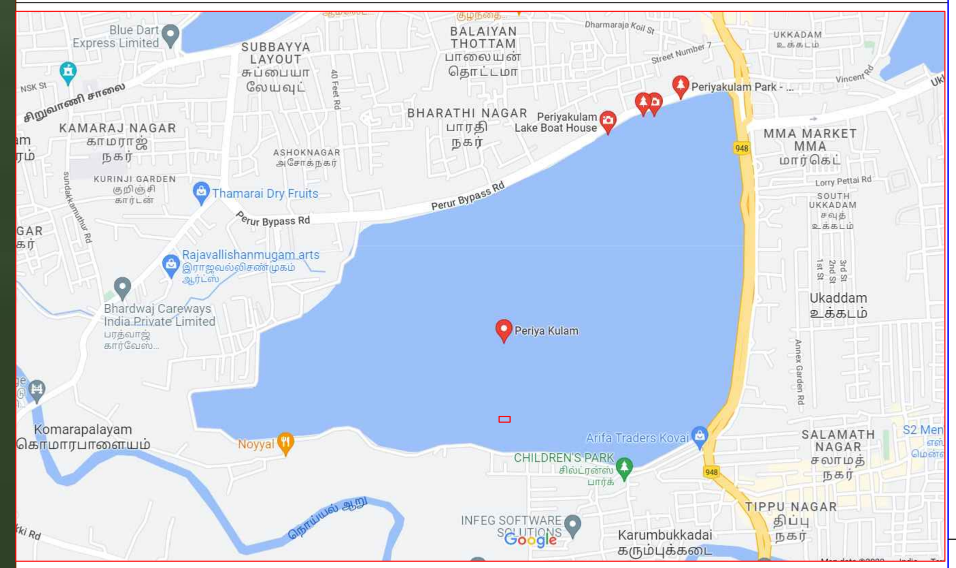
TruBoard Partners
Emaar Digital Greens, Tower B, 374, Golf Course Road Underpass, Baharampur Naya, Sector 61, Gurugram, Haryana – 122102

PROJECT TITLE
140 KWp PILOT FLOATING SOLAR PV PROJECT IN PERIYAKULAM LAKE, COIMBATORE

DRAWING TITLE
PLANT LAYOUT

DRAWING NO.	SHEET	Rev
P0032908 - LAY -01	01 OF 02	0

LOCATION MAP - SCALE : 1:50,000



SYSTEM SUMMARY :

ELECTRICAL CONFIGURATION:

TOTAL PV PLANT CAPACITY (DC): 140 kWp
TOTAL INVERTER CAPACITY (AC): 111 kW
MODULES PER STRING: 26
STRING QUANTITY: 10
PV MODULE:MONO CRYSTALLINE PERC, 540 Wp
MODULE QUANTITY: 260 NOS.
STRING INVERTER: 1 NO., 111 KW, 1500 V
FLOATING ISLAND: HDPE PONTOON SUPPORTED BY ANCHORING AND MOORING SYSTEM
POWER EVACUATION POINT: EXISTING 11KV TRANSMISSION LINE
EVACUATION VOLTAGE: 11 KV

SITE COORDINATES:
10.9787 °N, 76.9550 °E

NOTES :

1. ALL DIMENSIONS ARE INDICATIVE.
2. DESIGN BASED ON SITE BOUNDARIES PROVIDED WITHIN REFERENCE DOCUMENTS FROM THE CLIENT.
3. LOCATION OF THE PV ARRAYS, ANCILLARY BUILDINGS, SECURITY FENCE AND TRANSFORMER STATIONS ARE INDICATIVE AND MAY CHANGE DURING THE DETAILED DESIGN PHASE.
4. THE CABLE ROUTE CONNECTING THE PROPOSED PV PLANT TO EXISTING INFRASTRUCTURE IS INDICATIVE AND IS SUBJECT TO CHANGE AT THE DETAILED DESIGN PHASE AND ACCORDING TO THE GRID CONNECTION AGREEMENT.
5. SETBACKS CONSIDERED IN LAYOUT ARE INDICATIVE AND SUBJECT TO CHANGE DURING THE DETAILED DESIGN PHASE.
6. THE PREPOSED AREA FOR THE FLOATING SOLAR PV PROJECT IS 0.5 ACRES

REV	DESCRIPTION	DRN BY	CKD BY	APPV. BY	DATE
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Emaar Digital Greens, Tower B, 374, Golf Course Road Underpass, Baharampur Naya, Sector 61, Gurugram, Haryana – 122102

PROJECT TITLE
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DRAWING TITLE
PLANT LAYOUT

DRAWING NO.	SHEET	Rev
P0032908 - LAY -01	02 OF 02	0

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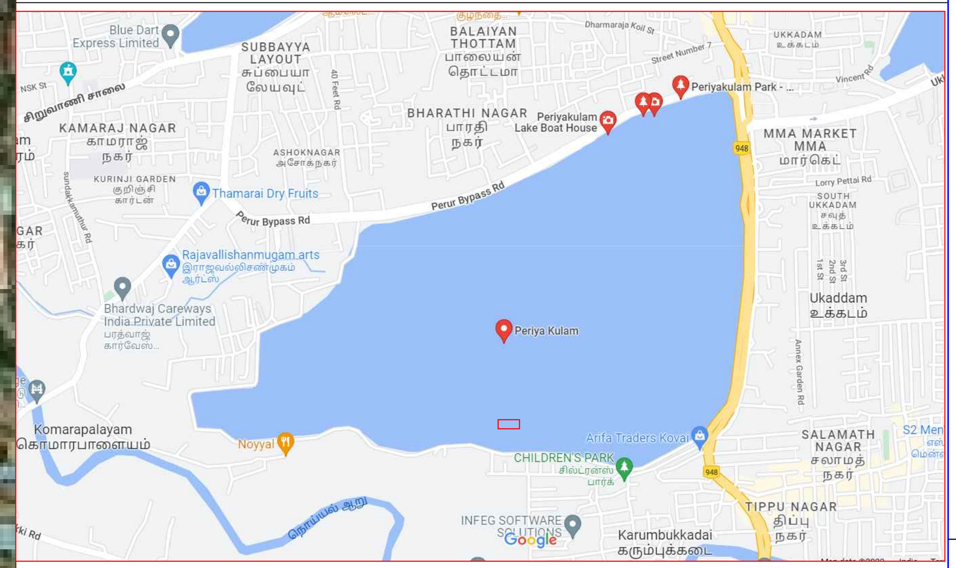
LOCATION MAP - SCALE : 1:50,000



SYSTEM SUMMARY :

ELECTRICAL CONFIGURATION:

TOTAL PV PLANT CAPACITY (DC): 18 MWp
TOTAL INVERTER CAPACITY (AC): 12.1 MW
MODULES PER STRING: 26
STRING QUANTITY: 1,282
PV MODULE:MONO CRYSTALLINE PERC, 540 Wp
MODULE QUANTITY: 33,332 NOS.
STRING INVERTER: 41 NO., 295 KW, 1500 V
FLOATING ISLAND: HDPE PONTOON SUPPORTED BY ANCHORING AND MOORING SYSTEM
POWER EVACUATION POINT: UPCOMING SELEVAPURAM SUBSTATION
EVACUATION VOLTAGE: 11 KV

SITE COORDINATES:

10.9787 °N, 76.9550 °E

NOTES :

1. ALL DIMENSIONS ARE INDICATIVE.
2. DESIGN BASED ON SITE BOUNDARIES PROVIDED WITHIN REFERENCE DOCUMENTS FROM THE CLIENT.
3. LOCATION OF THE PV ARRAYS, ANCILLARY BUILDINGS, SECURITY FENCE AND TRANSFORMER STATIONS ARE INDICATIVE AND MAY CHANGE DURING THE DETAILED DESIGN PHASE.
4. THE CABLE ROUTE CONNECTING THE PROPOSED PV PLANT TO EXISTING INFRASTRUCTURE IS INDICATIVE AND IS SUBJECT TO CHANGE AT THE DETAILED DESIGN PHASE AND ACCORDING TO THE GRID CONNECTION AGREEMENT.
5. SETBACKS CONSIDERED IN LAYOUT ARE INDICATIVE AND SUBJECT TO CHANGE DURING THE DETAILED DESIGN PHASE.
6. THE PROPOSED AREA FOR THE FLOATING SOLAR PV PROJECT IS 47 ACRES

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TruBoard Partners
Emaar Digital Greens, Tower B, 374, Golf Course Road Underpass, Baharampur Naya, Sector 61, Gurugram, Haryana – 122102

PROJECT TITLE

18 MWp FLOATING PV PROJECT IN PERIYAKULAM LAKE, COIMBATORE

DRAWING TITLE

PLANT LAYOUT

DRAWING NO.	SHEET	Rev
P0032908 - LAY -02	01	0

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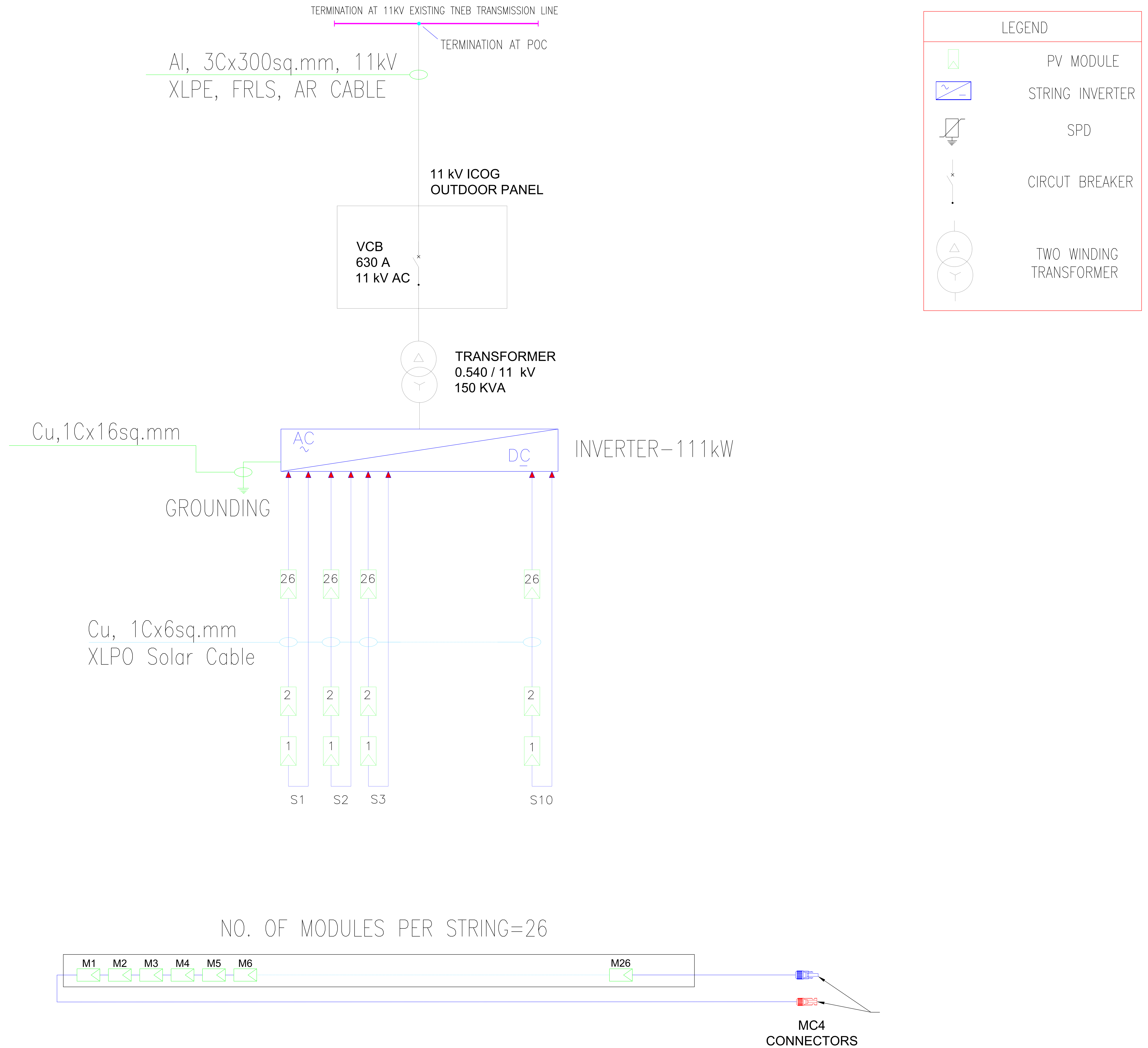
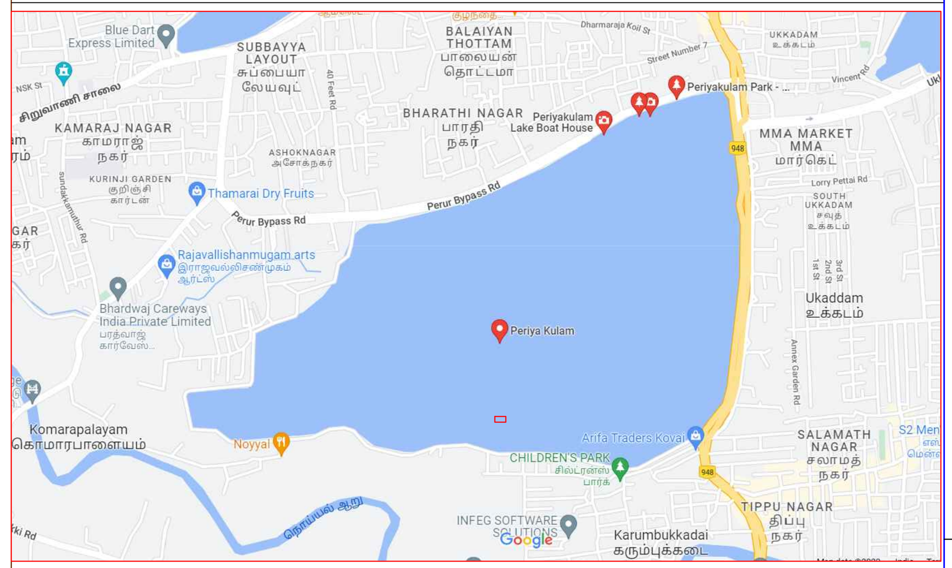


LOCATION MAP - SCALE : 1:50,000



SYSTEM SUMMARY :

ELECTRICAL CONFIGURATION:

TOTAL PV PLANT CAPACITY (DC): 140 kWp
TOTAL INVERTER CAPACITY (AC): 100 kW
MODULES PER STRING: 26
STRING QUANTITY: 10
PV MODULE:MONO CRYSTALLINE PERC, 540 Wp
MODULE QUANTITY: 260 NOS.
STRING INVERTER: 1 NO., 100 KW, 1500 V
EVACUATION VOLTAGE: 11 KV

SITE COORDINATES:
10.9787 °N, 76.9550 °E

NOTES :

1. PRELIMINARY SINGLE LINE DIAGRAM (SLD) SUBJECT TO BE CHANGED IN THE DETAIL DESIGN PHASE.
2. CABLE AND EQUIPMENT RATINGS ARE INDICATIVE ONLY AND SHOULD BE DEFINED DURING THE DETAILED DESIGN PHASE.
4. ALL DC COMPONENTS AND WIRING WILL BE RATED FOR 1,500 V DC.
5. NUMBER AND LOCATION OF METERS SHALL BE CONFIRMED AT A LATER STAGE IN ACCORDANCE WITH THE GRID CONNECTION AGREEMENT.
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0	FINAL ISSUE TO CLIENT	HM	SSU	PD	18-11-2022
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RINA
B-607/608, Everest Chambers, Andheri – Kurla Road, Andheri East, Mumbai – 400059, Maharashtra, India

TruBoard Partners
Emaar Digital Greens, Tower B, 374, Golf Course Road Underpass, Baharampur Naya, Sector 61, Gurugram, Haryana – 122102

PROJECT TITLE

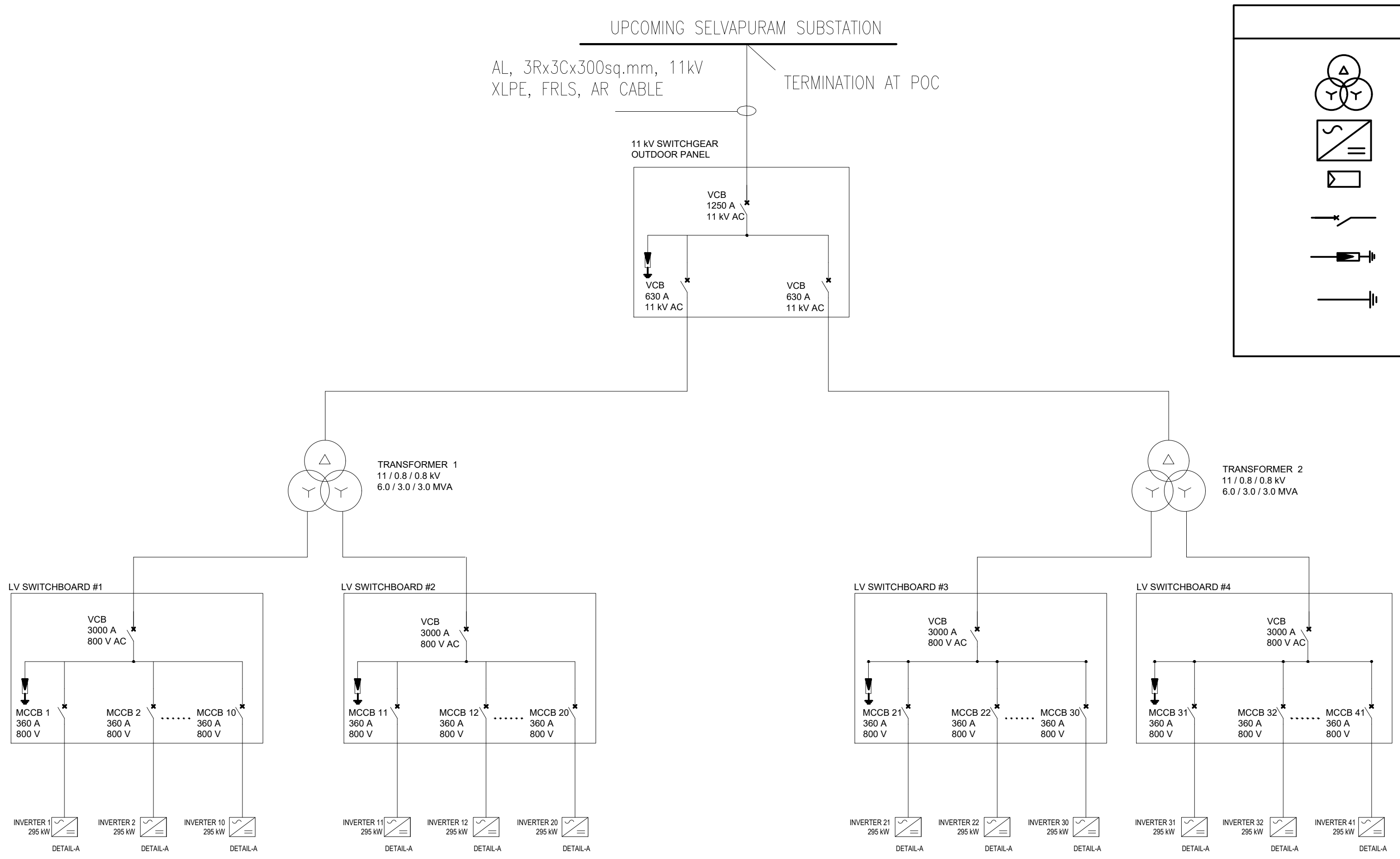
140 KWp PILOT FLOATING SOLAR PV PROJECT IN PERIYAKULAM LAKE, COIMBATORE

DRAWING TITLE

SINGLE LINE DIAGRAM

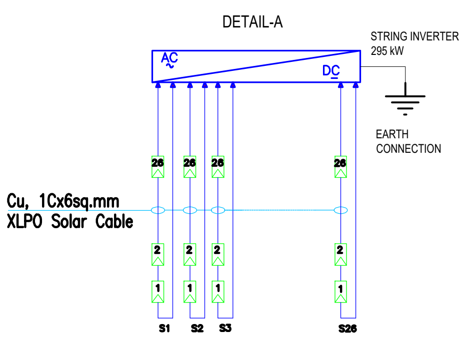
DRAWING NO.	SHEET	Rev
P0032908 - SLD -01	01	0

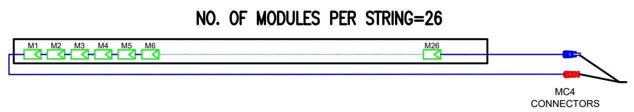
A1



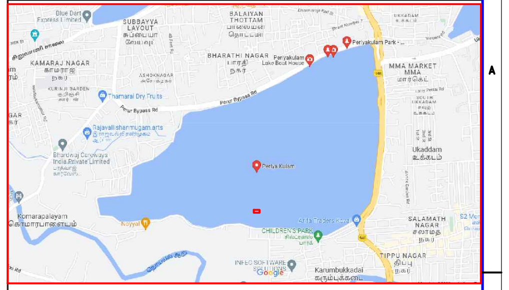
LEGEND

	THREE WINDING TRANSFORMER
	INVERTER
	SOLAR MODULE
	CIRCUIT BREAKER
	SURGE PROTECTION DEVICE
	ELECTRICAL EARTH





LOCATION MAP - SCALE : 1:50,000



SYSTEM SUMMARY :

ELECTRICAL CONFIGURATION:

TOTAL PV PLANT CAPACITY (DC): 18 MWp
TOTAL INVERTER CAPACITY (AC): 12.1 MW
MODULES PER STRING: 26
STRING QUANTITY: 1,282
PV MODULE:MONO CRYSTALLINE PERC, 540 Wp
MODULE QUANTITY: 33,332 NOS.
STRING INVERTER: 41 NO., 295 KW, 1500 V
EVACUATION VOLTAGE: 11 KV

SITE COORDINATES:

10.9787 °N, 76.9550 °E

NOTES :

1. PRELIMINARY SINGLE LINE DIAGRAM (SLD) SUBJECT TO BE CHANGED IN THE DETAIL DESIGN PHASE.
2. CABLE AND EQUIPMENT RATINGS ARE INDICATIVE ONLY AND SHOULD BE DEFINED DURING THE DETAILED DESIGN PHASE.
4. ALL DC COMPONENTS AND WIRING WILL BE RATED FOR 1,500 V DC.
5. NUMBER AND LOCATION OF METERS SHALL BE CONFIRMED AT A LATER STAGE IN ACCORDANCE WITH THE GRID CONNECTION AGREEMENT.

REV	DESCRIPTION	DRN BY	CKD BY	APPV. BY	DATE
0	FINAL ISSUE TO CLIENT	HM	SSU	PD	18-11-2022
A	INITIAL ISSUE TO CLIENT	HM	SSU	PD	06-10-2022

ICLEI
C-3, Lower Ground Floor
Green Park, Extension
New Delhi – 110016

south pole group
1A & 1B, Block - B, Vatika first India Place, near MG road metro station, MG Road, Sector - 28, Gurugram - 122002, Haryana, India

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TruBoard Partners
Emaar Digital Greens, Tower B, 374, Golf Course Road Underpass, Baharampur Naya, Sector 61, Gurugram, Haryana – 122102

PROJECT TITLE

18 MWp FLOATING PV PROJECT IN PERIYAKULAM LAKE, COIMBATORE

DRAWING TITLE

SINGLE LINE DIAGRAM

DRAWING NO.	SHEET	Rev
P0032908 - SLD -02	01	0

A1