# San Roque Power Corporation
# 150MWac to 165MWac Floating PV

San Roque Power Corporation

Feasibility Study Report - Final

145000079

20 December 2021

Report (final)



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| Project Number | 145000079 |
| Date | 20 December 2021 |
| Client | San Roque Power Corporation |

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Revision History

| Version | Description | Date | Checked Status | Sign |
|---|---|---|---|---|
| Draft | Draft Report | Nov 16 2021 | Checked | BEP |
| Final | Included the Clarification with SRPC | Dec 20, 2021 | Checked | BEP |

# 1 INTRODUCTION

## 1.1 Background

San Roque Power Corporation (the "Client" or "SRPC") has engaged Afry Philippines Inc. (the "Consultant" or "AFRY") to conduct a Feasibility Study of the First Phase - 150MWac Floating Solar PV Power Plant at the San Roque Reservoir (the "Project") targeting the development of grid-connected solar PV generation installed on a floating platforms. The project site is located on the reservoir of the SRPC Hydropower Plant in San Roque, Pangasinan. The capacity of the first phase can reach up to 165MWac but as agreed with the Client, the Feasibility Study will consider 150MWac for the time being.

## 1.2 Project Definition

The renewable power capacity is planned to be added to the grid via the NGCP Nagsaag Substation . The project will be a floating type solar PV project on the waters of the San Roque reservoir. San Roque reservoir is a being used by the existing San Roque Power Corporation 435MW Hydroelectric Plant.

The purpose of this Feasibility Study report is to provide analysis of the site visit findings, conceptual design, yield and high-level financial analysis to serve as a base for decisions on the further development of the Project. It contains review of available site investigation studies, conceptual design of PV plant, assessment of power evacuation options and grid interconnection, high level environmental and social consideration, high level management aspects for construction and operation and maintenance, high level market assessment, and the high level expected capital and operational costs for the power plant.

Aside from the 150MWac FPV and a 200kW pilot project, the Project Sponsor aims to develop in the future another FPV expansion (2$^{nd}$ phase) estimated to have a capacity of 320MWp (total 500MWp including the Phase 1 150MWac to 165MWac). The proposed location of the Phase 1 and the FPV expansion is the entire orange area of the reservoir as shown in Figure 1-1b. The final capacity needs to be confirmed during the FEED phase.

Further to the FVP expansion, the Project Sponsor also considers to put up an in-plant Battery Energy Storage System, integrated and coupled with the installation of the FPV expansion plant. The capacity of the BESS (possible up to 150 - 165 MWac/1500 - 1650 MWh and the details of the 2$^{nd}$ phase FPV expansion shall be determined through a Front End Engineering Design (FEED) Study. The surface area available within the boundaries of the San Roque Dam is sufficient for this extension.

The 2-phase Project will inject power to the grid , while the function of the BESS is to provide power when the solar plant is not producing (sufficient) power. The System Impact Study will be carried out in the next phase of the project and capacity will be based on the available options to be determined after the FEED phase.

This Feasibility Study will discuss the details and viability of the First Phase of the Project which is the 150 – 165 MWac as well as the 200kWac pilot project.

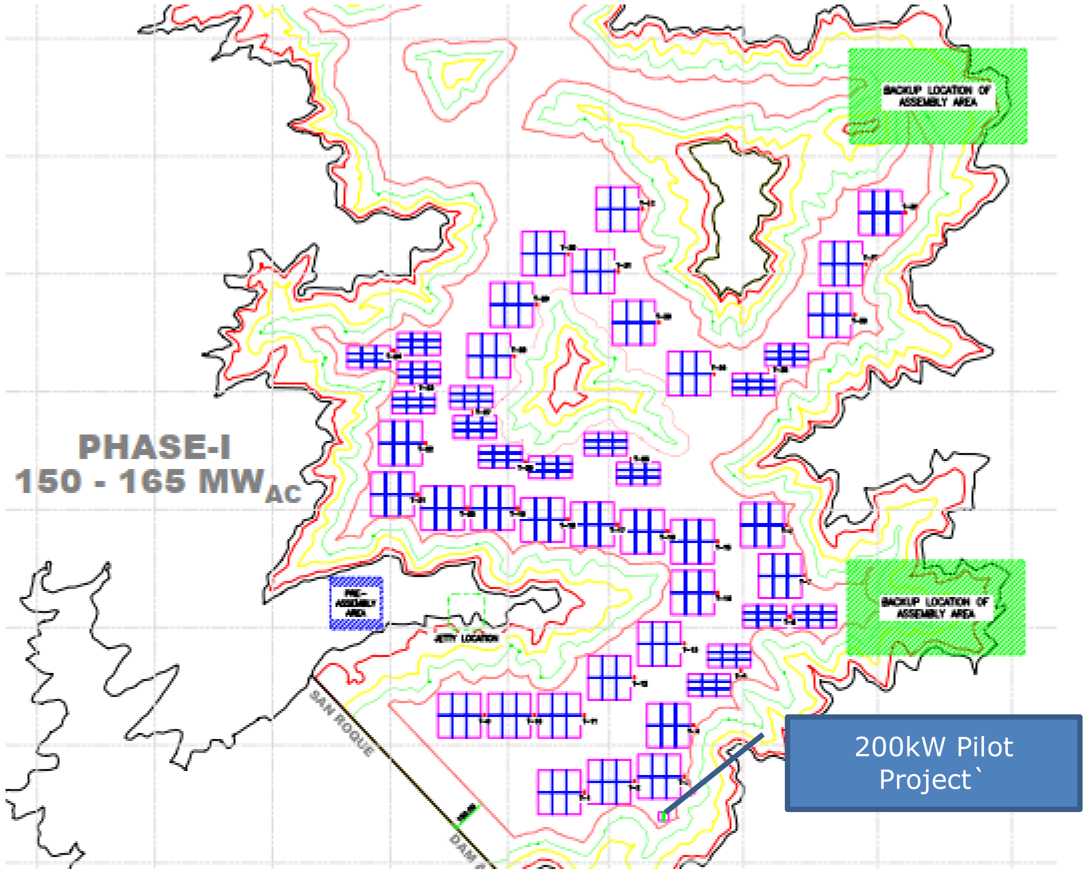



*Figure 1-1a: Overview of the Reservoir Allocated for the 150MWac to 165MWac*

The above layout shown in figure 1-1a is made for this feasibility study only to determine the feasibility of the project. The consultant believes that the size of the FPV modules and the selection of the inverters needs to be revisited and optimized in the next stage now the feasibility has been proven. With new PV modules entering the market with higher capacity (latest PV module model introduced has 700 Wp power output instead of the 500 Wp module used in this study) and optimization of the inverter to string type, with corresponding smaller size in PV module islands allowing for optimized use of the available surface, the total plant capacity after expansion stages could be able to reach 450 – 500 MWp.

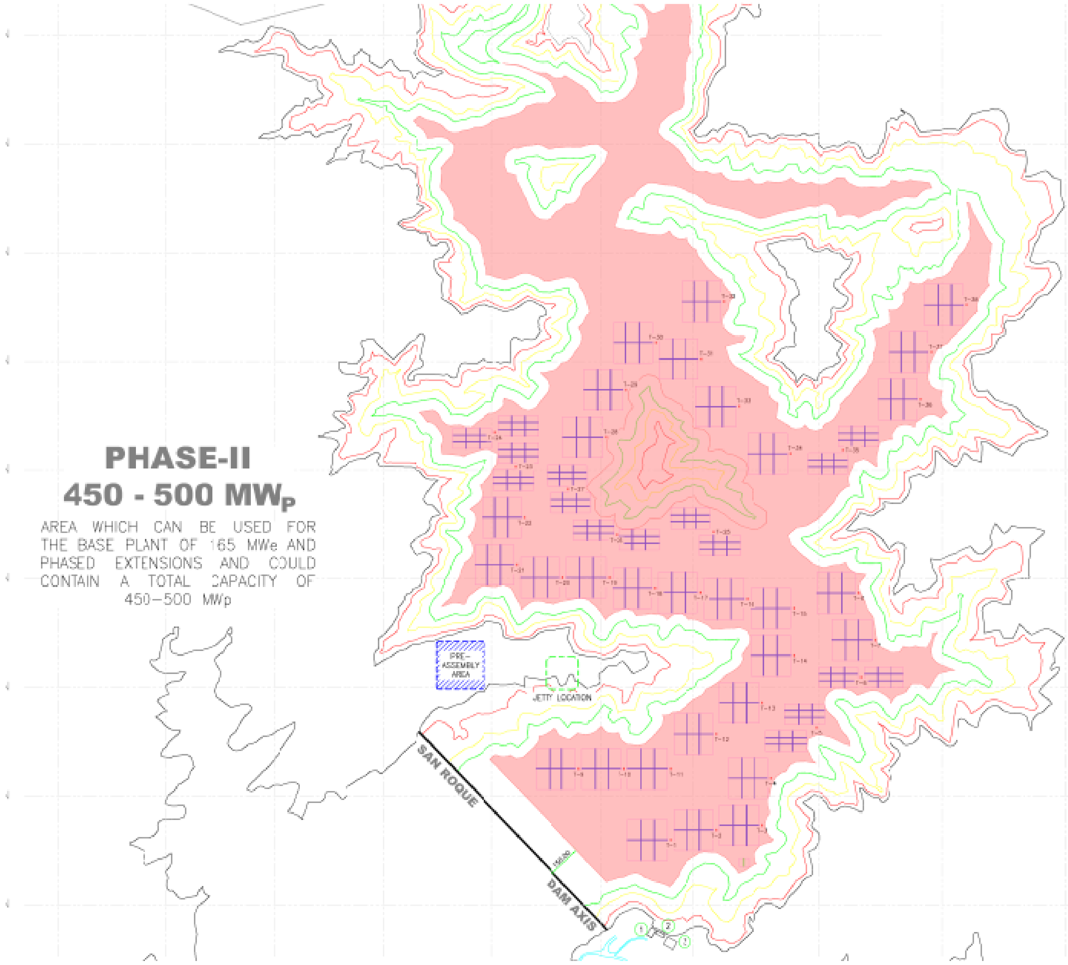



*Figure 1-1b Overview of the Entire Reservoir for FPV Expansion with estimated total capacity of 450 to 500MWp including Phase 1*

## 1.3 Scope of Study

This study provides a conceptual overview of the feasibility of the power plant based on the different parts included in this report, such as:

- Review of existing site studies;
- Site visit by expert engineer for visual assessment of location potential and limitations;
- Conceptual design and technology selection based on the site findings, energy resource/yield assessment, new and updated technology;
- Optimization of the floating solar PV system and its anchoring/mooring system;
- Assessment of the power evacuation/interconnection to grid options;
- Concept level cost estimates for Capex and Opex;
- Concept level market assessment;

- Indicative management aspect for construction and operation and maintenance;
- Conceptual design of 200kW floating PV pilot site.
- Risk analysis.

The above scope is purely for the purpose of conducting feasibility study hence the drawings, calculations and analysis envisaged are indicative in nature.

### 1.3.1 Data Collection

Beside the information provided by the client, the Consultant collected data and information from many public sources such as online databases, city/regional information center, national and regional, public reports, AFRY's internal knowledge center and observations during site visits. The Consultant has also obtained several secondary data to conduct the energy yield assessment for Solar PV power plant systems.

The major sources of data are listed below:

- Solar resource data: Solar GIS iMaps

Technology and costs benchmarks: AFRY's internal databases

### 1.3.2 Site Study

The Consultant reviewed the suitability of the Floating Solar PV Power project within the perimeter of the San Roque reservoir. The site study includes the assessment of layout/arrangement, technology, and the expected electricity output that can be produced from the available solar resource without disrupting the grid based on the following aspects:

- Location and landscape
- Access for construction and Operation & Maintenance
- Solar energy resource , including energy yield.
- Availability of land and usable area on the water
- Environmental and socio-economic aspects
- Transmission line and electrical power supply distance to the existing system

Finally, costs estimates were derived from the Consultant's previous projects in Asia for both operational expenses and capital expenses.

## 1.4 Site Visit

Site visits were undertaken on 29th October 2021 by the AFRY team. The Consultant has gone around the reservoir in two groups with two boats. One of the main findings of the visual inspection was that there are no landing place/construction area anywhere beside at the dam itself. There are no roads leading to the reservoir and all areas around the reservoir have a steep slopes. This will be a challenge for the construction of the floating platforms, which is normally done on an area with limited slope down to the reservoir. The conclusions from the site visits have been considered in this document.

*Figure 1-2: Overview of the Reservoir*

For the review of the power evacuation assessment of the proposed PV plant and the capacity as well as connection readiness, a clarification meeting with NGCP Northern Luzon was held at their office in San Manuel substation office, just across the Nagsaag substation. In this meeting it was verified that the existing 230kV double-circuit transmission line from San Roque Power Station to Nagsaag substation has a capacity of 2 x 600MW. This means that the power output of the PV plant 150MWac up to 165MWac can be combined with the hydro power plant and transmitted to the Nagsaag substation through the same existing transmission lines if so selected.

It was also confirmed that if a new connection is desired, there are available bays for connection. There are on-going reinforcements in the substation and it is believed that the proposed additional 150MWac to 165MWac capacity of the PV plant can be accommodated. The several options for interconnection to the grid are further detailed and discussed in Section 3.3.1.

*Figure 1-3: Existing 2 x 230kV bays for SRPC*

*Figure 1-4: Available 230kV bays for proposed PV plant*

## 1.5 Indicative Water/Land Area Requirements

The summary of approximate land area requirements for this project can be seen in the following table. The figures in the table are indicative in nature and are used to estimate the indicative project cost.

| Project Component | Area Requirement |
|---|---|
| Floating Solar PV System (178 MWp) including safe distance between each block | 661 Ha |
| Switchyard area, admin, warehouse building (on land/shore) | 2.00 Ha |
| Transformer station and its access (on land/shore) | 1.0 Ha |
| Floater Laydown and Assembly Area during construction (on land/shore) | 2.5 Ha |

*Table 1-1: Estimated Land Area Requirement for the main FPV Project*

The total project area on the reservoir identified by the Consultant for the FPV system only which is estimated for total DC capacity of 178 MWp (first phase) is approximately 661 Ha measured at 290msl water level (highest level), including safe distance between each block at the lowest reservoir water level of 225m msl. If the existing substation of the San Roque Power Hydro Plant will be utilized, there will be expansion needed for additional bay and the total area corresponds approximately 0.5 Ha. Land area will also have to be reserved for switchyard area, admin and warehouse building, transformer and floater assembly area during construction.

A housing complex, if needed, is recommended to be separated from the power plant site, and it can be located wherever is preferred by the Owner, whether near the existing public road, the existing operators village or near the selected site for the convenience of the Operation and Maintenance (O&M) staff. It is also possible that a housing complex may not be necessary for this project and this can be decided during the engineering design stage.

Additional area shall also be required for the proposed second phase FPV expansion by using the remaining portion of the reservoir and Battery Energy Storage System (BESS). The estimated total installed capacity including the expansion will be optimized and determined in the next stage, subject to the prudent consideration of the final anchoring and mooring design of each block.

The Figure 1-5 as provided by the Project Sponsor, shows the proposed location of the BESS.

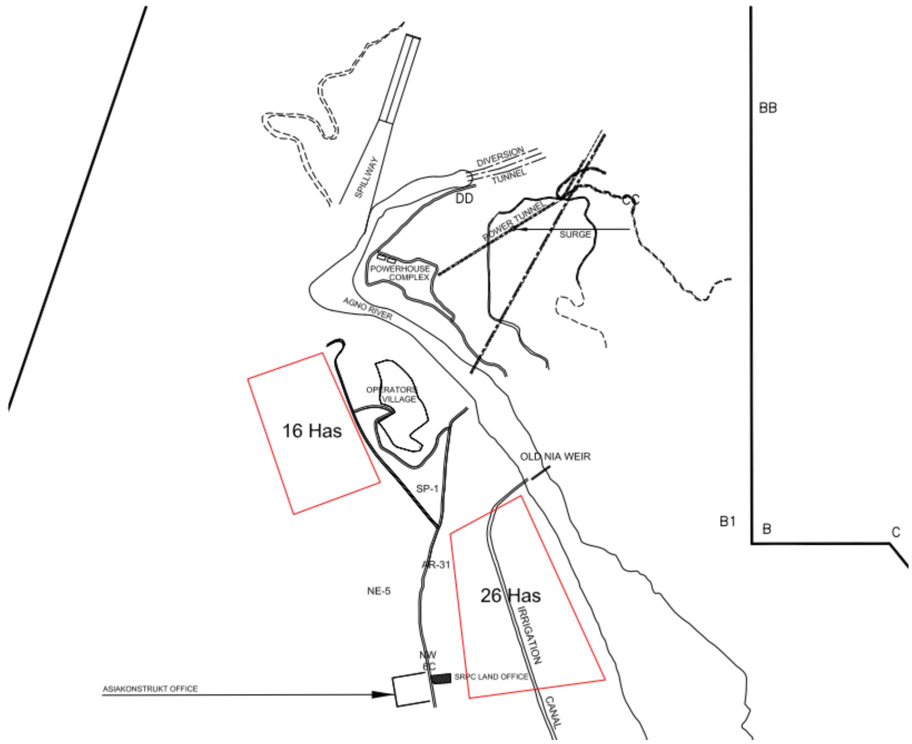



*Figure 1-5: Proposed Locations for BESS During FPV Expansion*

## 1.6 Natural Hazards

An overview of the project vulnerability to potential natural disasters is described in this section. In general, in the absence of formal study, the Consultant has formed its observation according to the Climate-Responsive Integrated Master Plan for the Agno River which was conducted by College of Forestry and Natural Resources of the University of the Philippines Los Baños and funded by the Department of Environment and Natural Resources. According to the report, the area surrounding the San Roque reservoir has no present risk for earthquake hazard. Flooding is the most common and most destructive natural hazard in the area. About 121,588 hectares of the river basin is highly susceptible to floods and 109,868 hectares have moderate to low susceptibility.

Of the provinces encompassing the river basin, the highly landslide susceptible provinces include Zambales, Benguet, Mountain Province, Ifugao, Nueva Vizcaya, and parts of Tarlac. However, the area is more susceptible to rain-induced rather than earthquake-induced landslides. The location of the Project site is at Pangasinan which was not mentioned among those areas with high susceptibility of landslides.

Liquefaction susceptible areas occur in the central valley of the river basin near major tributaries underlain by sandy soils. Pangasinan is the most liquefaction prone, covering about 60% of all the liquefaction prone areas; followed by Tarlac and Nueva Ecija. Therefore, the design should consider this liquefaction risk on the detailed design engineering for the equipment and facilities to be situated on land.

## 1.7 Climatic Conditions

The climate of the project site location in San Manuel, Pangasinan is considered as tropical climate, typically warm, hot and humid. The baseline data for this section are obtained from *SolarGIS Database.*

The average ambient annual temperature is 27.6 ºC in San Manuel. May is the warmest month with an average of 29.1ºC. The lowest average temperatures in the year occur in January, when it is around 26.0 ºC. Annual precipitation is about 2555 mm. The driest month is February which has only 10mm of rain. The greatest rainfall occurs in August with an average of 581 mm of rain.

The main climatic conditions of the projects are summarized in Table 1-2 below.

| Features | | Values |
|---|---|---|
| **Ambient Temperature** | Minimum | 26.0ºC |
| | Maximum | 29.1ºC |
| | Average | 27.6 ºC |
| **Rainfall** | Minimum | 10 mm (February) |
| | Maximum | 581 mm (August) |
| | Average Annual | 2555 mm |
| **Major Seasons & Months** | Wet Season | March to November |
| | Dry Season | December to March |
| **Relative Humidity** | | 83% |
| **Distance from nearest coast** | | ~30km |

*Table 1-2: Climatic Condition of San Manuel, Pangasinan*

# 2 SITE INVESTIGATION

The Consultant has surveyed the identified site and performed a review of the following site studies provided by the Client for conducting this feasibility study:

- Topographical map
- Bathymetry survey
- Geotechnical investigations
- Hydrography survey : (Reservoir water level, Hydrology Report)

## 2.1 Geological Condition

From document “Reservoir Slope Stability Study Jul 2002, Berthelsen”:

The Geological Map of the Philippines (Bureau of Mines, 1963) indicates that the rocks encountered in the project area are predominantly igneous rocks of Neogene age (i.e. Miocene and Pliocene epochs of the Tertiary Period, 2 to 25 mya.). These are described as intrusive rocks, largely quartz diorite and include granodiorite and diorite porphyry and dacite. These rocks were emplaced as mostly batholiths and stocks, with some laccoliths and also sills, dikes and other minor bodies. These igneous rocks are apparently emplaced in older metamorphosed volcanic rocks, remnants of which are generally confined to structural highs and principal mountain ranges. These were apparently often designated in early literature as 'metavolcanics' and comprise submarine flows, largely spilites and basalts, with some kerotophyres and andesites on Figure 2-1. Most of these units are considered to be probably of Cretaceous and Paleogene Periods.

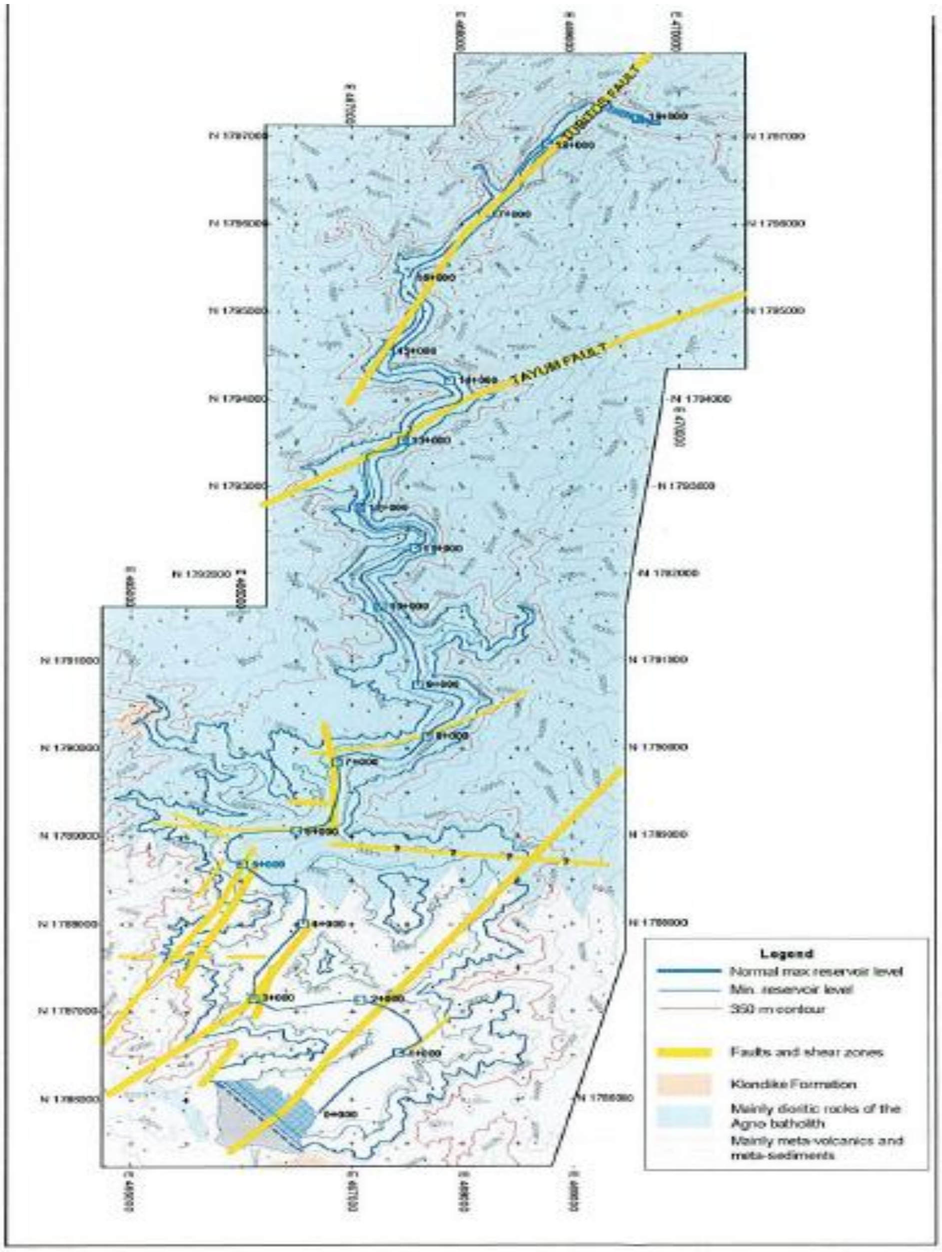



*Figure 2-1: Outline of Geology*

### Faults

A number of faults in three principal orientations have been identified. Faults have also been inferred from the aerial photographs and observed in the dam foundation. The faults do not appear as strong lineation on the aerial photographs. They have only been partly exploited by the Agno River and tributaries. In other areas they cross ridges with little visible effect on the topography. The faults are generally undulating and curved.

Mines and Geoscience Bureau, 2000, also identifies a number of faults with three apparent trends: ENE-WSW (N60ºE) orientation (Tayum, Paday, and Copperque faults); NE-SW orientation (N40ºE) (Tubutos, Dulong and San Roque faults); and NW-SE orientation (Bulangit and Baloy faults).

**Weathering**

The landscape has been subject to deep tropical weathering and this process continues. The weathering profile is in its full development, as observed in ridges excavated near the dam site, following the classical pattern shown in the left half of Figure 2-2. The completely weathered rock consist of red plastic clay, has been observed to be up to 1.5 meter thick, though it may be thicker locally. This followed by a pale yellow clay of low to moderate plasticity with a varying thickness of up to 3 or 4 meters and then material of insignificant plasticity which may be up to 10 meters thick and sometimes more. The underlying moderately weathered rock comprises highly weathered seams and rocks fragments which are week compared to the parent rock (weathering grade III). Its thickness has been observed to be up to some 15 meters. The maximum total thickness of this weathered sequence observed in drill holes is about 25 meters. Below this, there is slightly weather rock (Grade II) which has engineering properties close to those of the un-weathered rock (Grade I).

In engineering terms, rock of weathering grades IV, V and VI is treated as soil and the less weathered material as rock.

Generally, rock is exposed on parts of steep slopes along the Upper Reservoir and it appears that the depth of weathering is relatively shallow with a general absence of highly and completely weathered rock (weathering grades IV and V).

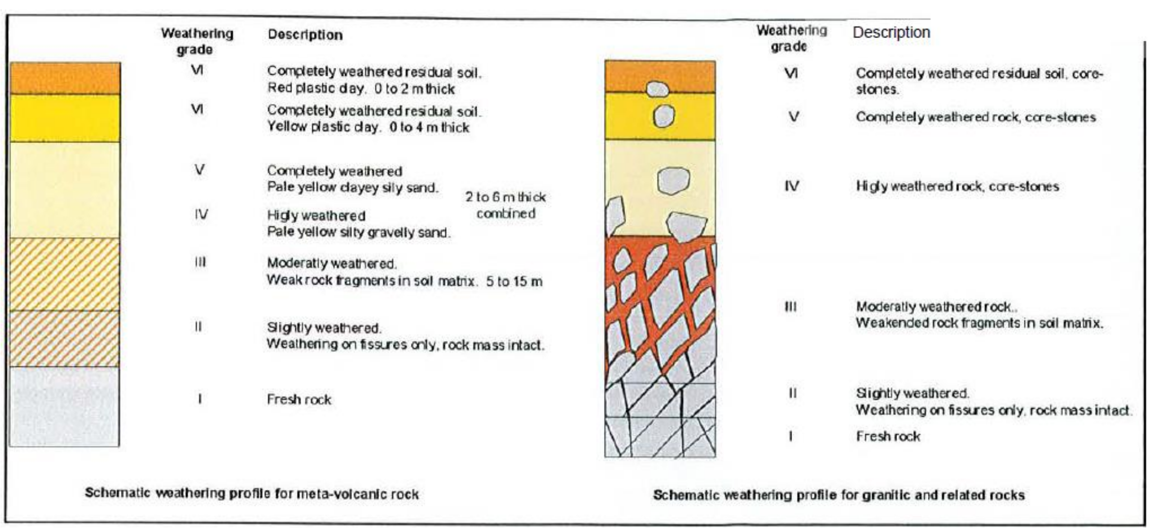



*Figure 2-2: Typical Weathering Profiles*

**Stability of Soil Slopes**

Most of the soil slopes are within the Lower Reservoir. The overall impression of the landscape is one of stability. Only few isolated areas of instability have been found except those associated with current river erosion. However, the 4 July 2001 rainfall event precipitated a number of shallow slide in topsoil and other superficial deposits. Subsequently, reservoir clearance has revealed features that show that there have been previous such episodic events. Most of these slide occurred in the Lower Reservoir area with few slides in the Upper Reservoir area where the soil cover is thin or absent. Most of the slopes where such superficial slides have occurred are at about 35º**.**

Site Visit Photos:

*Figure 2-3: Rock is exposed on parts of steep slopes*

*Figure 2-4: Shallow Slides*

## 2.2 Bathymetry

From document “2018 Bathymetric Survey Report – NPC”.

The San Roque Reservoir is an enormous body of water formed by the construction of a 200 meter high San Roque Dam. The normal High Water Level is at elevation 280 masl and the maximum surcharge level is at elevation 290 masl. The minimum operating level is 225 masl from which no plant operation is permitted below this elevation. At this point water releases is allowed thru the Low Level Outlet where the intake level is 10 meters below the power intake. The reservoir is 3.12 kilometers in its widest width and about 18 kilometers long. The reservoir capacity is 850 million cubic meters at its normal high water level, and additional 120 million cubic meters is allocated for flood control and the dead storage is about 309 MCM based on 2003 data.

The result of the 2018 bathymetric survey of San Roque Reservoir is presented in Figure 2-5. Reservoir capacity at elevation 280.00 masl was calculated at 710.8 million cubic meters (MCM) and comparing to the reservoir capacity from the 2013 survey which is 744.3 MCM there is a difference of 33.5 MCM. This corresponds to an average of 6.7 MCM per year. From the final report of “Reservoir Sedimentation Study and Management Plan for San Roque Multi-purpose Reservoir” in 2007 September, estimated reservoir sedimentation was 6 MCM per year.

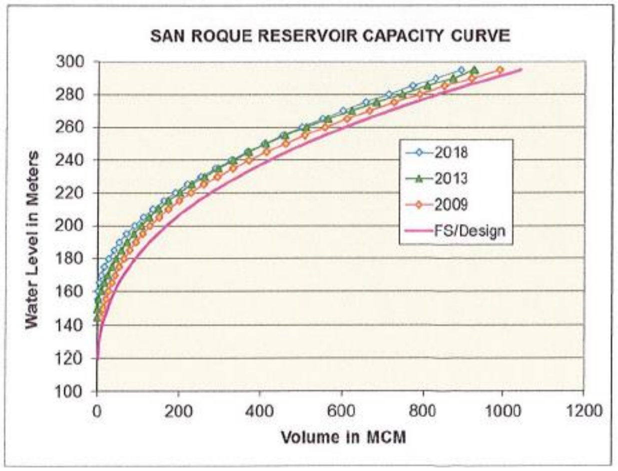



*Figure 2-5: San Roque Reservoir-Capacity Curve*

Collected coordinates are in UTM and elevation are in meters above sea level (masl). The elevation is referenced to the gauge located at the San Roque Spillway and Dam area. The equipment and instrument used are Garmin Handheld GPS, Tru-Pulse Finder, Calibration Tagline and Motorized boat. A total of 879 data points were collected consisting of bathymetric and range finder data. Data processing was then performed and point elevations were incorporated. From the bathymetry survey the surface area of reservoir is tabulated to corresponding water elevation on Figure 2-5 with plotted profile of river center line on Figure 2-7.

| RESERVOIR WATER LEVEL (M) | SURFACE AREA (Sq. Km.) | VOLUME (Million Cubic Meters) |
|---|---|---|
| 295 | 13.8 | 893.46 |
| 290 | 13.0 | 830.24 |
| 285 | 12.4 | 769.34 |
| 280 | 11.9 | 710.76 |
| 275 | 11.0 | 654.50 |
| 270 | 10.2 | 600.56 |
| 265 | 9.5 | 548.94 |
| 260 | 8.8 | 499.64 |
| 255 | 8.2 | 452.66 |
| 250 | 7.8 | 408.00 |
| 245 | 7.3 | 365.66 |
| 240 | 6.7 | 325.64 |
| 235 | 6.2 | 287.94 |
| 230 | 5.7 | 252.56 |
| 225 | 5.3 | 219.50 |
| 220 | 4.8 | 188.76 |
| 215 | 4.4 | 160.34 |
| 210 | 4.0 | 134.24 |
| 205 | 3.5 | 110.46 |
| 200 | 3.0 | 89.00 |
| 195 | 2.6 | 69.86 |
| 190 | 2.2 | 53.04 |
| 185 | 1.8 | 38.54 |
| 180 | 1.5 | 26.36 |
| 175 | 1.3 | 16.50 |
| 170 | 1.0 | 8.96 |
| 165 | 0.8 | 3.74 |
| 160 | 0.5 | 0.84 |
| 155 | 0.2 | 0.26 |

*Figure 2-6: Surface area of water*

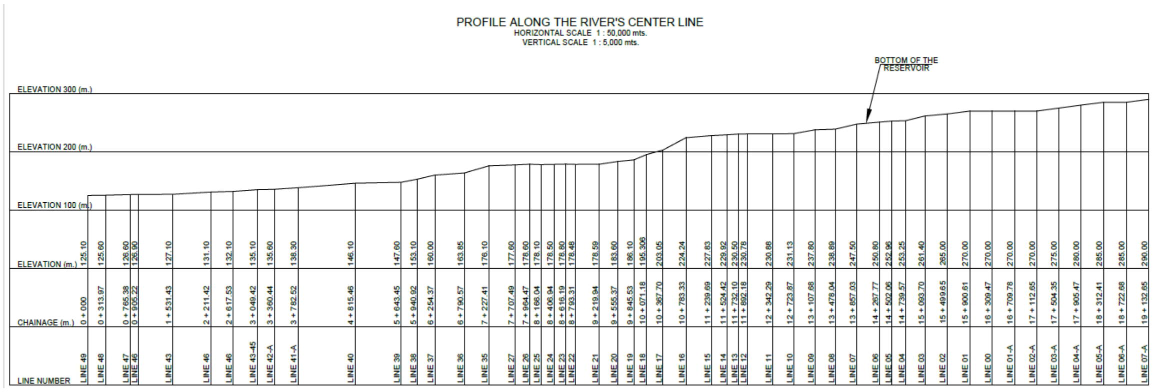



*Figure 2-7: Profile along river center line*

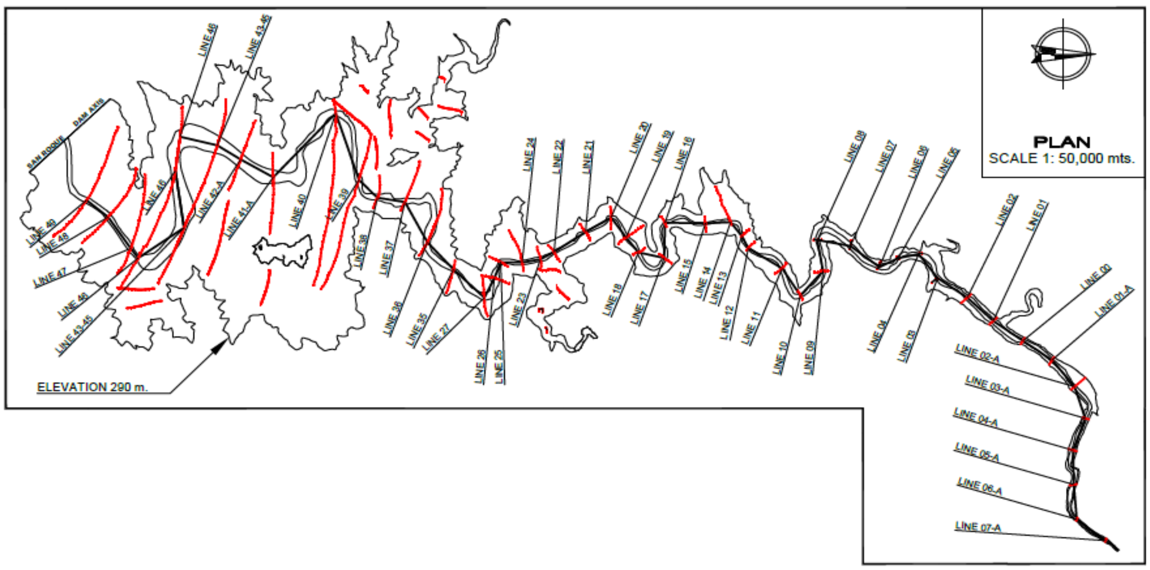



*Figure 2-8: Location of line of profile*

## 2.3 Geotechnical Investigation

The Consultant has reviewed the provided Geotechnical report which was a report made for the San Roque Dam and the reservoir slope stability study. Initial analysis and through the visual inspection during the site visit (most of the visually inspected areas are composed of solid rocks) indicates that the soil properties around the area are suitable for the heavy equipment associated with the floating solar such as the transformer, control room and possibly transmission posts/towers. Nonetheless, a detailed geotechnical analysis shall be performed by the EPC Contractor on the execution phase to verify the suitability and design of the foundation for equipment and foundation.

## 2.4 Topography Survey

The Consultant has been provided with a topographical map as shown in the below figure.

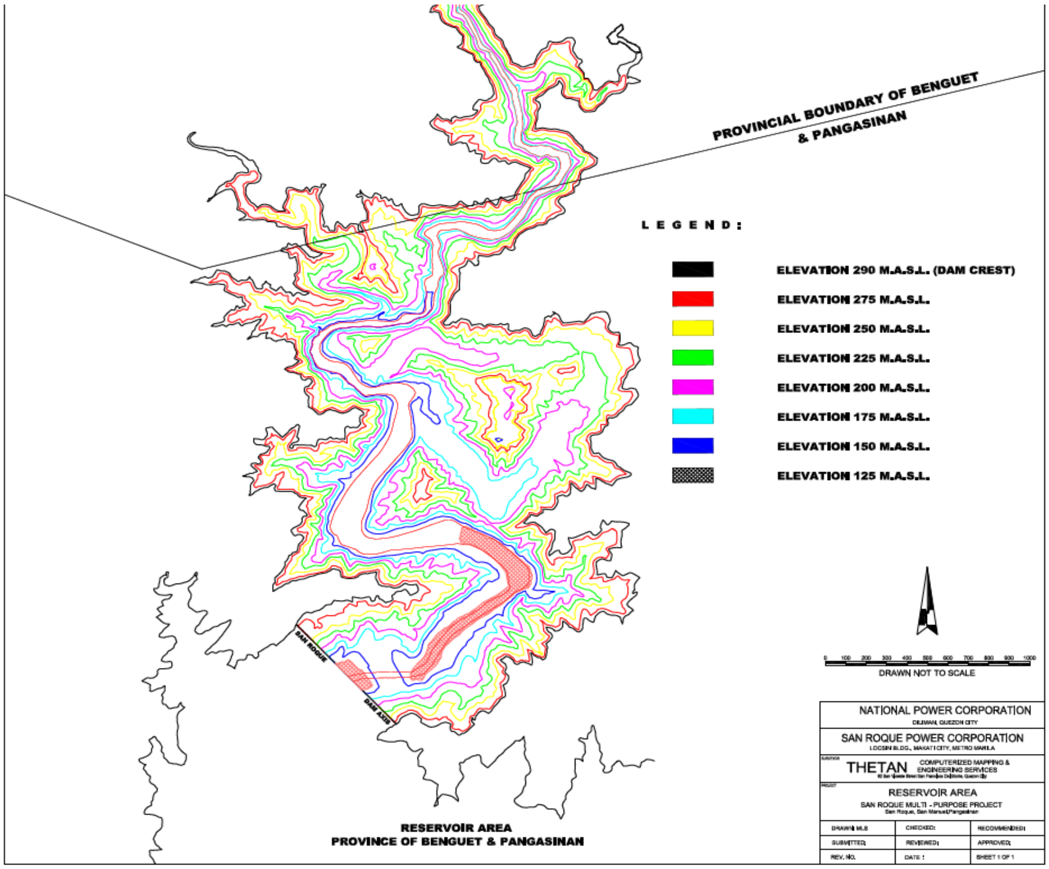



*Figure 2-9: Reservoir contours*

| RESERVOIR AREA | | |
|---|---|---|
| ELEVATION (M.A.S.L.) | AREA (HAS.) | PERIMETER (KM.) |
| 290 | 1,418.3011 | 74.279 |
| 275 | 1,235.1663 | 66.043 |
| 250 | 979.6245 | 52.473 |
| 225 | 705.9328 | 47.492 |
| 200 | 471.9465 | 41.782 |
| 175 | 296.3179 | 30.330 |
| 150 | 150.3641 | 17.235 |
| 125 | 29.2161 | 5.210 |

*Figure 2-10: Reservoir area based on MASL*

## 2.5 Hydrological Study

Based on the hydrology report provided by the Project Sponsor, the Agno River originates in the Cordillera Central Mountain range in the northern part of the Island of Luzon more than 2,000 m above sea level. It runs generally southward through the mountain system. The Dam is located on the Agno River where the Cordillera Mountains transition to the Pangasinan plain thereby maximizing the available watershed basin area that can be impounded by the Dam. The drainage area at the Dam is approximately 1,250 km² and yields an average annual flow of 83.6 cms. (See Figure 2-11) The climate of the Agno River Basin consists of a dry season extending from November to late June (when daily flows can be less than 5 cms) and a single wet season over the remainder of the year. Figure 2-11 shows the average monthly flows available for the Dam. In the wet season, most of the typhoons develop over the open waters of the Pacific Ocean east of the Philippines and a few over the China Sea. During an average year, one to three major storms pass over the watersheds of central Luzon and the Dam. A typical typhoon moves rapidly across Luzon but is accompanied by intense downpours. A major typhoon can produce over 500 mm of precipitation within a 24-hour period causing corresponding daily peak Agno River flows to reach several thousand cms within only a few hours. Figure 2-12 shows the expected return interval of storms and their related flows.

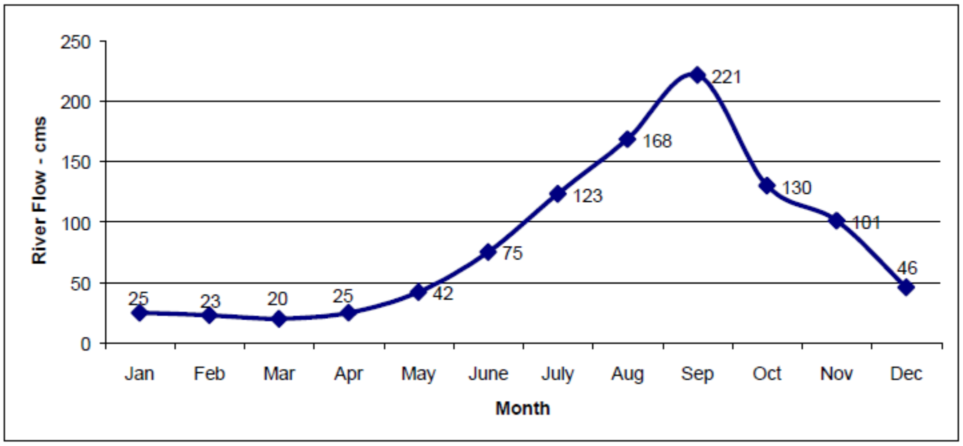



*Figure 2-11: Average Monthly Agno River Flow at the San Roque Dam*

| Return Period Interval | Reservoir Inflow Peaks (cms) |
|---|---|
| 2 – Year | 2,200 |
| 3 – Year | 2,600 |
| 5 – Year | 3,100 |
| 10 – Year | 3,700 |
| 30 – Year | 4,600 |
| 50 – Year | 5,000 |
| 100 – Year | 5,600 |
| 500 – Year | 7,000 |
| PMF | ~ 13,000 |

*Figure 2-12: Expected return interval of floods*

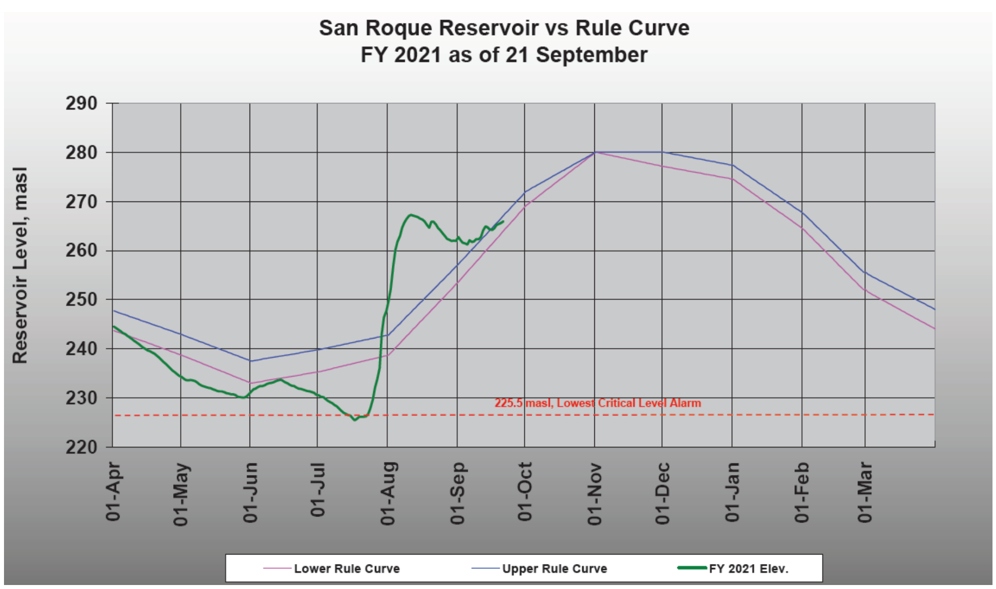



*Figure 2-13: Reservoir Level Year 2021*

On the current report of reservoir level for year 2021 as shown on Figure 2-13, it shows that on the mid of July from lowest level 225 masl it increases in a very short period at the first week of August to 267 masl and this report is consistent with the document "SRPC_EAP_Ver2.9" (Hydrology) from the month of May to September.

Site Photos

*Figure 2-14: Water level below 280 masl*

*Figure 2-15: Current Elevation is 267 masl (Sep 29, 2021)*

## 2.6 Wave Study Analysis

No wave study or document reference is available, from the interview/discussions with the SRPC staff, no noticeable wave or significant height of wave was observed during their stay for almost 19 years, even a wave caused by earthquake was not registered. The most height of wave observed by the operators of the dam is only 0.4 meter. It was therefore that for this study it was decided to use a wave height of 0.5 meter.

## 2.7 Seismicity

Seismic coefficients as prescribed in the National Structural Code of the Philippines (NSCP) may be determined considering the geological condition the site is **Rock Type $S_B$** - Based on available information, the project site in SAN ROQUE DAM is located at a distance of about 2.1 kilometers from the known trace of the Tuba Fault. Considering that the area is prone on ground shaking a Seismic Source Type A can be used.

**SEISMIC HAZARDS ASSESSMENT**

| HAZARD | ASSESSMENT | EXPLANATION AND RECOMMENDATION |
|---|---|---|
| Ground Rupture | **Safe; Approximately 2.1 km from the Tuba Fault** | Active faults are those that have moved within the last 10,000 years. It shows evidence or has documented history of its recent movement. Ground rupture is a displacement along an active fault trace that reaches the surface. |
| Ground Shaking | **Prone** | All sites may be affected by ground shaking in the event of an earthquake and can be mitigated by following the provisions of the National Building code and the Structural code of the Philippines. |
| Liquefaction | **Safe** | Liquefaction is a phenomenon wherein the ground, especially near the river, lake and coasts, behaves like liquid similar to quicksand due to very strong shaking. |
| Earthquake-Induced Landslide | **Data are being updated** | Earthquake-induced landslides are the downward slope movement of rocks, solid and other debris commonly triggered by strong shaking. Avoidance is recommended for sites with earthquake-induced landslide hazard unless appropriate engineering interventions are in place. |
| Tsunami | **Safe** | A tsunami is a series of sea waves commonly generated by under-the-sea earthquakes and whose heights could be greater than 5 meters. |

*Figure 2-16: From hazardhunter.georisk.gov.ph*

Table 208-2 - Soil Profile Types

| Soil Profile Type | Soil Profile Name / Generic Description | Average Soil Properties for Top 30 m of Soil Profile | | |
|---|---|---|---|---|
| | | Shear Wave Velocity, $V_S$ (m/s) | SPT, $N$ (blows/ 300 mm) | Undrained Shear Strength, $S_U$ (kPa) |
| $S_A$ | Hard Rock | > 1500 | | |
| $S_B$ | Rock | 760 to 1500 | | |
| $S_C$ | Very Dense Soil and Soft Rock | 360 to 760 | > 50 | > 100 |
| $S_D$ | Stiff Soil Profile | 180 to 360 | 15 to 50 | 50 to 100 |
| $S_E$[1] | Soft Soil Profile | < 180 | < 15 | < 50 |
| $S_F$ | Soil Requiring Site-specific Evaluation. See Section 208.4.3.1 | | | |

[1] *Soil Profile Type* $S_E$ *also includes any soil profile with more than 3.0 m of soft clay defined as a soil with plasticity index,* $PI > 20$, $w_{mc} \geq 40\%$ *and* $s_u < 24\ kPa$. *The Plasticity Index,* $PI$, *and the moisture content,* $w_{mc}$, *shall be determined in accordance with approved national standards.*

*Figure 2-17: Soil Profile Type*

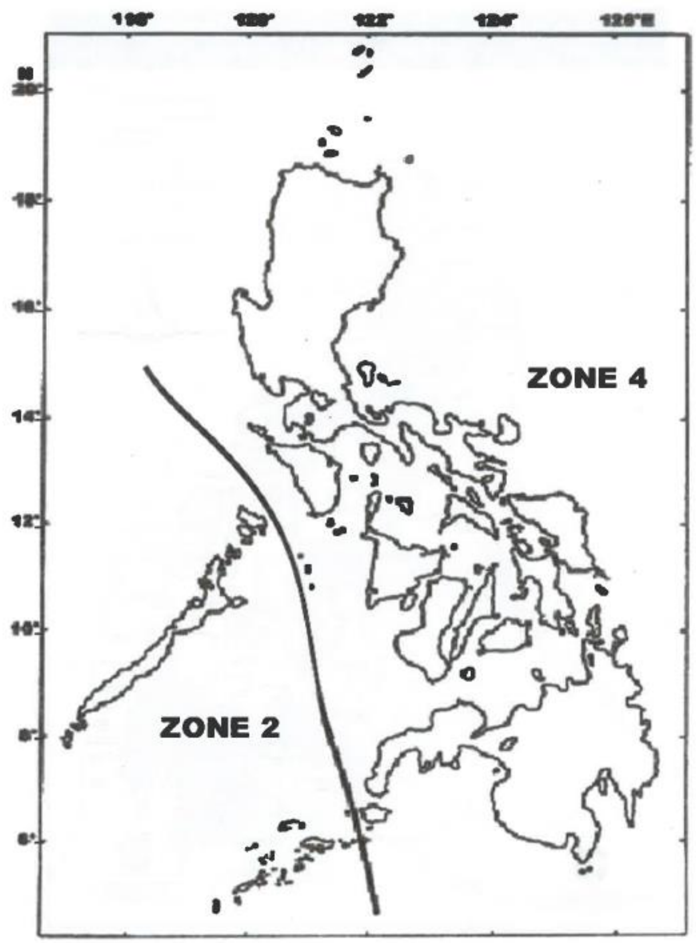



Figure 208-1 Referenced Seismic Map of the Philippines
National Structural Code of the Philippines Volume I, 7th Edition, 2015

*Figure 2-18: Seismic Map of the Philippines*

| Seismic Source Type | Seismic Source Description | Seismic Source Definition<br>Maximum Moment Magnitude, M |
|---|---|---|
| A | Faults that are capable of producing large magnitude events and that have a high rate of seismic activity. | $7.0 \leq M \leq 8.4$ |
| B | All faults other than Types A and C. | $6.5 \leq M \leq 7.0$ |
| C | Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity. | $M < 6.5$ |

## 2.8 Wind Speed

According to the latest version of the National Structural Code of the Philippines (2015) , the design wind speed for the Project site is 260 km/hour. Although the maximum measured windspeed at the weather station in SRPC is 150km/hr, it is advised to follow what the code recommends except otherwise agreed with the insurance provider.

# 3 CONCEPTUAL DESIGN

## 3.1 Power Plant Capacity

For the feasibility study, a high-level conceptual design and layout of the floating solar PV plant was prepared by the Consultant for the pilot project and the main project with equivalent capacities of 200kWac and 150MWac, respectively. The conceptual layout in Annex 1-1 shown an indicative locations such as PV panel area, inverter houses, step up transformers, HV switchyard, and any facility building.

The design assumes solar modules, inverters and MV Power Stations (MVPS) installed on top of floating platforms. For the pilot project, a single floating platform is considered. For the main project, group of blocks and floating islands were considered to form the overall system size.

A unit floating platform supports PV modules, DC Combiner boxes, cables and other associated Balance of Systems (BOS) to constitute a 260 $KW_{DC}$ array. Such Floating platforms of 260 $kW_{DC}$ are joined together to make a larger size Floating Island (FI). In this project, two types of Floating Islands have been formed—a 4.68 $MW_{DC}$ capacity and another 2.34 $MW_{DC}$ capacity. Each Floating Island is then connected with one 4.0 MVA SMA MV Power Station (MVPS 4000-S2), which consists of a Central Inverter, MV Transformer, and an MV Switchgear, in a standard 20-foot HC size container. These MV Power Stations shall be installed on barges which shall be located near the Floating Islands. Multiple MV Power stations shall be connected via ring main units (RMUs) and further be connected to a switchyard which is located on the shore.

The Project's configurations are summarized in Table 3-1 below.

| SITE CONFIGURATION | VALUES |
|---|---|
| Site Coordinates | 16.152646°N, 120.695586°E |
| Site Altitude | 290 masl |
| AC Capacity | 152 MWAC |
| DC Capacity | 177.84 MWDC |
| DC Design Voltage | 1500 V |
| DC:AC Ratio | 1.17 |
| Solar PV Modules Make & Rating | Trina Solar TSM-DE18M(II), 500Wp |
| No. of PV Modules | 355,680 |
| Dimension of PV Module | 2187 x 1102 x 35 mm |
| Inverters Make and rating | SMA MV Power Station 4000-S2, 4.0 MVA |
| No. of Central Inverters | 38 |
| No. of Strings | 13,680 |
| No. of Modules per String | 26 |

| SITE CONFIGURATION | VALUES |
| --- | --- |
| Solar PV Module Orientation | Landscape |
| Angle of orientation (Tilt/Azimuth) | 5°/180° Facing South |
| No. of strings in One row | 2 |

*Table 3-1: Solar PV Plant Configuration for 150 MW Main Project*

| SITE CONFIGURATION | VALUES |
| --- | --- |
| AC Capacity | 200 $kW_{AC}$ |
| DC Capacity | 234 $kW_{DC}$ |
| DC Design Voltage | 1000 V |
| DC:AC Ratio | 1.17 |
| Solar PV Modules Make & Rating | Trina Solar TSM-DE18M(II), 500Wp |
| No. of PV Modules | 468 |
| Dimension of PV Modules | 2187 x 1102 x 35 mm |
| Inverter Make & Rating | SMA Sunny Highpower SHP100-20-PEAK3, 100 kWac |
| No. of String Inverters | 2 |
| No. of Strings | 26 |
| No. of Modules per String | 18 |
| Solar PV Module Orientation | Landscape |
| Angle of orientation (Tilt/ Azimuth) | 5°/180° Facing South |

*Table 3-2 Solar PV Plant Configuration for 200kW Pilot Project*

## 3.2 Power Plant Technology

The technology selected for this solar PV project is a Floating type project on a reservoir. The general configuration for a Floating PV (FPV) system is similar to a land-based PV system, apart from the fact that the PV arrays and often the inverters are floating on water. Figure 3-1 shows one typical schematic of a FPV power plant using central inverters that are also built on a floating pontoon. Electricity generated by the various strings of PV modules is collected at the combiner boxes and is then converted to AC power by inverters. The floating devices, together with its anchoring and mooring system, are an essential part of a FPV system.

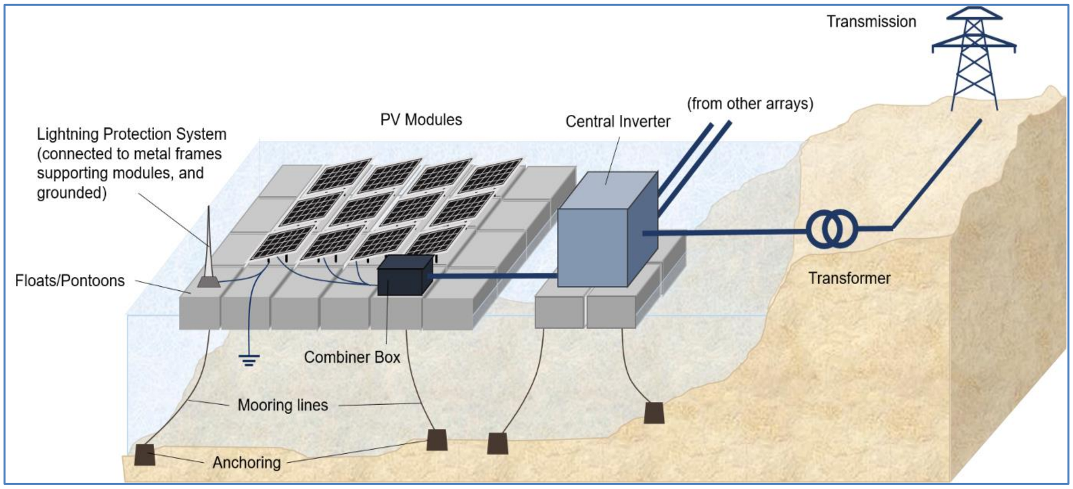



*Figure 3-1: Schematic of a typical floating PV system, with its key components. (Source: SERIS)*

### 3.2.1 Types of Floating Platforms

Apart from the typical design in Figure 3-1, there are also several other variants of system design and technology concepts. A brief overview of the various types of floating technology options is given in Figure 3-2.

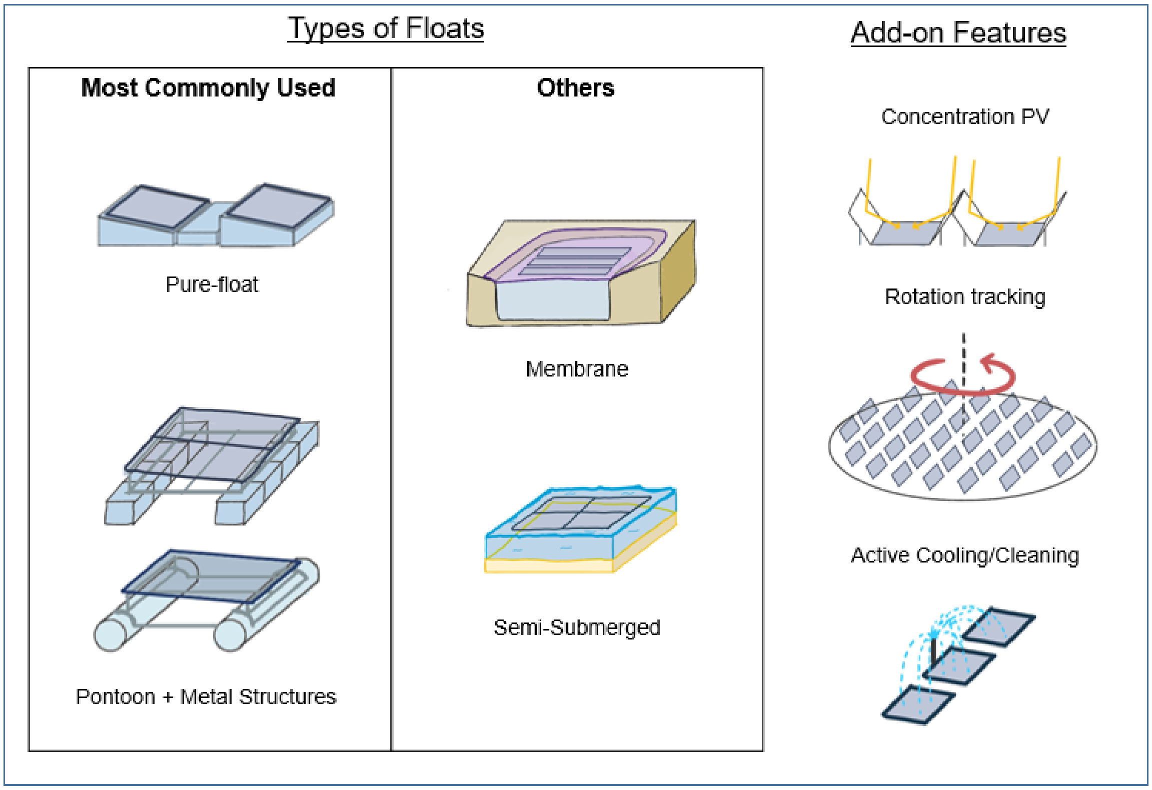



*Figure 3-2: Graphical summary of floating PV related technologies and the various application scenarios. (Source: SERIS)*

In this report, in order to put some light on the selection of the floating technology, the Consultant discusses the two most commonly used types of floating platforms that are relevant to the project.

#### 3.2.1.1 **Pure-Float Design**

Pure-float configurations consist in a modular floating platform using specially designed floats for different usages within the FPV plant: be it for mounting PV panels, mounting accessories (e.g. combiner boxes or string inverters) or for walkways. French company Ciel & Terre (C&T) has pioneered this specialized floating PV solution, which basically became industry-standard today for large floating PV farms. It is offered by many large players in the field and is relatively a more mature and reliable type of technology, compared to other concepts, which have not been deployed in large-scale yet. As an example, the Hydrelio floats from Ciel & Terre International are illustrated in Figure 3-3. The float system is modular and consists of two types of floats. "Main floats" support the PV modules and provide an optimum tilt to the module (different tilt angles are possible, depending on the model used). "Secondary floats" ensure connection with the main floats, provide sufficient spacing to limit the shading of PV modules, and are used as maintenance walkways while lending additional buoyancy. The floats are connected with pins, bolts or special plastic bands to form a large platform. The material used is UV- and corrosion-resistant high-density polyethylene (HDPE) that is usually manufactured through a blow-moulding process.

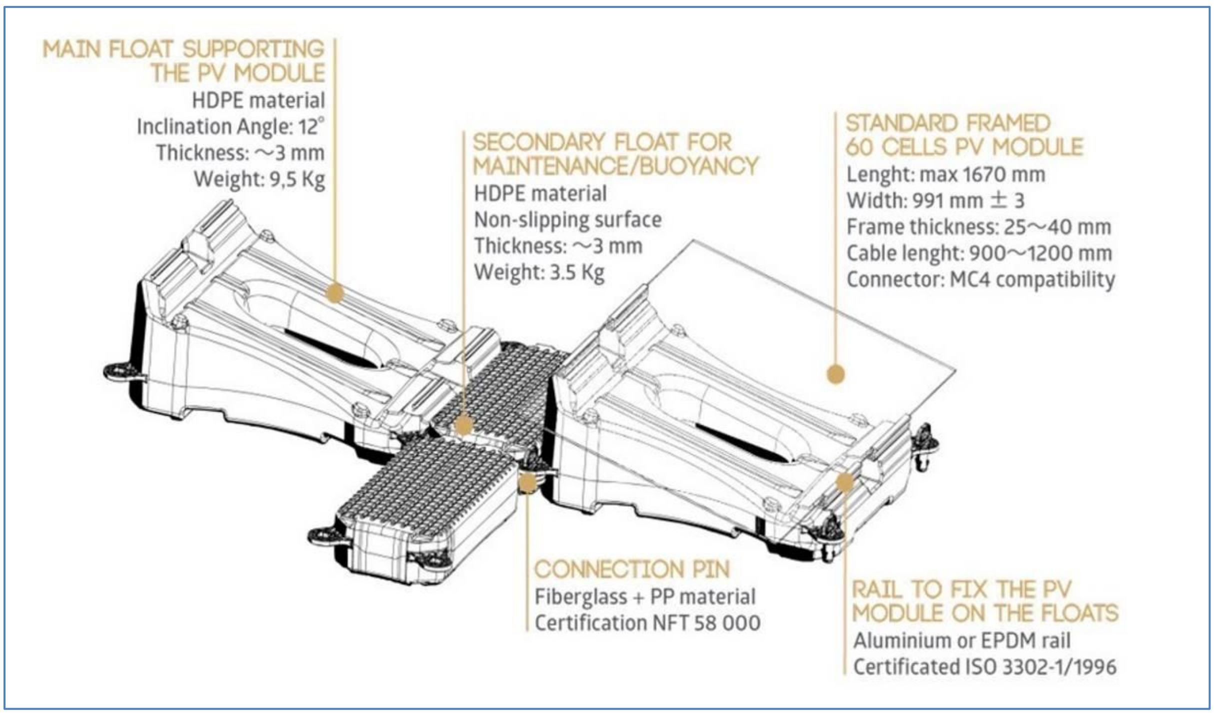



*Figure 3-3: Components of floats designed by Ciel & Terre.*

Among others, a leading Inverter manufacturer from China, Sungrow has also established its name in the turnkey business to supply Floating PV solutions. They have supplied mostly in the Chinese markets but they have total credentials of more than 1.1 GW of projects, claiming to have market share of more than 30%. The Client would have choice later to choose among the best in the industry, as per the suitability of this project. However, in this report the feasibility has been established without recommending any particular supplier and these brands are only to be taken indicatively.

The table below summarizes the pros and cons of this pure-float design.

| Advantages | Disadvantages |
|---|---|
| • Easy to assemble and install.<br>• Fast installation speed (50 workers can install up to 1 MWp per day)<br>• Highly scalable without much change of design.<br>• Little metal parts, hence less corrosion.<br>• Platform adapts to wave motion and relieves stress. | • Modules are mounted very close to the water. This limits the benefits from the evaporative cooling effect. High moisture levels need to take into account for PV module and cable selections.<br>• It is not cost-effective to transport floats for large-scale (MW) projects across long distances. Therefore, floats may need to be moulded at a pre-fabricated manufacturing shop close to the site to save on transportation cost.<br>• Constant movement may cause stress and fatigue to joints and connectors (which are typically made of plastic as well). |

*Table 3-3: The pros and cons of pure float designs.*

**List of Potential Suppliers**

Below is a list of Potential Suppliers for these systems. Other suppliers also offer similar products and this list is not to be considered restrictive.

| Supplier | HQ location | Local office/ agent/ support | Manufacturing location | Track record | Product/service features |
|---|---|---|---|---|---|
| Ciel & Terre International | France | Thailand, Malaysia, Indonesia, Vietnam, Myanmar, etc | China, Taiwan, Korea, Thailand, etc | 300MW | Comes with various choice. Good quality and long history of track record. Experienced with anchoring solutions. |

| | | | | | |
|---|---|---|---|---|---|
| Sungrow | China | Thailand, Vietnam, Malaysia, etc | China | 1.1GW | Multiple float types suited for different components. Offers inverters and EPC service as well. |
| Mibet New Energy | China | Thailand, Myanmar, etc | China | 30MW | Good air ventilation at the back. |
| Sumitomo Mitsui Co. | Japan | Singapore, etc | Japan | 10MW | Filled with polystyrene foam to prevent sinking. Tied with flexible rubber bands to reduce stress at connection points |
| SCG Chemicals | Thailand | N/A | Thailand | 8MW | One type of float, easier to manage |

*Table 3-4: List of some potential suppliers for floating platform with pure-float design*

#### 3.2.1.2 **Pontoon and Support Structures**

Another design, although less common with large scale systems, is to use metal structures to support PV panels in a similar fashion as land based systems, and fix the metal structures to pontoons, which only serve to provide buoyancy. In this case, there is no need for specially designed floats. A common option is to use Sealed Polyethylene pipes (with both ends closed). As a result, they may be more easily sourced locally compared to specially designed floats in the previous case. Such platforms are offered by companies such as 4C Solar and Koiné Multimedia, see Figure 3-4 (a) and (b). Alternatively, the metal trusses can be built on floats of other shapes, such as the design in Figure 3-4 (c) and (d) by NRG Energia and Takiron respectively. In another design by Israeli company Solaris Synergy, the metal frame stands on four specially designed floats, as shown in Figure 3-4 (e). Each such assembly can host a few PV panels, to form one floating unit. Multiple units are then grouped and held together by cables and an outer ring, as illustrated by Figure 3-4 (f).

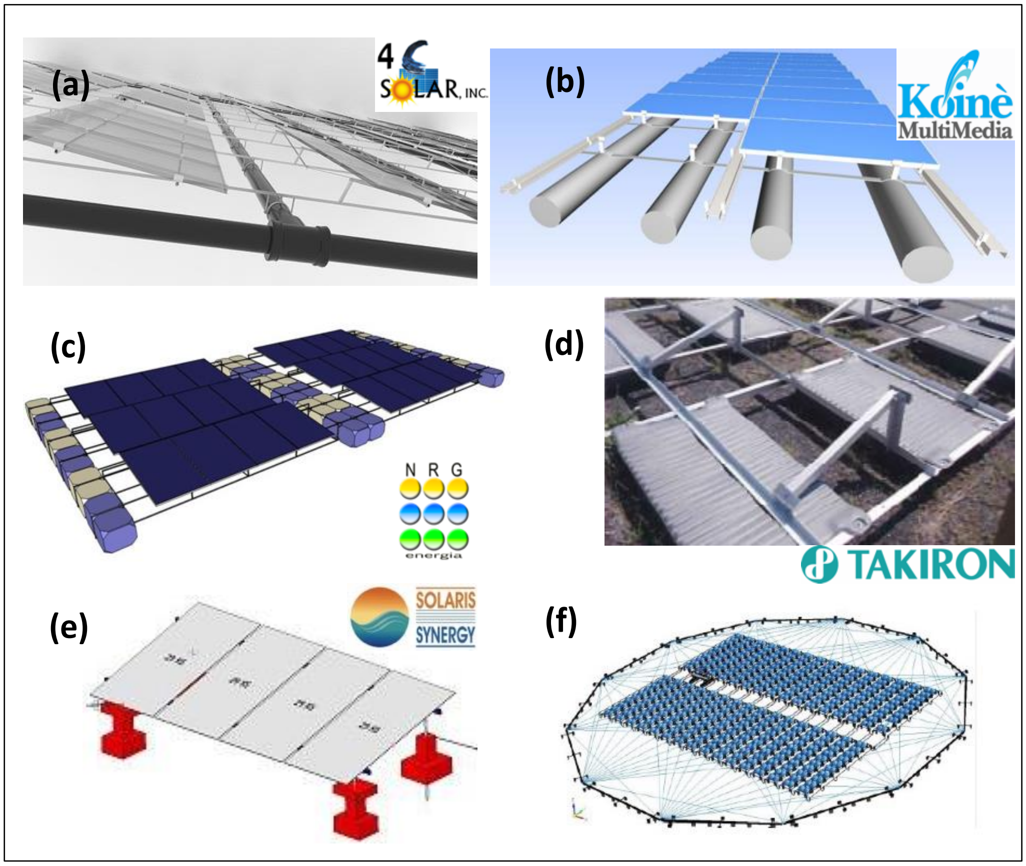



*Figure 3-4: Illustration of various designs using pontoon + framing structure configuration to host PV panels.*

The general advantages and disadvantages of this type of design are listed in the following table.

| Advantages | Disadvantages |
|---|---|
| • It is conceptually simple.<br>• Floats are easier to make, and therefore can potentially even be sourced locally.<br>• There is less relative movement between PV modules, which reduces wear and tear. | • Rigid structure tends to have high stress concentrated at certain parts in the presence of waves.<br>• It requires more effort to assemble and hence throughput may be affected.<br>• Access pathways for O&M activities is difficult for some, very open structures (which in turn have a high benefit from the evaporative cooling though). |

*Table 3-5: The pros and cons of float + framing structure designs.*

**List of Potential Suppliers**

Below is a list of Potential Suppliers for these system. Other suppliers also offer similar products and this list is not to be considered restrictive.

| Supplier | HQ location | Local office/ Support | Manufacturing Location | Track record | Product features |
|---|---|---|---|---|---|
| Koine Multimedia | Italy | N/A | N/A | <1MW | Pipes can be sourced locally from water piping industry |
| 4C Solar | USA | N/A | N/A | N/A | Pipes connected to form islands, conceptually easy |
| Takiron | Japan | N/A | Japan | N/A | Stable platform |
| Solaris Synergy | Israel | N/A | Israel | 1 | Excellent ventilation and cooling, self-adaptation to wind |

*Table 3-6: List of some potential suppliers for floating platform with float + framing structure design*

#### 3.2.1.3 Summary and Recommendation

For large FPV farms, it is recommended to go for the pure-float solution offered by established, reputable suppliers. This type of platform is more scalable than the other types of floating platforms and is currently the mainstream solution. In addition, the main players such as C&T and Sungrow have rich experience in large projects.

### 3.2.2 Anchoring and Mooring System

The floating platforms are kept in place via the anchoring and mooring system. It is an essential part of the FPV system. There are mainly two options for anchoring: bank anchoring and bottom anchoring.

Bank anchoring is particularly suitable for small and shallow ponds where the FPV plant is close to the shore. The shore ground conditions must be evaluated, but in general, bank anchoring is cheaper than bottom anchoring. Bank anchoring could be realised either through driven anchors / piles or deadweight or combination of both (see Figure 3-5). It also allows for easier access of the anchoring, both for deployment and for periodical inspection during O&M. Wherever possible, bank anchoring is the preferred option.

*Figure 3-5: Dead weights in the form of concrete pre-cast or drilled piles used for bank anchoring.*

Bottom anchoring is used in the majority of existing FPV plants. Many mature solutions exist in marine and offshore engineering applications, which can be transferred to floating PV. The most economic and most commonly used solution are dead-weight anchors, which consist of appropriately sized concrete blocks acting as anchor (Figure 3-6). The weight of the concrete, as well as the settling inside the reservoir bed, provide the downforce required for the anchors. For more sophisticated bottom anchoring, the cost can be more expensive, and it may require greater efforts and costs to inspect and maintain. The equipment required (working rafts, barges, cranes and winches) may also be more specialized. However, bottom anchoring allows deployment in locations that would not allow for bank anchoring, where the shore is in a distance from the FPL installation.

A gravity / deadweight anchor is any heavy object placed on the lake floor to resist vertical and/or lateral loading.  It can be fabricated from concrete and steel which are also known as “clumps” or “sinker “and configured to enhance lateral capacity. Deadweight anchors are often used because they are inexpensive and readily sized for most lake floor and loading conditions. In general, they are not very efficient (ratio of holding capacity to weight) compared to the other anchor types, thus they may require heavy lift capabilities for installation and they are less favourable on sloping lake floors. However, on very hard bottoms they might provide the only reasonable anchoring option. They rely only on their weight and friction with the lake bed to generate holding resistance. Some features of gravity/ dead weight anchor are described below

- Large vertical reaction component, permitting shorter mooring line scope
- No setting distances
- Lateral load resistance decreases rapidly with increase in lake floor slope
- Reliable holding capacity because most capacity due to anchor mass
- Simple on-site construction possible, tailored to task
- Size limited by load handling equipment
- Material for construction readily available and economical
- Reliable on thin sediment over rock
- Mooring line connection easily to inspect and service
- In shallow water, the large mass can be an undesirable obstruction
- Lateral load resistance is low compared to other anchor types
- Works well as a sinker in combination with drag-embedment anchors to permit shorter scope
- A good energy absorber when used as a sinker with non-yielding anchors (pile and plate)
- Lateral load resistance is low compared to most anchors except for very hard bottom conditions

For FPV, wind load consideration is of particular importance here. This is not only for floaters and the metal supporting structure, but also for the entire floating platform and anchoring. Wind will cause a drift of the entire platform, so it requires a suitable anchoring with mooring cable lines to keep the platform in place. The maximum size for an island depends on the floats' capability to withstand the stresses induced by various forces, which is typically evaluated by a finite element analysis.

Failure of the mooring system (anchor pull-out or mooring line failure) can be catastrophic and would leave severe impacts on the project. The mooring system should therefore incorporate redundancy so that failure of a single mooring line does not cause progressive cascading failures of the other remaining lines.

The design of the anchoring plus mooring system should also take into account durability and reliability of the components used over the expected system lifetime, and allow additional margins for wear and tear, corrosion, shock loading or other compounding factors. Requirements for periodical testing and inspection as well as preventative maintenance must be specified. Other general guidelines to take into account include:

a. Anchor types suitability for different reservoir bed types
b. Wire, rope or chain choice as mooring line material
c. Compliance to local standards and recommended practice
d. Corrosion of components of the anchoring system
e. Algae growth and marine growth
f. Environmental impact on neighbouring fauna and flora, as well as water quality

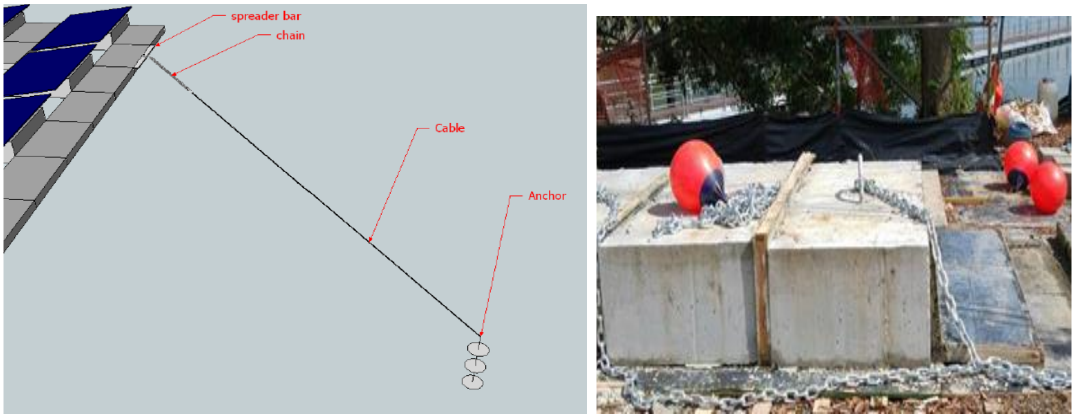



*Figure 3-6: A representative mooring and anchoring drawing on the reservoir bottom with concrete sinkers*

*Figure 3-7: Load transfer points from floating platform to mooring lines*

Some examples of the attachment between mooring lines and floats are shown in Figure 3-7. A spreader bar is typically used to transfer the loads from the floating island to the mooring and anchoring systems. D shackles are also frequently used as connections – alternatively, synthetic ropes have been knotted to the floats directly. Typically, redundancy is provided by designing systems with several chains or wire ropes. Requirements for periodic testing and inspection as well as preventative maintenance must be also be considered during the O&M phase.

In general, the detailed design of the anchoring system is undertaken by the EPC or the subcontracted civil / structural engineering company, sometimes the float supplier can also do the design themselves to provide solutions that are more compatible with their floating platform designs. The project developer is recommended to check with the float suppliers the considerations mentioned above regarding the anchoring designs. In many cases, the supplier can at least give recommendation and requirements of design, and even on-site technical support for the installation. The general information needed to facilitate the design of anchoring system include:

- Bathymetry survey (for bottom anchoring)
- Soil condition survey
- Water quality
- Wind speed
- Prevailing water current and waves

More care must be given to designing anchoring and mooring at sites with large water level variations. Large water level variations is being defined as more than 5 meters. Very Large water level variations is being defined as more than 20 meters. The SRPC project maximum water level fluctuation is 65 meters.

Enough slack needs to be given to mooring lines, but at the same time the lateral movement needs to be constrained. Simpler ways to achieve this include putting auxiliary buoys or weights (Figure 3-8). More advanced systems with dampened pulley systems, or mooring lines with adjustable lengths are also available, but at higher costs. For example, SEAFLEX® provides a reinforced homogenous rubber based elastic mooring system, which can slowly elongate and retract in a smooth, even movement (Figure 3-9). The mooring system can resist sudden forces but can slowly self-regulate according to variations in water level seen in seasonal changes or flooding events. Figure 3-10 shows schematic drawings of the SEAFLEX mooring system and its applications. SEAFLEX has demonstrated the successful functionality in projects with 7 meter (23 feet) tidal fluctuation as well as 25 meter (82 feet) artificial variation. In Canoe Brook Solar Park the complete structure is moored with SEAFLEX and has already in the first year of operation proven to withstand the strike of Hurricane Irene as well as a full "winterization" of the still floating platforms.

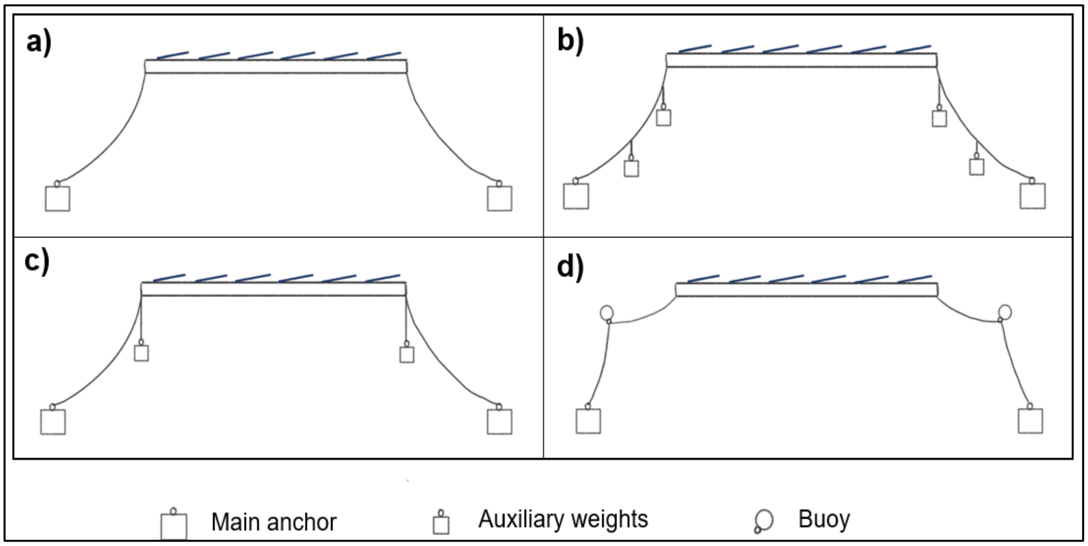



*Figure 3-8: Various designs of anchoring and mooring: a) simple mooring; b) and c) mooring with auxiliary weights; d) mooring with buoys. (Source: SERIS)*

*Figure 3-9: SEAFLEX elastic mooring component.*

*Figure 3-10: SEAFLEX mooring system.*

### 3.2.3 Summary & Recommendation

One of the most challenging part of the project is the large variation in maximum water level and minimum water level (65 meters) in relation to the anchoring. Currently there are no project operational which have such a large variation in level. Up until a couple of years ago, this would be a deal breaker in the development and realization of a FPV project such as SRPC, however in the last couple of years the technology for anchoring/mooring with very large level fluctuations has been further developed.

Based on the traditional anchoring for FPV project the anchoring cables will have a lot of slack, resulting in possible unsafe drifting (maximum drifting at low water level) of the FPV islands. This drifting will result in a reduction of number of islands which can be placed on the reservoir, since it needs to be prevented that the islands drifts in to a less deep part of the reservoir where it could run ashore when the reservoir level drops to its minimum. This drift could also be unsafe for the electrical cables running from the FPV islands to the shore, additional length for these cables need to be taken in to account during the design depending on the possible drift. Furthermore there can also be twisting of the FPV island which not only lowers the optimum orientation of the panels but can cause tangled mooring lines. The anchoring/mooring in combination with the 65 meter level variation will be the most challenging aspect from a technical perspective.

A second challenge is the high windspeeds for which the floaters and the anchoring will need to be designed. The information received from SRPC shows that the highest windspeed measured at the reservoir (which is protected against high windspeeds by the surrounding mountains) is 150 km/h, however the National Structural Codes of the Philippines (NSCP) prescribes a windspeed design of 260 km/h (3 second gust) for the area in which the reservoir is located. This NSCP specified windspeed is a very high value for FPV projects and makes the floaters and anchoring designs even more challenging.

AFRY has contacted the leading floater and anchoring/mooring suppliers with operational experience in FPV projects. Although all mentioned that the conditions (level change and wind conditions) are very challenging and at the limit of what is possible with today's technology, the developments in the FPV industry have been substantial over the past years. Both the float suppliers and the anchoring/mooring suppliers have stated that it is possible to realize this project without too many risks. For the anchoring/mooring the most promising solution is a flexible anchoring solution, which limits the drift of the PV islands. The leading technology supplier for this is Seaflex, a company from Sweden with over 40 years' experience in flexible anchoring of marina's and FPV projects. Seaflex confirmed to AFRY in writing that there are several possible solutions for the challenges, depending on the float system used. These possible solutions need to be worked out in the next phase of the project, which is expected to be the FEED phase. Seaflex has stated that they look forward to be part of the Front End Engineering Design team (against a fee) to find the optimum solutions for this project.

Considering all the factors described above it looks possible to deploy gravity (dead weight) anchors made of precast concrete blocks and lowered down to the reservoir bed (Figure 3-11). The mooring lines will be connected to the concrete blocks and to the FPV platform at the other end. Auxiliary buoys, elastic mooring components or other specialized mooring systems may need to be designed by the EPC Contractor (FPV System Provider) to consider the high water depth and to accommodate the water level variation. In the latter stages, the detailed design may also propose for a combination of bank anchoring and gravity anchoring, but that would need to be suitably designed keeping in view of the cable management, shore pile strengths, access and other technical parameters. However, at this stage, the feasibility is conducted considering gravity anchors.

*Figure 3-11: Gravity precast concrete block used for bottom anchoring*

### 3.2.4 Solar PV Plant Equipment & Specifications

This section provides basic technical and minimal acceptable standards which shall be applied to the electrical equipment supplied as part of the project. The electrical systems, plant, equipment, and others, provided under this contract, shall comply with all relevant International Standards, and Philippine Electrical Code (PEC), Philippine Grid Code (PGC) and statutory requirements.

The standards used in the implementation of the design of PV farms and are not limited to those mentioned below such as:

1. Related IEC.
2. Related PEC and PGC.
3. Related IEEE.

In general, the basic electrical scheme of the floating PV farm can be seen in the picture below:

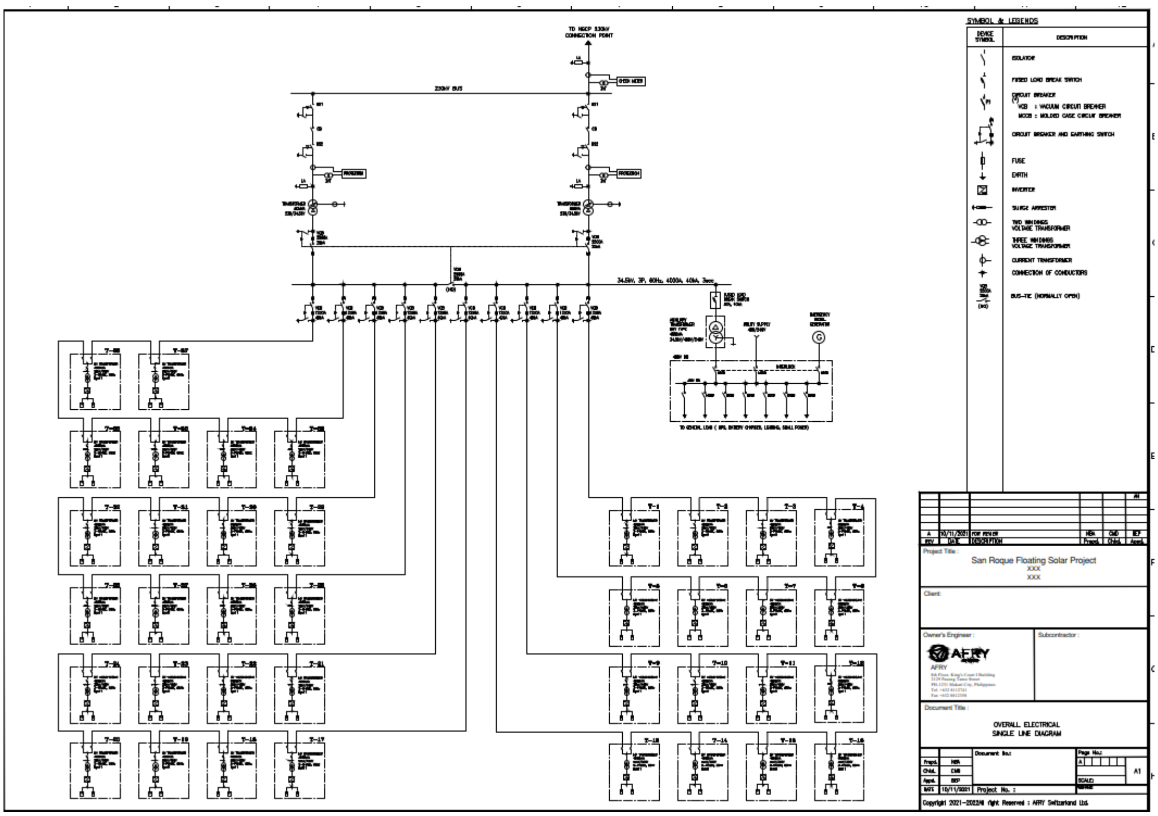



*Figure 3-12: AC Single Line Diagram of PV*

The project is designed for maximum 1500V DC system voltage which is typical for Utility-scale Solar PV Plants. A 1500V DC system voltage is beneficial for large scale plants mainly because of cost savings and efficiency gains by using lesser number of strings, cable lengths, and wirings.

### 3.2.4.1 **DC/AC Ratio**

DC/AC ratio is the DC capacity of the plant (i.e., the total solar panel capacity installed in Watt) divided by the inverter AC power rating. Typical design DC/AC ratio can range between 1.0 to 1.5 depending on climate and techno-economic optimization. Adding more panels, within the compatibility of the inverter capacity, to increase the size of the solar array increases the DC/AC ratio of the system, which allows more energy generated throughout the day. However, oversizing the solar arrays may induce high losses at the inverter due to clipping, or power limiting especially during the peak production hours where maximum DC power is reached.

In this project, the DC/AC ratio is optimized at 1.17, according to the configurations and equipment selected.

#### 3.2.4.2 Solar Module

There are several technologies available, which are being used commercially in large scale projects. But, in Floating Solar PV segment, only few PV technologies are recommended from various suppliers, among which Mono-crystalline type PV modules are considered suitable. The silicon solar modules proposed as reference for the purpose of calculating the project’s energy yield are modules with rated power not less than 500 Wp. The supplier chosen for the purpose of conducting this feasibility study is Trina Solar Co., which is one of the leading suppliers. The module chosen is a standard type with back sheet, which has the multi-busbar technology that uses 1/3-cut cells that introduces a total of 150 cells per Solar PV Module. It is designed with 25 years of life and power degradation of -0.55% per year. However this does not constitute an advice from the Consultant to favor this supplier and model ; actual products selection will be made in contractor/supplier bidding stage. At the detailed FS or FEED, the consideration to use PV modules with higher capacity and is available in the market with proven installation experience will be studied to further minimize footprint.

The main specification of PV module of reference is shown in the table below.

| Specifications | Value |
|---|---|
| **Electric features** | |
| Type | Mono |
| Rated Capacity $P_{mpp}$ | 500.00 Wp |
| Rated voltage $V_{mpp}$ | 42.8 V |
| Rated Current $I_{mpp}$ | 11.69 A |
| Open-circuit voltage $U_{OC}$ | 51.70 V |
| Short-circuit current $I_{SC}$ | 12.28 A |
| Module Efficiency | 20.7% |
| Operation temperature range | - 40°C ~ + 85°C |
| Maximum System voltage (Standard IEC) | 1500V (IEC) or 1500V (IEC/UL) |
| Maximum Series Fuse Rating | 20.00 A |
| Power tolerance | 0 ~ + 5W |
| **Temperature features** | |
| NOCT | 43 ± 2°C |
| Temperature coefficient of $P_{max}$ | -0.34% / °C |

| | |
|---|---|
| Temperature coefficient of $V_{OC}$ | -0.25% / °C |
| Temperature coefficient of $I_{SC}$ | 0.04% / °C |
| **Mechanical features** | |
| Type of photovoltaic cells | Mono-crystalline |
| Number of photovoltaic cells | 150 Cells |
| Dimension | 2187 x 1102 x 35 mm |
| Weight | 26.5 kg |
| Front Cover | 3.2 mm, AR Coated Heat Strengthened Glass |
| Frame | 35 mm, Anodized Aluminium Alloy |
| Junction box ingress protection (IP) | IP 68 rated |
| Output cable | 4.0 mm² (IEC) |
| Connector | MC4 EVO2 / TS4 |
| Guaranteed performance | Minimum 98.0% of the labelled power output after first year;<br>Minimum 84.8% of the labelled power output at the end of 25 years. |

*Table 3-7: Main Specifications of Solar PV Modules*

#### 3.2.4.3 Inverter

The Inverter of reference proposed for the project is a standard central inverter, with rated power not less than 4000kVA. The supplier chosen for the purpose of conducting this feasibility study is SMA, which is one of the leading suppliers.
Various opinions about floating PV inverter type coexist among suppliers and EPC turnkey contractors. Some are in favor of central type inverters and others stand for using string inverters for the ease of installation on the floating platform thanks to distributed weight.
For the purpose of conducting this feasibility study, the consultant have chosen central inverter for the following key reasons:

- Central Inverters have higher capacity than string inverters which can easily accommodate one floating island.
- Only few central inverters will be required for the required overall system size.
- The placement of Central inverters adjacent to the floating islands would use less amount of DC cables therefore minimal DC cable losses.

However, the EPC turnkey supplier would be free to select the inverter technology and the supplier as per the suitable standard and design for the project. The use of string inverters can also be further studied and detailed during the detailed FS or FEED to determine whether it can increase more the capacity by eliminating the footprint required for central inverters.

Since for the 200 kW pilot project a central inverter is more than oversized, 2 string inverters with a capacity of 100 kW each have been selected

The main technical parameters are as in Table 3-8 for the central inverter and in Table 3-9 for the string inverter.

| Item | Value (SMA Sunny Central SC 4000 UP) |
|---|---|
| MPPT DC voltage range (at 25°C / at 50°C) | 962 - 1325 V / 1000 V |
| Max DC Voltage | 1500 V |
| Maximum DC current | 4,750 A |
| Rated AC Output Power | 4000 kVA (at 35°C) |
| Maximum AC Current | 3850 A |
| AC voltage range | 660 V (528 – 759 V) |
| European Efficiency | 98.7 % |
| CEC Efficiency | 98.5% |
| AC Power frequency | 50/60 Hz |
| Total Harmonic Distortion (THD) | < 3% |
| Adjustable power factor | 0.8 leading – 0.8 lagging |
| Dimension (W x H x D) | 2815 x 2318 x 1588 mm |
| Weight | 3,700 kg |
| Degree of Protection (Electronics) | IP54 |

*Table 3-8: Main Specifications of the Central Inverter for the 150MW Project*

| Item | Value (SMA Sunny Highpower Peak3 – 100-20) |
|---|---|
| MPPT DC voltage range / rated input voltage | 590 to 1000 V / 590 V |
| Max DC Voltage | 1000 V |
| Maximum DC current | 180 A |
| Rated AC Output Power | 100 kVA |
| Maximum AC Current | 151 A |
| AC voltage range | 400 V (304 to 477 V) |
| European Efficiency | 98.6 % |
| CEC Efficiency | 98.6 % |
| AC Power frequency | 50/60 Hz |

| | |
|---|---|
| Total Harmonic Distortion (THD) | < 3% |
| Power factor at rated power / power factor adjustable | 1.0 / 0 leading to 0 lagging |
| Dimension (W x H x D) | 770 x 830 x 444 mm |
| Weight | 98 kg |
| Degree of Protection | IP65 |

*Table 3-9: Main Specifications of the String Inverter for the 200 kW Pilot Project*

#### 3.2.4.4 **DC Combiner Box**

The combiner box shall be placed adjacent with an inverter. Requirements for busbar, connection, cable suitable for Inverter cabinet - DC input module.

General Parameters of the proposed DC combiner box for the design for both the Central Inverter (Table 3-10) and String Inverter (Table 3-11) are as follows:

| Specification | Values |
|---|---|
| Input | |
| Nominal Voltage | 1500 V |
| Number of inputs | Minimum of 20 |
| Input Current | 12.28 A per string |
| Output | |
| Nominal current | 330 A |
| Disconnect switch | 400A/1500V |
| Number of outputs | 1 |
| Protection class | IP65 or above |

*Table 3-10: DC Combiner Box Configuration for 150MW Project*

| Specification | Values |
|---|---|
| Input | |
| Nominal Voltage | 1000 V |
| Number of inputs | Minimum of 13 |
| Input Current | 12.28 A per string |
| Output | |
| Nominal current | 220 A |
| Disconnect switch | 250A/1000V |
| Number of outputs | 1 |
| Protection class | IP65 or above |

*Table 3-11: DC Combiner Box Configuration for 200kW Pilot Project*

#### 3.2.4.5 Connecting Cables

Cable connects the solar panels to the junction/combiner box with standard cable and grade cable connectors, cable junction boxes for the panels must have a minimum protection rating of IP65 that allows the spray in the form of rays.

The modules in the serial array are connected to the cathode - anode and the cables connecting beginning and ending arrays must be standard connectors fitted with standard jacks. The protection level of the connection jack is not less than IP65.

Conductive materials of copper electrolytic cables of purity not less than 99%, cross-section of cables equipped with modules of up to 4 $mm^2$.

The cable from the junction/combiner box to the inverter cabinet uses XLPE insulated cables in accordance with IEC 60502-1.

Cable cross-section is designed according to the voltage loss criterion on each cable from the junction box to the inverter cabinet does not exceed 3% of the rated string voltage.

Low voltage cables connecting solar panels from junction/combiner box to the inverter cabinet must be metal sheathed to prevent electromagnetic interference.

Medium power collecting cables rated at 35kV from MVPS transformers to the MV switchgears will have a 3-core cable design suitable for water submersion. The MV cables shall have water and UV-resistant properties that ensure a high failure safety and long lifetime. It shall be certified as water resistant according to new standards and requirements for installation in floating solar.

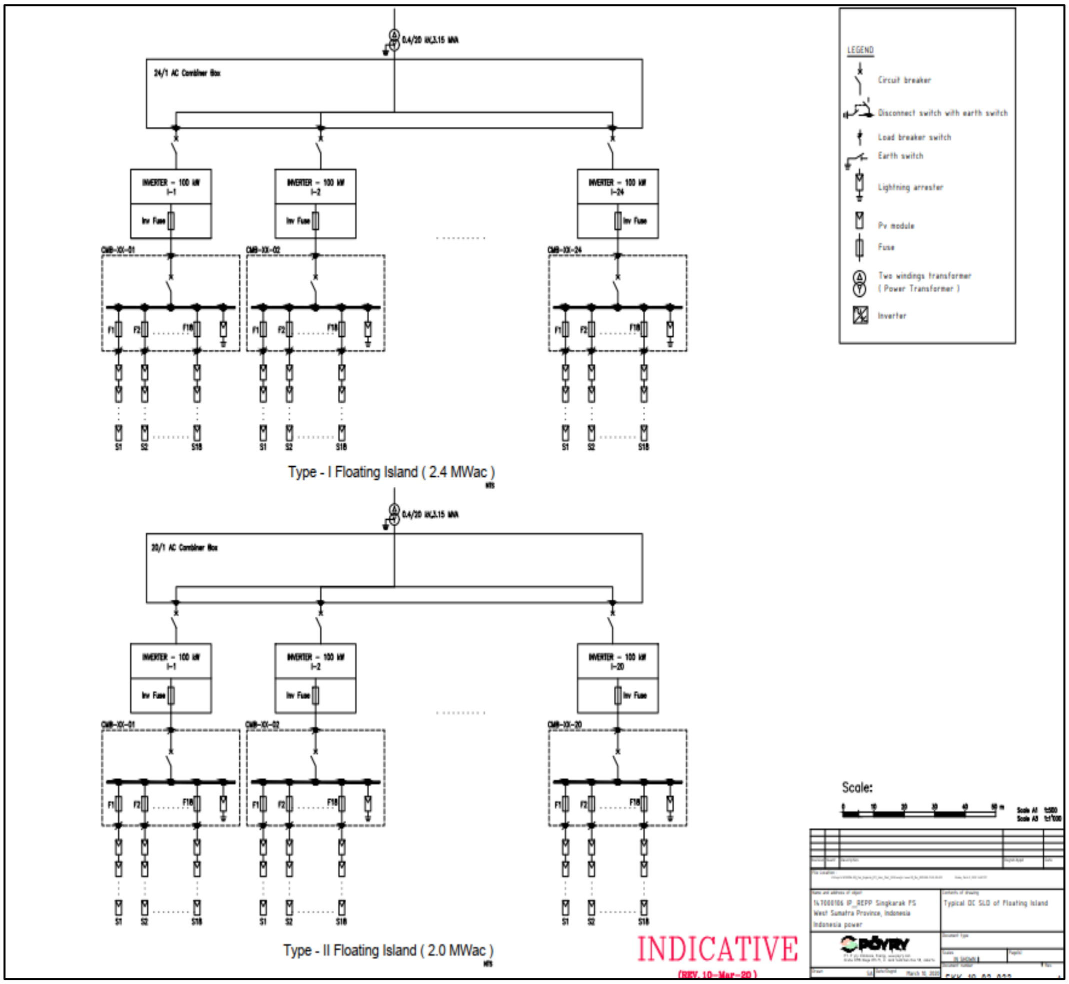



*Figure 3-13: Indicative Scheme of Connection*

### 3.2.4.6 **Medium Voltage Power Station (MVPS) Transformer 35 / 0.4 kV**

The transformer type selected for the MVPS design is a 3-phase step-up transformer type which is closed oil immersed or with oil reservoir; radial-wave radiator or with radiator wings; for Outdoor installation.

Steel Core

The steel core must be composed of thin-walled, cold-rolled, cold-rolled steel sheets, with high magnetic permeability, low magnetization currents and small losses.

Steel core is designed and installed to withstand without causing damage due to pressure placed in operating, transporting and packaging conditions.

The transformer core grounding must allow isolation from the frame for testing, the entire nut and bolt must be tightened.

Coils

The coils must be made of copper electrolytic. The coil terminals must have a silver-plated contact head~~.~~

Insulating Oil

The oil used for the transformer must be new (unused) oil, clean, manufactured in accordance with IEC 60296, antioxidant and no Polychlorinated Biphenyl (PCB). The insulating oil shall be readily available in Philippines.

Protecting Relay for Transformer

Transformers should be protected by a two-stage coil thermal protection relay.

Neutral Pole

The neutral terminal of the low voltage coil of each transformer shall be connected to the neutral cable of the low voltage switchgear and directly grounded.

Transformer Enclosure

Transformers are placed in the outdoor cabinet with ingress protection IP54.

Main Specification of Transformer

Transformer 35 / 0.4 kV- 4 MVA
The 4 MVA transformer is selected to ensure the following specifications:

*Table 3-12: General Specification of the MVPS transformer*

| | Category | Unit | Requirements |
|---|---|---|---|
| | Transformer | | |
| 1 | Applied standard | | IEC60076 |
| 2 | General parameter: | | |
| | - Type | | Immersing in oil |
| | - Phases | | 3 phases |

| | Category | Unit | Requirements |
|---|---|---|---|
| | - Operating frequency | Hz | 60 |
| | - Cooling method | | ONAN |
| 3 | Nominal power | MVA | 4 MVA |
| 4 | Nominal voltage | kV | 20, -10%. +5% |
| 5 | Voltage regulator: | | |
| | - Type | | No load |
| | - Installation position | | on primary side |
| | -Potentiometer range | | ± 2x2.5% |
| 6 | Coil materials | | copper |
| 7 | Wire connecting cubicle | | $Dy_n$-11 |
| 8 | Impulse withstand voltage(1.2/50μs) high voltage coil | $kV_{peak}$ | 125 |
| 9 | Voltage tolerance of industrial frequency: | | |
| | -High voltage coil | $kV_{rms}$ | 50 |
| | -Low voltage coil | $kV_{rms}$ | 3 |
| 10 | No load current | % | 1 |
| 11 | Short-circuit voltage | % | 4-6 |
| 12 | Allowable heat-increasing level<br>- Coil<br>- Top oil layer | °C | <br>60<br>55 |
| 13 | Length of high-pressure side insulation leakage current | mm/kV | 25 |
| 14 | The accessories: | | |
| | -The primary element for copper wire | | Yes |

| | Category | Unit | Requirements |
|---|---|---|---|
| | -Secondary element for copper wire | | Yes |
| | Transformer oil | | |
| 1 | Type of oil | | Transformer oil where used shall be in accordance with IEC 60296 or equivalent. The insulating oil shall be readily available in Philippines. |
| 2 | Applied standard | | IEC 60296 |
| 3 | Viscosity, at 40°C | $mm^2$ | ≤ 9.2 |
| 4 | Observation from the outside | | Clear, there is no water and impurities |
| 5 | Blinking point:<br>- Open cup<br>- Closed cup | <br>°C<br>°C | <br>≥ 148<br>≥ 144 |
| 6 | Water content | $P_{pm}$ | ≤ 30 |
| 7 | Puncture Voltage:<br>- Before filter & dryer<br>- After filter & dryer | <br>kV<br>kV | <br>≥ 35<br>≥ 70 |
| 8 | Neutral value (acidity) | mgKOH/g | ≤ 0.01 |
| 9 | Specific weight | $Kg/dm^3$ | ≤ 0.9 |
| 10 | Content of antioxidant additives | % W | ≤ 0.4 |
| 11 | Corrosion of Sulphur | | No |
| 12 | PCB | | No (*) |

#### 3.2.4.7 **Grounding and Lightning Protection**

A proper grounding and lightning protection system which suitable in covering the whole plant area shall be provided. A stable ground grid provides for grounding of equipment and structures and maintaining the step and touch potentials within safe limits.

The plant grounding system shall be designed in accordance with IEEE std 80 "IEEE Guide for Safety in AC Substation Grounding", IEEE std 665 " Guide for Generating Station Grounding".

## 3.3 Electrical System

### 3.3.1 Proposed Power Evacuation System for the 150MW PV Plant


*Figure 3-14: Location of Proposed PV Plant*

The location of the proposed PV plant is shown in Figure 3-14 in Northern Luzon transmission grid map. As can be seen from the figure, there is a major NGCP substation (NGCP Nagsaag) nearby, about 10kms distance. In addition to this, the proposed PV plant is within the facility of the San Roque Power Corp., where a 230kV plant switchyard is installed.

It is typically designed that the 150MW PV plant AC power output from central inverters be collected to a control/electrical room where all the medium switchgears are installed for ease of maintenance. The configuration of the collection system is a ring-bus scheme for higher reliability compared to a simple radial network. The 34.5kV switchgears are then connected to two 80MVA 34.5/230kV step-up transformers which will be tied-up to the grid. The configuration is outlined in Annex 3-1 150MW PV Plant Single Line Diagram (Option 1).

Due to the distance of some inverters from the proposed control/electrical room, an option 2 is presented in Annex 3-2 to have a sectionalized switchgear room in a separate location (in a barge or utilize an island in the reservoir) in order to increase the efficiency. Having XLPE medium voltage cables run long distances would be costly and the losses would be significant. Inverters which are near the electrical room will still be collected in sheathed cables through floaters, while the outlying cables will be collected to the separate switchgear room and connected to the step-up transformer via overhead lines. Moreover, it can be seen in the plant layout that the distance of the PV plant to the proposed substation particularly on the north side is very far. This will require long collector medium voltage cables that could be kilometers in length. The ampacity (current carrying capacity) of insulated cables is much less than that of bare cables with the same size, especially if they are bundled together. This means that it is needed to increase the size of insulated cables in order to carry the output power, and increasing the size corresponds to higher copper or aluminum losses. Using bare cables through overhead line "will increase the efficiency" through lower copper or aluminum losses compared to insulated cables.

Considering the existing substation connection facilities in this area, three (3) different power evacuation schemes are investigated in this study. To evacuate the maximum power from the PV plant site, 150MWe, options to evacuate at high voltage of 230kV is proposed. The power evacuation schemes (PES) are described in the following sub-sections.

#### 3.3.1.1 PES-1: Connection to SRPC 230kV Switchyard

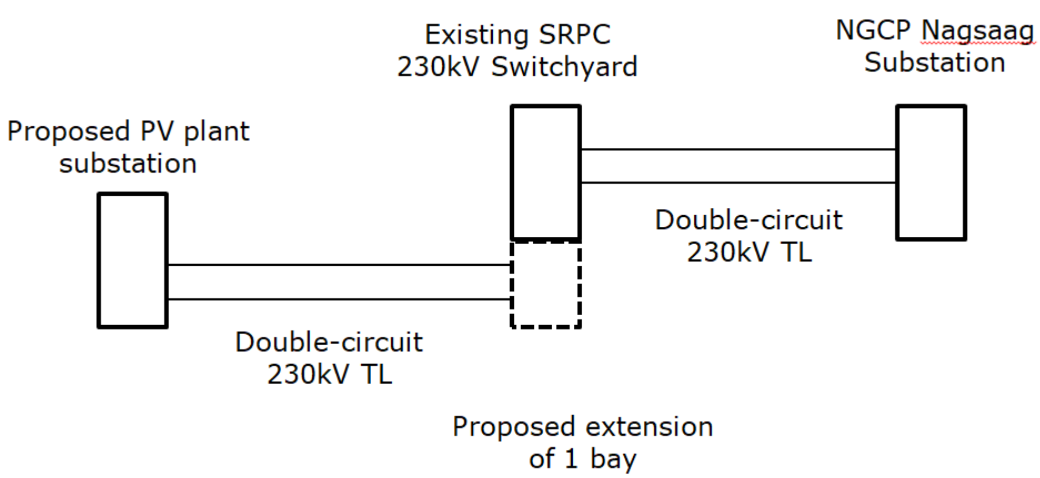



*Figure 3-15: PES-1*

A schematic diagram of PES-1 is shown in Figure 3-15. This evacuation system is an extension of 1-bay of existing SRPC 230kV switchyard. The purpose of the extension is to maximize the capacity of the existing switchyard, which is a double-bus topology where each bus is rated at about 600MW. Considering the maximum capacity of hydro generators connected to this switchyard (150MVA x 3, 0.85pf), the maximum output capacity in MW will be 150MVA x 3 x 0.85pf = 382.6MW. When the proposed PV plant capacity is added (382.5 + 150 = 532.5MW), the 230kV switchyard is still sufficient to accommodate the additional power and still maintains the N-1 contingency.

The proposed extension for PES-1 scheme is superimposed in the Figure 3-16 below (with cloud mark) to have an estimate of the area required. Note that there is an existing building which has to be demolished in order to put up the bay.

AFRY believes that this is the most cost-effective solution for the power evacuation of the proposed FPV plant. If there are conflicts to this, two alternatives are presented below.

*Figure 3-16: Proposed Bay Extension for PES-1*

#### 3.3.1.2 **PES-2: Connection to 230kV Switching Station**

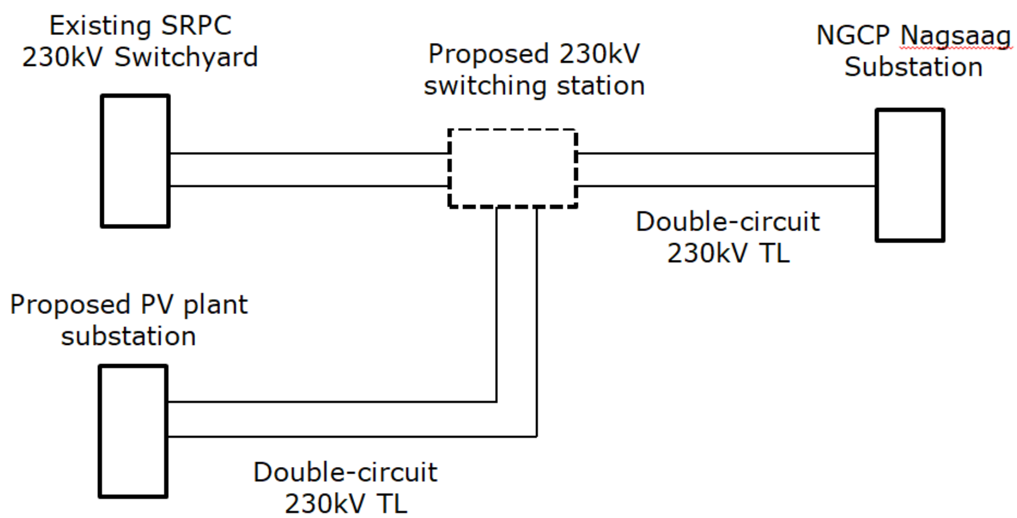



*Figure 3-17: PES-2*

A schematic diagram of PES-2 is shown in Figure 3-17. In this case a 230kV switching station will serve as a converging point to evacuate the power separately from the existing SRPC plant and the proposed PV plant. The switching station will be installed in a flat area within the facility of SRPC. A typical NGCP breaker-and- a-half scheme 230kV air-insulated switching station with two incoming and one outgoing lines will need approximately 5,000sq.m. land area.

#### 3.3.1.3 **PES-3: Direct Connection to NGCP Nagsaag S/S**

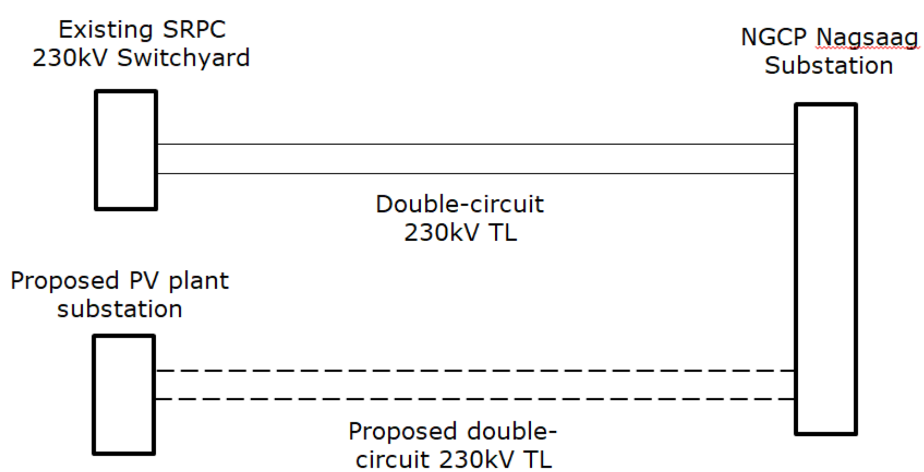



*Figure 3-18: PES-3*

There is an existing 230kV double circuit transmission line from the outgoing gantry of the SRPC plant switchyard to NGCP Nagsaag substation through two outgoing overhead line circuits.

The Nagsaag substation is approximately 9.3 km away from the hydro plant switchyard as shown in Figure 3-19.

The proposed direct connection will follow the same route as the existing line. However, the route will pass through mountainous areas and AFRY believes that not only that cost but also constructability will be a major challenge.

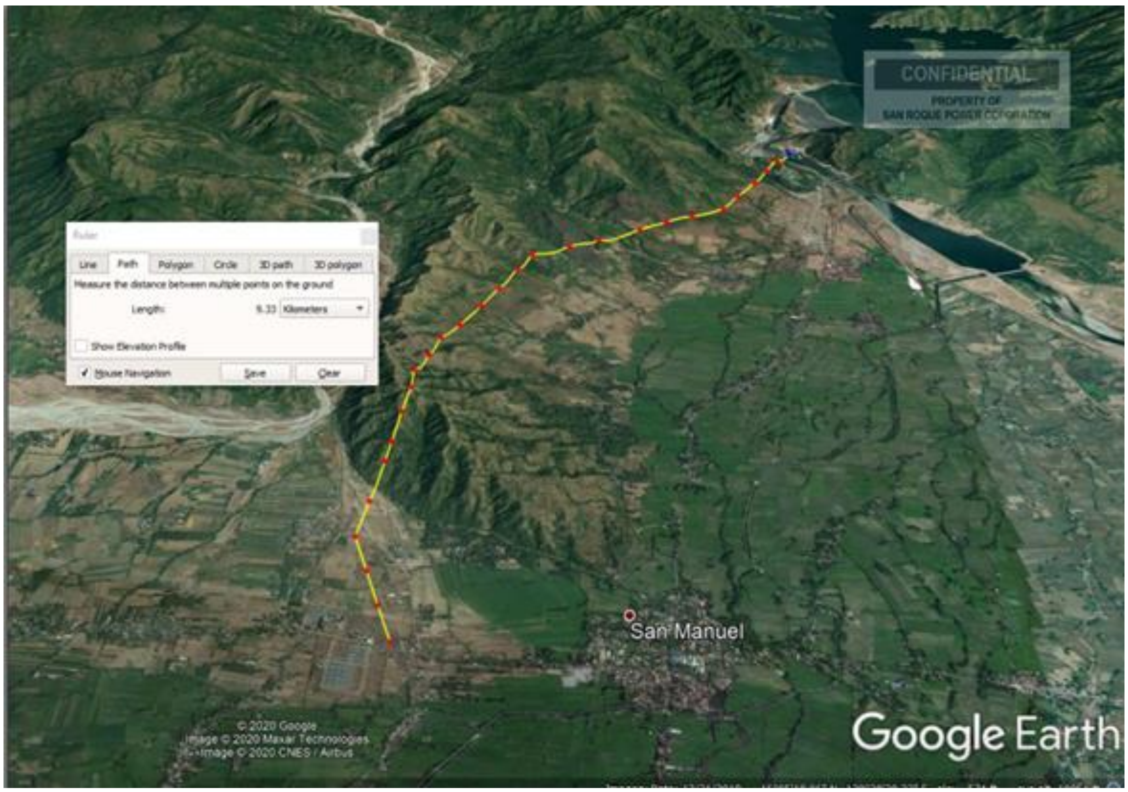



*Figure 3-19: Proposed direct connection*

The new transmission line shall be provided complete including, but not limited, with following main parts:

- Phase conductors, earth wires and conductor fittings
- OPGWs
- Insulators and fittings
- Supports / Towers
- Support accessories
- Foundations
- Earthing

### 3.3.2 Proposed Power Evacuation System for the 200kW Pilot Plant

The proposed PV pilot plant DC power output cables will be collected to two (2) sets of 100kW, 400V inverters which will convert DC to AC power. These inverters will then be cabled separately to a 220/110/110kW, 13.8kV/400V three-winding step-up transformer and connected to the 13.8kV overhead line of the hydro intake gates for the power evacuation. Annex 3-3 shows the single line diagram (SLD) of the proposed pilot plant.

## 3.4 Site and Conceptual layout

### 3.4.1 Block Design

The basic energy generating element of the 150 MWac San Roque floating solar PV plant is the unit 260 $kW_{DC}$ Floating platform. This block has a standard size of around 30 m x 60 m and consists of interconnected UV-resistant floats. These floats are made of high-density polyethylene (HDPE) and possess specified buoyancy capacity. The "main floats" are carrying solar panels and the "secondary floats" are used to accommodate walkways and installation of other key electrical equipment like inverter, combiner boxes and cables etc. The "mooring floats" are used for connection of the mooring lines and have higher buoyancy capacity to resist the downwards pooling forces of the mooring lines. The floats are interconnected by pins and provide certain vertical movement flexibility of the block platform floating on the water.

On each 260 $kW_{DC}$ block there are 10 arrays (rows) equipped with 2 strings (per array). Each string has 26 standard solar PV modules. In total, the 260 $kW_{DC}$ block accommodates 520 solar panels with single panel rating of 500 Wp. Between each array there is a walkway provided to allow access for solar panel cleaning and execution of maintenance and repair works. Each of the 260 $kW_{DC}$ blocks possesses its own 20 channel combiner box and then will be connected to a MVPS floating platform adjacent to the floating island. Figure 3-20 depicts schematic layout of a typical 260 $kW_{DC}$ block.

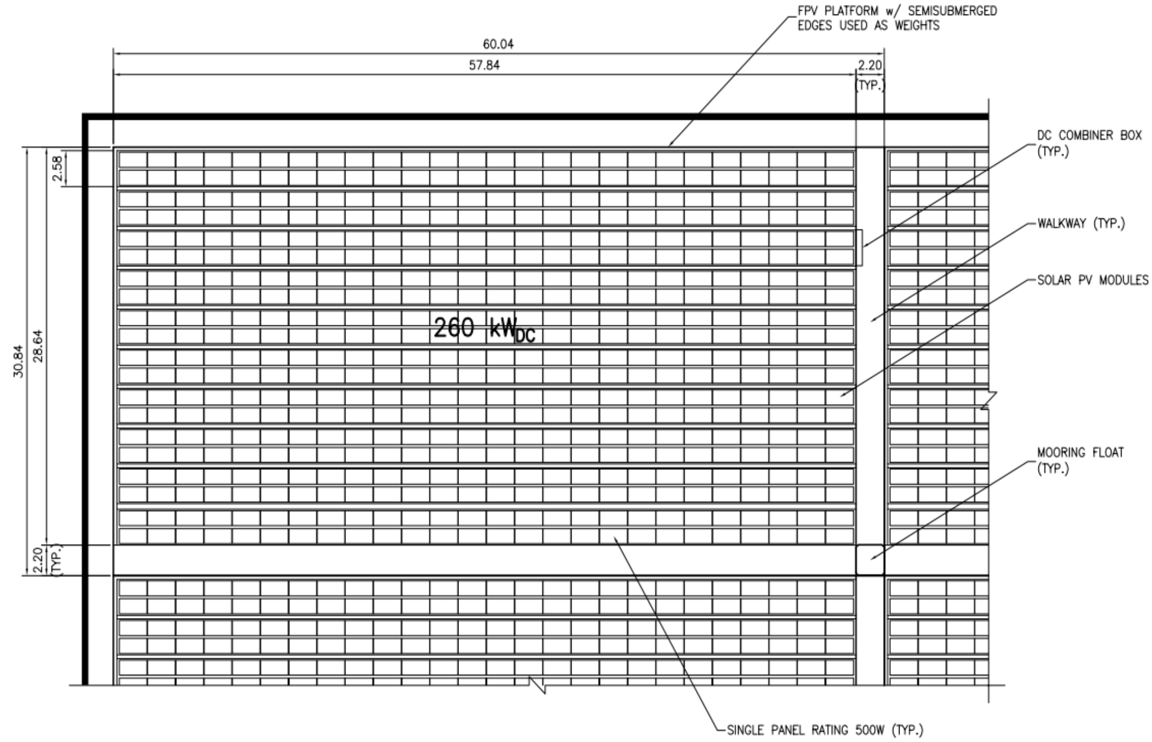



*Figure 3-20: Schematic layout of a typical floating PV solar 260 kW$_{DC}$ block*

The 260 kW$_{DC}$ Floating block has been designed in such a way that the replication of these blocks allows to form larger Floating solar islands geometrically fitting into the available project water area and having standard capacity of 4.68 MWdc as Island Type I and 2.34 MWdc as Island Type II. The below Table 3-13 provides equipment quantities installed within one 260 kW$_{DC}$ solar panel block.

| Specifications | Value |
|---|---|
| Total Capacity | 260 kW$_{DC}$ |
| No. of rows | 10 |
| String/row | 2 |
| Modules in one string | 26 |
| Total no. of strings | 20 |
| Total no. of modules | 520 |
| Capacity of Module | 500 Wp |

*Table 3-13: Quantities per one 260 kWdc Floating Solar unit*

For the 200kW Pilot project, the Consultant considered to use a single floating island with center pathway as main access to the equipment. The Solar PV Modules, DC combiner boxes and the string inverters are all located on the floating island and will be connected to an MV Step up Transformer located at the shore. The pilot project has a size of around 38 m x 43 m and consists of the same float materials as the main 150MW project. The below Table 3-14 provides equipment quantities installed for the pilot project.

| Specifications | Value |
|---|---|
| Total Capacity DC | 234 $kW_{DC}$ |
| Total Capacity AC | 200 $kW_{AC}$ |
| No. of rows | 13 |
| String/row | 2 |
| Modules in one string | 18 |
| Total no. of strings | 26 |
| Total no. of modules | 468 |
| Capacity of Module | 500 Wp |
| Number of String Inverters (100$kW_{AC}$ /each) | 2 |
| Number of DC Combiner Boxes | 2 |
| DC/AC Ratio | 1.17 |

*Table 3-14: Quantities for the 200kW Pilot Project*

### 3.4.2 Floating Island and PV System Configuration

The entire 150 MW floating solar PV plant consists of Solar PV Floating islands and barges for the MV Power Stations. Two different island types, Type I and Type II, have been developed, as shown in Figure 3-21 and Figure 3-22 respectively. Each of the typical island is composed of 30 (Type I Floating Island) and 16 (Type II Floating Island) typical 260 $kW_{DC}$ solar panel blocks. The MV Power Stations are positioned adjacent to the Solar Floating island connected to it. A single central inverter can be connected to either one Type I Floating Island or two Type II Floating islands.

The solar panel island Type I has a standard size of around 183 m x 188 m (6 x 3 260 kWdc blocks). The solar panel island Type II has a standard size of around 95 m x 183 m (3 x 3 260 kWdc blocks). The total weight of one island, without considering the temporary acting life load (man load), is approximately 650 ton (island Type I) and 325 ton (island Type II). This single floating mass needs to be kept in place by the mooring system.

To ensure adequate boat passage and access for maintenance, and to avoid collision of the single floating islands during strong winds, the minimum distance of 30 m has been selected between the islands.

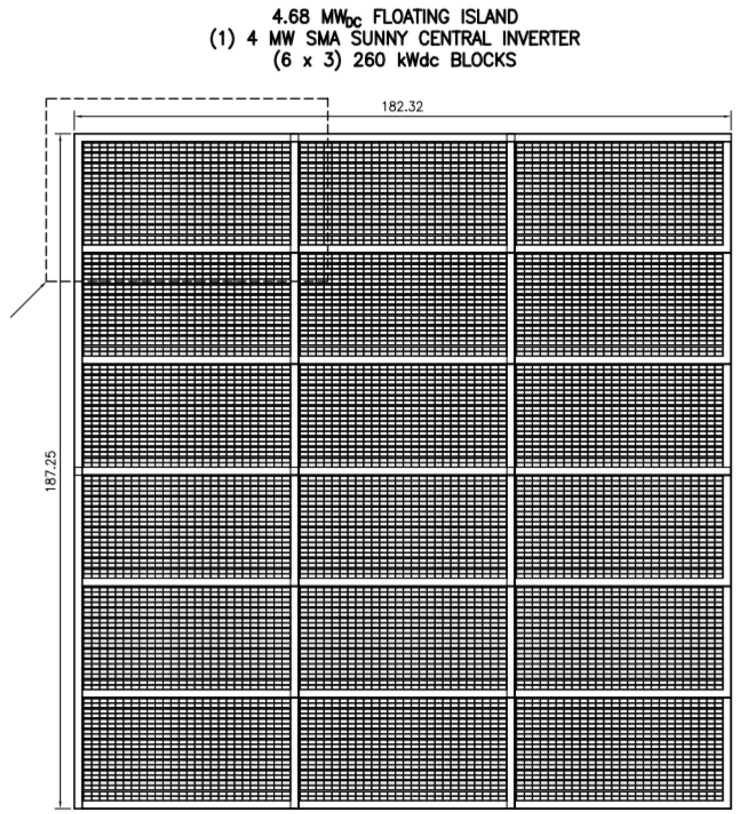



*Figure 3-21: Schematic layout of a typical PV floating solar 4.68 MWdc Floating Island Type I*

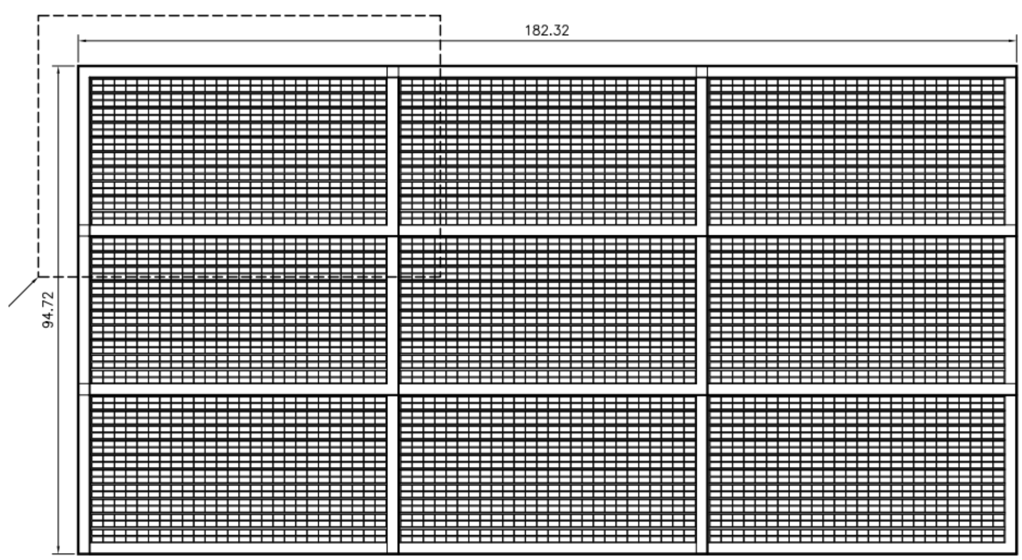



*Figure 3-22: Schematic layout of a typical PV floating solar 2.34 MWdc Floating island Type II*

The below provides equipment quantities installed within one 4.68MWdc (Type I) and 2.34 MWdc (Type II) floating island.

| Specifications | Type-1 | Type-2 |
|---|---|---|
| Capacity kWdc | 4680 | 2340 |
| No. of 260kWdc blocks | 18 | 9 |
| No. of Strings | 360 | 180 |
| No. of Modules (500Wp) | 9360 | 4680 |
| Configuration | (1) Type I to (1) Central Inverter (MV Power Station) | (2) Type II to (1) Central Inverter (MV Power Station) |
| DC/AC Ratio | 1.17 | |

*Table 3-15: Quantities for Floating Solar Island 4.68MWdc (left) and 2.34 MWdc (right)*

### 3.4.3 Connection Between Floating Islands

The floating islands are distributed from the dam axis going north till the middle of the reservoir. The floating power cables are collected together suitably and connected to an adjacent Medium Voltage Power Stations (MVPS) of 4 MVA capacity (see Figure 3-23). The floating islands are not joined together by any means over the reservoir and can move independently from each other according to their particular mooring system, water depth and acting loads (e.g. wind or wave from particular direction). The floating cables will have to have the required moving flexibility.

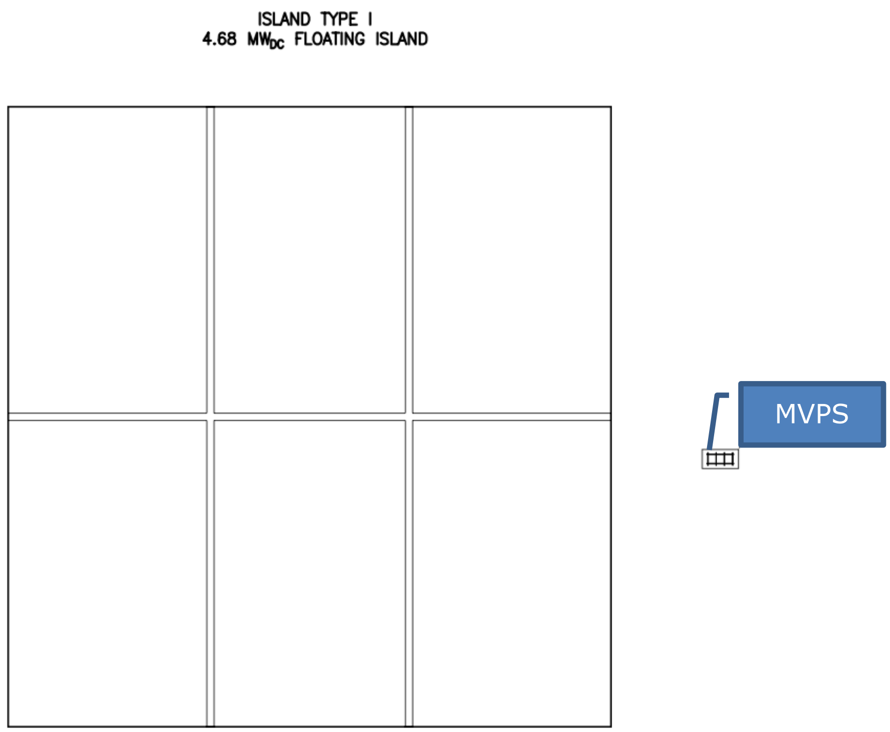



*Figure 3-23: MVPS Floating Platform positioned adjacent to a Floating Island*

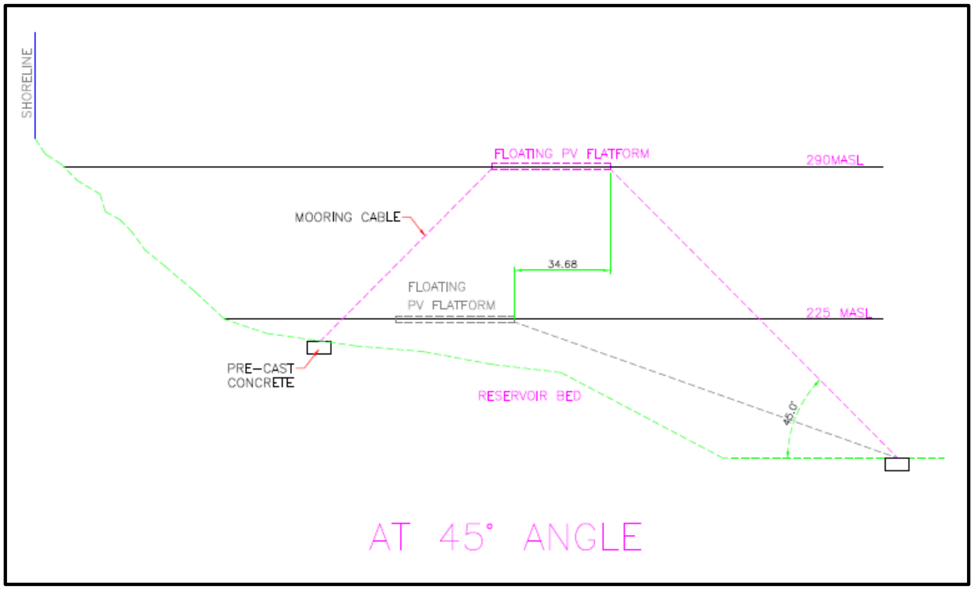
### 3.4.4 Connection to Shores

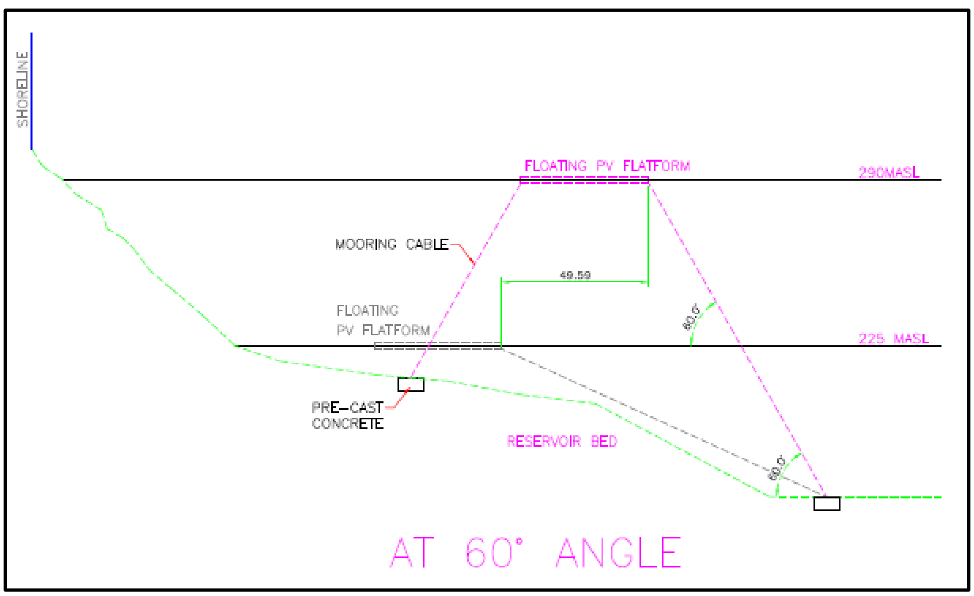
The section 3.2.2 describes two general concepts of mooring of the FPV platforms, one is anchoring to the bank of the shore and the other is anchoring to the bottom of the water body. At the present feasibility study stage, a bottom anchoring concept is taken into consideration for the floating platforms. No connection to the shore is considered at presence, except for the floating power cables arranged between the floating islands and the transformer clusters installed on shore.

### 3.4.5 Anchoring and Mooring

The Consultant performed schematic arrangement types of mooring to develop the conceptual arrangement of the mooring system. The minimum level difference of 65 meters is from maximum level of reservoir is 290 masl to minimum operating level of 225 masl the displacement occur when the level of water drops while the PV islands drift by the slack in the anchoring cable and the wind. Please see next page for more detailed explanation.

Typical anchoring with a dead weight (pre-cast concrete) on the reservoir bed where one end of mooring cable is attached and the other end is at the FPV floating solar island/platform. It is the angle of mooring cable inclination which dictates how much space/buffer from the shoreline needed and space from other nearby FPV, for the 60 degree angle a maximum 50 meters displacement will occur once the water level drops by 65 meters from 290 masl, other displacement are shown on Figure 3-24.



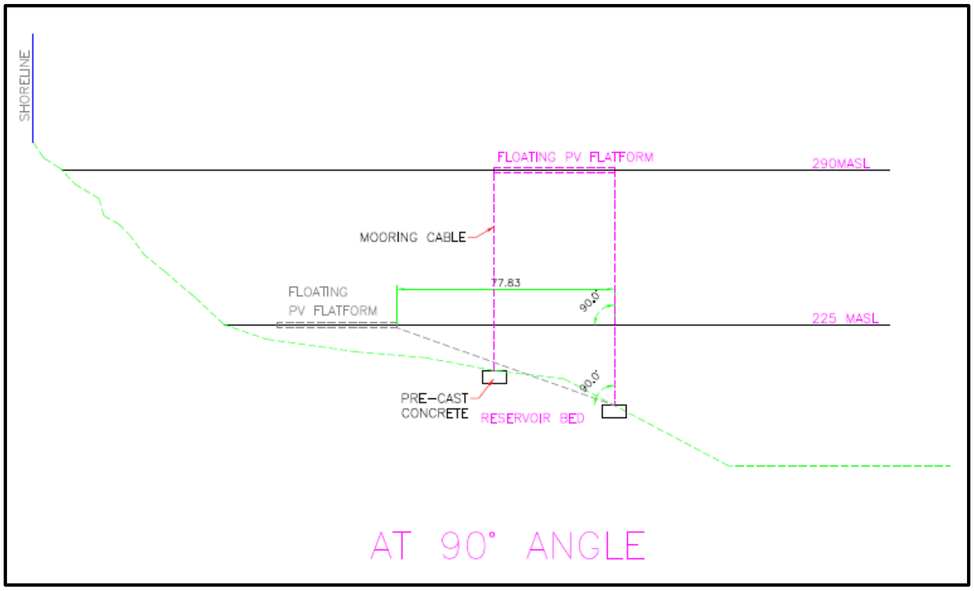


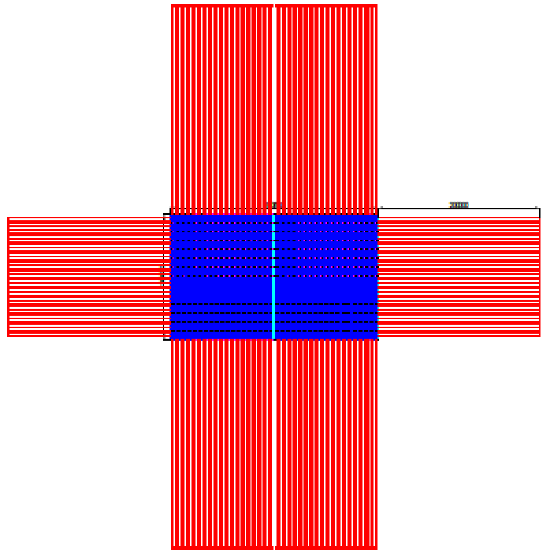

*Figure 3-24: Schematic Mooring Arrangement types*

The Consultant performed preliminary design to develop the conceptual arrangement of the mooring system. The following parameters have been used:

| | |
|---|---|
| Max. design water level | +290.00 m asl |
| Min. design water level | +225.00 m asl |
| Max. water level fluctuation | 65.00 m |
| Max. water depth below FPV island | 165.00 m |
| Min. water depth below FPV island | 100.00 m |
| Floating PV island weight (Type I) | 650 ton |
| Floating PV island weight (Type II) | 325 ton |
| Max. wind velocity | 75 m/s |
| Max. wave height | 0.50 m |

*Table 3-16: Design Parameters*

The preliminary design estimate, results in the material properties and quantities listed in the Figure 3-25.



112 columns, 84 rows, 9408 PV Modules, 500W
DC:4.704MW
Area:260.64*119.97

| Date input | | Date output | |
|---|---|---|---|
| Tilt Angle | 5° | Max drift | 28 m |
| Wind speed | 75 m/s | Anchor radius | 200 m |
| Max. water depth | 125 m | Length of one Rope | 235.8 m |
| Water level variation | 65 m | Anchor truss of N-S | 168 PCS |
| Max current speed | 0.7 m/s | Anchor truss of W-E | 88 PCS |
| Max wave height | 0.4 m | | |

Note:The Anchoring drawing is used for reference only.

It can not be used as a basis for construction.

*Figure 3-25: Estimate Properties and Quantities for Mooring for Type I*

The number and the length of the mooring lines, the property of the elastic mooring element and the weight of the gravity anchor blocks will be finally determined during the EPC bidding process or after award of the EPC contract and execution of the detail design of the selected floating and mooring system.

### 3.4.6 Layout Explanation

The project area was already identified, which are located in the San Roque Reservoir and are foreseen to be used for the installation of the floating solar PV platforms.

Due to the varying depth or the reservoir up to 65 meters difference, the floating solar PV platforms can be only installed within the area where the minimum water level of 225m (with additional 50m surface buffer for drift allowance) is available as well as to keep the platforms' mooring system technically feasible. The enormous varying water level and the limitation of the water body width require special arrangement of the mooring system. Figure 3-26 shows the selected project layout arrangement. <u>This should be noted that all kinds of drawings prepared for the purpose of conducting this feasibility study should not be used for construction purposes as these are purely indicative in nature.</u>

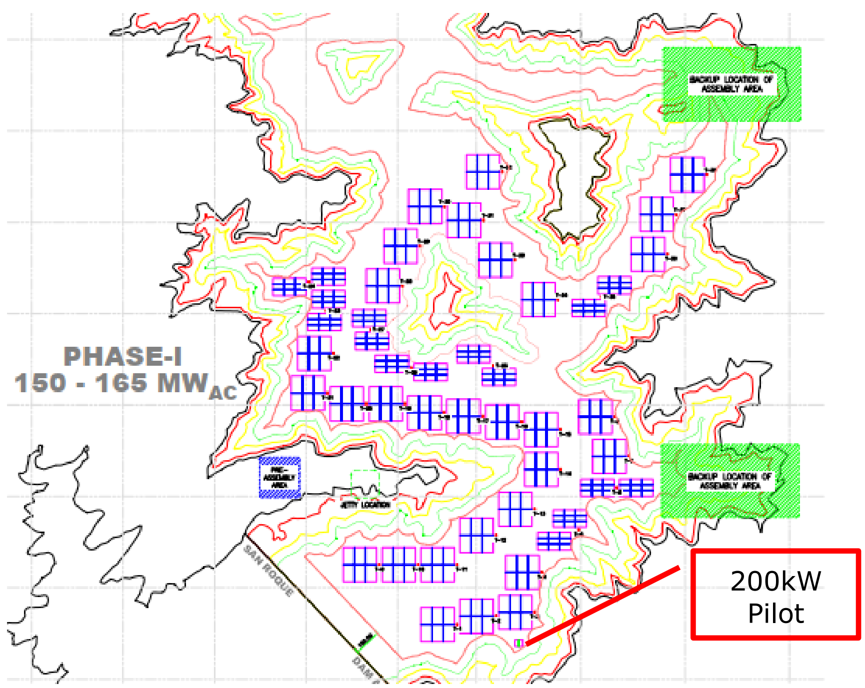



*Figure 3-26: Proposed Project layout arrangement*

### 3.4.7 Deployment and Construction

The main construction / installation activities at the FPV project consist of assembly and floating into the water of the smaller floating units (260 $kW_{DC}$ blocks), forming of bigger floating platforms (the islands) and floating them into the final position on the lake. For these activities sufficient in size and well accessible temporary site installation and storage area is required with a direct access to the reservoir. Based on the planned project implementation and construction time, several such site installation areas at different locations might be required. However during the site visit to the SRPC project it was found that these site installation area's and storage area are not available and will be very difficult to create. This will be beside the anchoring are one of the major challenges for the project and will influence the construction period negatively.

The normal size for an assembly area for a Floating PV Solar project (FPV) is around 1.5 - 2.5 hectare, with an appropriate slope towards the water. One of such suitable and accessible areas has been identified at the flat shore located at the upstream of the spillway gates about 4.7Ha area.  The Owner shall continue to explore the solutions with the contractors and other solution provider in the next stage.

The timing of assembly of the floating blocks could also be done during the months when the water level is at the lowest so there will be more space available on the assembly area. This can be further planned during the advanced stage of project development.

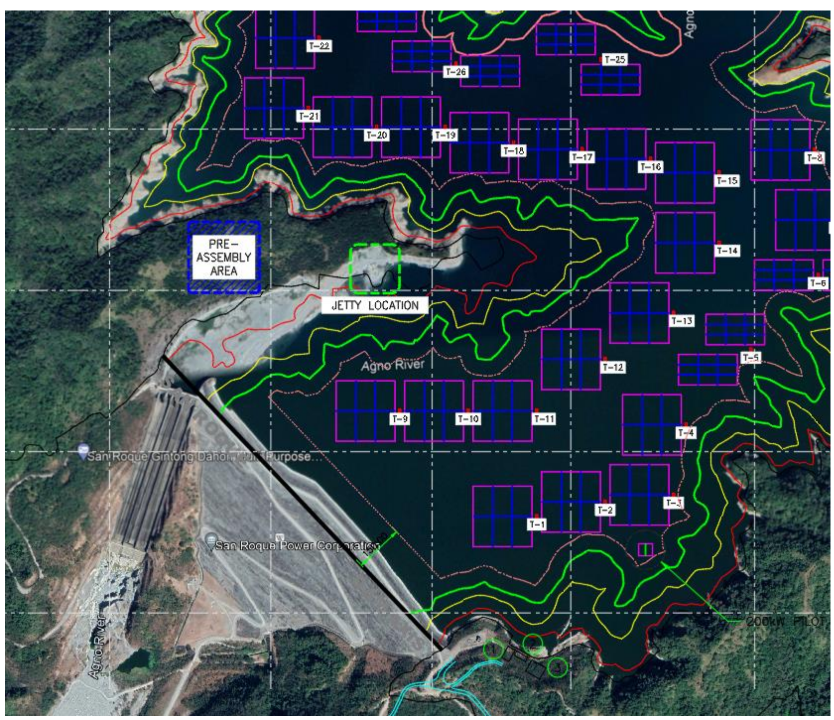



*Figure 3-27: Suitable location for site installation and floating platforms assembly*

All FPV Project components need to be transported by truck to the site installation area. On the flat shore, in best case, stabilized and covered by a concrete slab, the single floats will be assembled, equipped with support frames (if required based on the float type) and solar panels, cables, combiner boxes, inverters, cable ducts and mooring lines connection points. The assembly will start up to the 260 $kW_{DC}$ blocks, and these blocks will be interconnected to the large floating solar islands. The completed island will be floated to the final position at the reservoir.

The general sequence for the main deployment and construction / installation activities at the FPV project can be summarized as follow:

- Deployment of staff and construction equipment to the project site,
- Set-up of the temporary site installation area including float and solar panel storage areas, lifting and moving equipment, workshops, staff containers, offices, canteen and accommodation,
- Assembly and floating into the water of the smaller floating units (260 kW blocks), forming of bigger floating platforms (the islands),
- Construction of mooring gravity anchor blocks and lowering them onto the reservoir ground,
- Floating of the solar panel islands to the final position on the lake and mooring them to the gravity anchors on the ground,
- Installation of main power cables and connection to the transformers

## 3.5 Energy Yield Assessment

### 3.5.1 Solar Resource at San Roque Reservoir Area

In order to quantify the level of solar radiation at the project site, the Consultant used commercial solar database SolarGIS to fetch global horizontal irradiation (GHI), diffuse horizontal irradiation (DHI) and temperatures. This data source provides monthly irradiation data in a typical meteorological year format (TMY) at any selected geographical coordinates.

The data quality of this provider stands out among other satellite-based providers for its high accuracy in solar irradiance. The Consultant further notes that irradiation data from SolarGIS iMaps shows good agreement with ground measurement data in other parts of Asia. Far shading losses from terrain is accounted for in the solar radiation data. Horizon data is taken from digital elevation models with spatial resolution of 250 m and the availability of historical data for this Project’s area is starting from 2006.

The following table and figure present the monthly average Global Horizontal Irradiation and temperature data used for the purpose of the energy yield modelling.

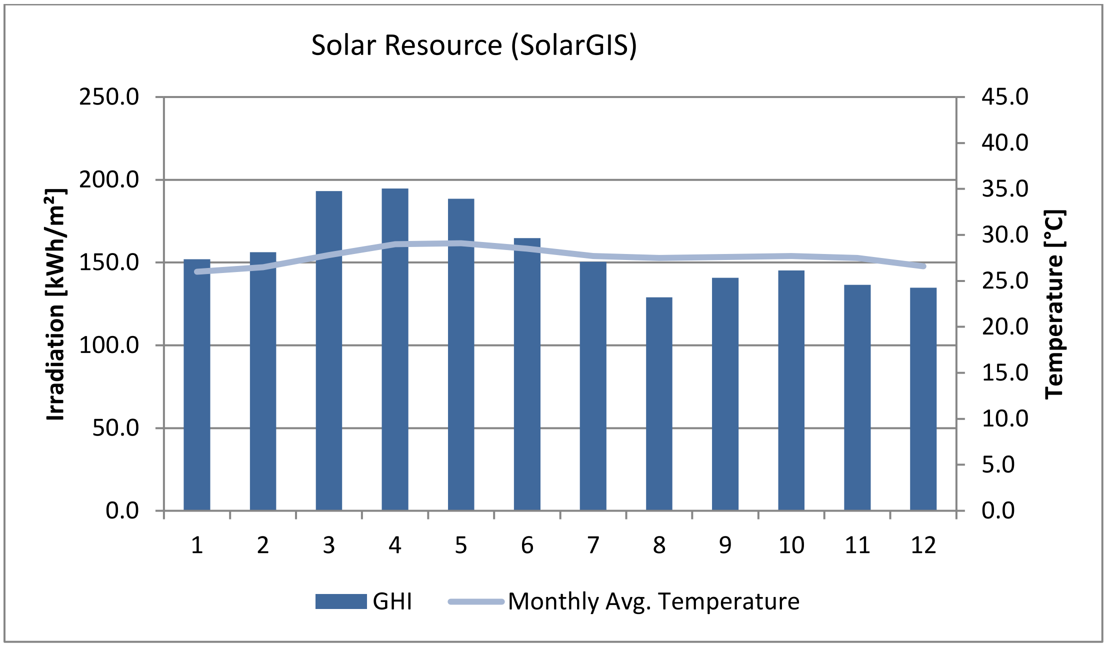



*Figure 3-28: Irradiation Data (GHI) and Monthly Average Temperature Data at San Roque Dam (SolarGIS)*

| Month | GHI | DHI | GII | Ambient Temperature |
|---|---|---|---|---|
| | ($kWh/m^2$) | ($kWh/m^2$) | ($kWh/m^2$) | (°C) |
| January | 151.9 | 51.1 | 161.4 | 26.0 |
| February | 156.3 | 50.0 | 163.3 | 26.5 |
| March | 193.1 | 66.3 | 197.5 | 27.8 |
| April | 194.8 | 68.6 | 195.5 | 29.0 |
| May | 188.5 | 70.0 | 185.9 | 29.1 |
| June | 164.8 | 68.5 | 161.6 | 28.5 |
| July | 150.4 | 72.5 | 147.9 | 27.7 |
| August | 129.0 | 70.5 | 128.6 | 27.5 |
| September | 140.7 | 69.4 | 142.4 | 27.6 |
| October | 145.3 | 61.8 | 150.2 | 27.7 |
| November | 136.5 | 51.8 | 144.1 | 27.5 |
| December | 134.8 | 52.2 | 143.6 | 26.6 |
| Annual | 1,886.1 | 752.7 | 1,922.1 | 27.6 |

*Table 3-17: Monthly meteorological input data used by the Consultant*

### 3.5.2 Inputs for Energy Yield Analysis

The Consultant has conducted an energy yield assessment according to the plant layout and configuration discussed in previous sections. The energy yield result is simulated and calculated using PVsyst software. It is noted that assumptions based on our knowledge and experience have been applied where necessary.

The inputs parameters in the PVSyst software include:

- Site location and altitude;
- Plant layout and detailed configurations;
- Meteorological data;
- Modules and inverters models;
- Shading scene; and
- Equipment and system losses.

More details are discussed in the following sections.

#### 3.5.2.1 Assumptions Applied in the Energy Models

A number of assumptions based on the Consultant experience from previous projects were applied in conducting the energy production assessment to where supporting information is not provided as summarised in the table below.

It should be noted that these assumptions can be further refined with supporting documents (e.g. test reports) in order to obtain more accurate results. Further detailed description for each assumption used is provided in the table below of the later section.

| Parameters | Assumptions |
|---|---|
| Spectral loss | 0.0% |
| IAM loss | Based on the module definition in PVsyst |
| Soiling loss | 2.0% |
| Low Irradiance loss | Default profile embedded in .PAN file |
| Power tolerance (gain) | +0.75% |
| Light-induced degradation (LID) | 2.0% |
| Mismatch loss | 1.1% |
| Auxiliary loss | 0.11% |
| Total unavailability | 1.0% |
| Annual deg. PV module | 0.55% |
| Constant loss factor for thermal loss (Uc) | 35 W/m$^2$k |

*Table 3-18: : Assumptions Applied in the Energy Production Assessment of the Project*

### 3.5.2.2 **Shading Simulation**

**Far-Shading**

Far-shadings are described by a horizon line in which losses arise from objects sufficiently far from the site location. Such shading objects (e.g. nearby mountains) cause the sun not to be visible to some certain altitudes over the horizon line.

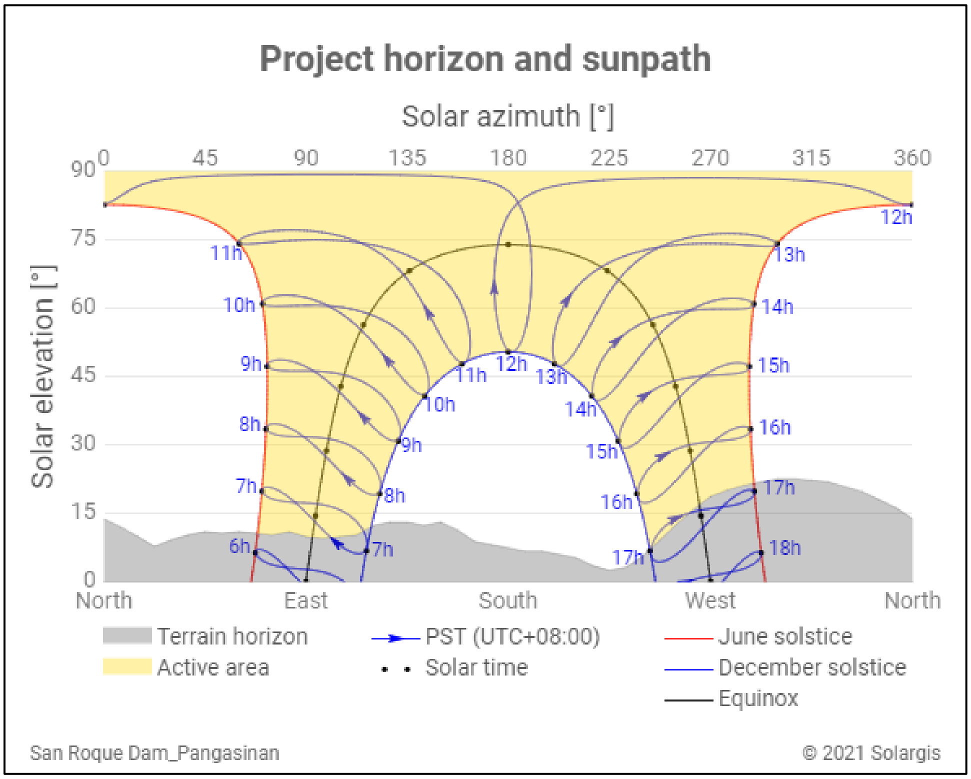



*Figure 3-29: Project Horizon and sun path*

The Consultant however notes that the effect from far-shading is already accounted for in the irradiation data (as defined by SolarGIS) and therefore the Consultant doesn't specifically mention this loss in the PVsyst simulation i.e. considering zero far-shading loss. In other words, the far-shading loss is not segregatedly appearing in the system loss breakdown (see section 3.5.2.3).

**Near-Shading**

Near-shading losses are caused by row of PV modules themselves (i.e. mutual shading) and nearby shading objects (e.g. trees, buildings, transmission lines, etc.). For this project, the near-shading losses are simulated by PVsyst taking into account the shading effect caused by mutual shading. Figure 3-30 illustrates near-shading simulation created by the Consultant.

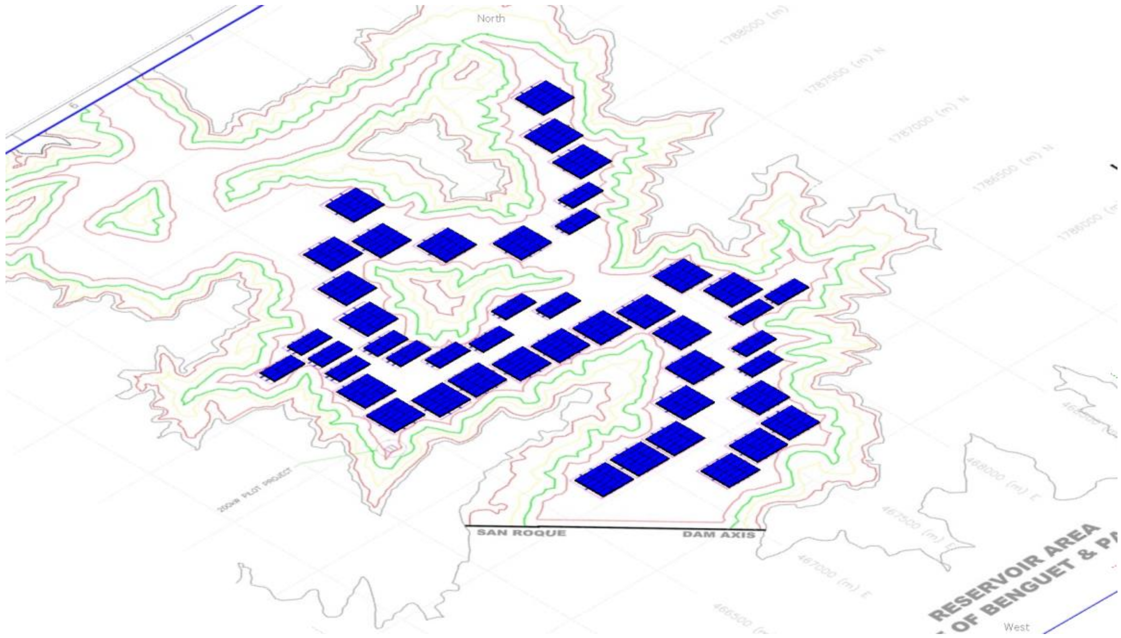



*Figure 3-30: Near Shading Simulation in PVsyst*

### 3.5.2.3 **Evaluation of Performance Ratio**

The Consultant evaluated the plant performance ratio (PR) from PVsyst software based on the aforementioned information and assumptions. The PR results are given in the table below with breakdown system losses and descriptions of the Consultant's approach.

This is to be noted that the System losses calculated at this stage is solely indicative and for the purpose of conducting a feasibility study and might vary with actual system design and equipment selected during detail design and engineering.

*Table 3-19: Summary of system losses*

| Losses | Value | Remarks |
|---|---|---|
| Spectral | 0.0% | Spectral is assumed to be 0.0% as the spectral shift effect is considered minimal to such type of module. |
| Far-Shading | 0.0% | Far-shading loss is omitted from PVsyst simulation given that its effect has already been incorporated in the irradiation data as claimed by SolarGIS. |
| Near-Shading | 0.5% | Near-shading loss is calculated from PVSyst based on 3-D simulation with rows |

| | | |
|---|---|---|
| | | of PV arrays, as well as other potential shading objects. |
| IAM Loss | 2.77% | IAM loss assumed as per the definition of PV in the PVsyst. |
| Soiling Loss | 2.0% | Assumption for soiling given the PV module cleaning is regularly conducted. |
| Low Irradiance Loss | 0.60% | Low irradiance loss is calculated based on default setting in .PAN file of a general mono C-Si PV module obtained from the PVsyst library. |
| Temperature Loss | 6.64% | Temperature loss is calculated from PVsyst based on the ambient temperature input data from SolarGIS. |
| Electrical Loss at string level | 0.39% | Electrical loss is calculated by the shading simulation with "according to module string" option selected in PVsyst. |
| Power Tolerance | 0.75% | The Consultant used power tolerance derived from the value specified in the datasheet and calculated as per PVsyst recommendation. |
| Light-induced Degradation (LID) | 2.0% | The Consultant assumed LID based on benchmark for the crystalline module on floating systems. |
| Mismatch Loss | 1.10% | Mismatch loss is assumed based on a typical value for Monocrystalline PV module. |
| DC Cable Loss | 1.0% | High-level DC wiring loss is calculated based on cable sizing conducted by the Consultant with cable length estimated from the plant layout. |
| Inverter Efficiency Loss | 1.57% | The loss is PVsyst generated, based on inverter specifications extracted from the inverter datasheet. |
| Auxiliary Loss | 0.11% | Auxiliary loss of MVPS (Central Inverter) during operation. |
| AC wiring Loss | 0.01% | AC wiring loss is assumed based on Consultant's estimations. |

| | | |
|---|---|---|
| Transformer Loss | 1.08% | Transformer loss is calculated for typical MV transformer |
| Transmission line Loss | 0.57% | Loss estimated of MV line from MV Transformer. |
| Plant Unavailability | 1.0% | Plant internal unavailability of 0.8-1.0% is assumed for a typical well maintained PV plant. |
| Annual PR | 81.12% | Note: The loss figures are indicative, which may change based on selection of technology, equipment and implementation approach in the later stages of the project. |

#### 3.5.2.4 **Uncertainty**

The sources of uncertainty introduced to the yield results of the Project and their values based on validation results including our judgements are summarized in the table below.

*Table 3-20: Summary of uncertainty*

| Source of uncertainty | Values | Description |
|---|---|---|
| Inter-annual variability | 3.0% | Variation in year-to-year of solar irradiation where the data is obtained.<br><br>For the projects, we have assumed a typical value of 3.0% interannual variation. |
| Irradiation measurement accuracy | 3.0% | Measurement bias error of the solar resource model.<br><br>Irradiation measurement accuracy is based on the measurement accuracy value extracted from SolarGIS validation report. |
| Availability of irradiation data period | 0.80% | Reflect how well the available period of data record may represent the true long-term average values.<br><br>The result is based on 14-year data period of SolarGIS (2007-2020). |

| Source of uncertainty | Values | Description |
|---|---|---|
| Spatial variability | 0.0% | Error incurred when using irradiation resource data that is not co-located with the project site location (e.g. in case irradiation data from ground weather station is selected).<br><br>SolarGIS is a satellite-based source which can provide irradiation data at the site location and thus no spatial bias in this case. |
| Modelling accuracy | 2.06% | Error from inputs applied into the models including from the models themselves. |
| Total 25-year uncertainty | 3.78% | The effect of longer year reduces uncertainty from inter-annual variation. |

### 3.5.3 Solar PV Plant Energy Yield

The Consultant has conducted an evaluation of energy production following a formula provided below with additional assumptions on PV module degradation and total unavailability of the Project as summarized below:

$$Energy\ Output = \frac{GII}{1{,}000W/m^2} \times PR \times Plant\ DC\ capacity \times Degradation \times (1 - Unavailability)$$

Given that the PV module degradation study specifically conducted for monocrystalline PV module is not currently available, the Consultant has considered the annual PV–module degradation rate of typical monocrystalline based on the limited supplier warranty for the module. 0.55% annual degradation has been assumed.

The specific yield and 1st year energy production of the project based on P50 estimates are presented in Figure 3-31 and Table 3-21.

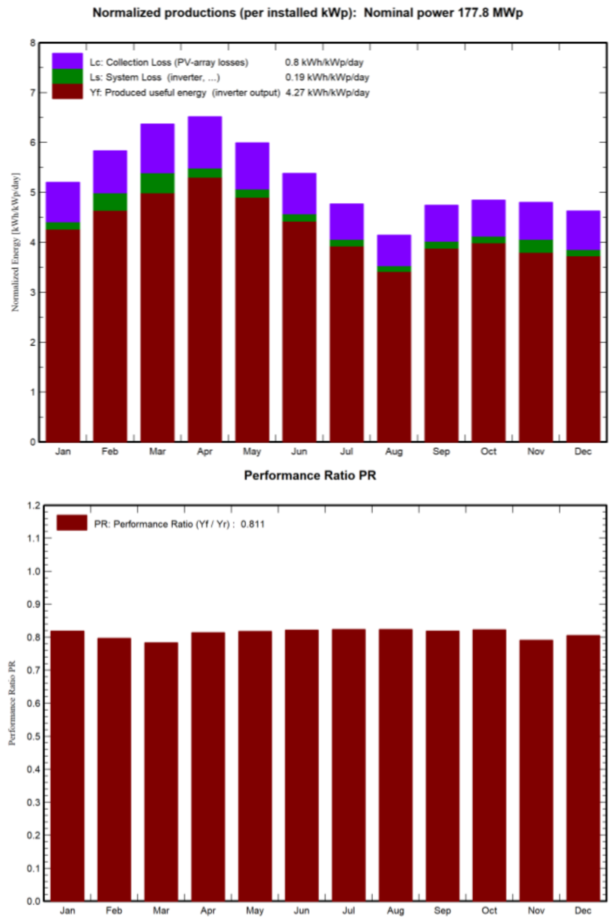



*Figure 3-31 Energy Yield Analysis Result (PVSyst) 150MW Project*

*Table 3-21: Specific yield and first year energy production (150MWac)*

| Parameters | Values |
|---|---|
| Global Horizontal Irradiance (kWh/m$^2$-yr) | 1886.10 |
| Initial PR | 81.12% |
| Initial specific yield (kWh/kWp-yr) | 1,559.19 |
| 1$^{st}$ year energy production (kWh) | 274,424,673 |
| DC Capacity Factor % | 17.62% |
| AC Capacity Factor % | 20.61% |

The complete yearly probabilistic energy production (P50, P75 and P90) for the lifetime of the asset based on 25-year uncertainties calculated by the Consultant are presented in Table 5-26 below.

| | Annual Generation (25-yr Uncertainty) [MWh] | | | |
|---|---|---|---|---|
| Year | P50 | P75 | P90 | P99 |
| 0 (initial) | 277,287 | 270,224 | 263,867 | 252,925 |
| 1 | 274,425 | 267,434 | 261,143 | 250,314 |
| 2 | 270,954 | 264,052 | 257,840 | 247,149 |
| 3 | 269,429 | 262,566 | 256,389 | 245,758 |
| 4 | 267,904 | 261,080 | 254,938 | 244,367 |
| 5 | 266,379 | 259,593 | 253,486 | 242,976 |
| 6 | 264,854 | 258,107 | 252,035 | 241,584 |
| 7 | 263,329 | 256,621 | 250,584 | 240,193 |
| 8 | 261,804 | 255,135 | 249,133 | 238,802 |
| 9 | 260,279 | 253,649 | 247,681 | 237,411 |
| 10 | 258,754 | 252,162 | 246,230 | 236,020 |
| 11 | 257,228 | 250,676 | 244,779 | 234,629 |
| 12 | 255,703 | 249,190 | 243,327 | 233,238 |
| 13 | 254,178 | 247,704 | 241,876 | 231,847 |
| 14 | 252,653 | 246,217 | 240,425 | 230,456 |
| 15 | 251,128 | 244,731 | 238,974 | 229,065 |
| 16 | 249,603 | 243,245 | 237,522 | 227,674 |
| 17 | 248,078 | 241,759 | 236,071 | 226,282 |
| 18 | 246,553 | 240,272 | 234,620 | 224,891 |
| 19 | 245,028 | 238,786 | 233,169 | 223,500 |
| 20 | 243,503 | 237,300 | 231,717 | 222,109 |
| 21 | 241,978 | 235,814 | 230,266 | 220,718 |
| 22 | 240,453 | 234,328 | 228,815 | 219,327 |
| 23 | 238,927 | 232,841 | 227,364 | 217,936 |
| 24 | 237,402 | 231,355 | 225,912 | 216,545 |
| 25 | 235,877 | 229,869 | 224,461 | 215,154 |
| Total Year 1 to 25 | 6,356,402 | 6,194,486 | 6,048,757 | 5,797,946 |

*Table 3-22: San Roque Floating Solar 150MW Project - P50, P75, P90, and P99 expected power generation over plant lifetime (based on a 25-year uncertainty)*

## 3.6 Instrumentation and Control System

### 3.6.1 Hierarchical Control Structure

A hierarchical control structure of the control system mentioned below is proposed for active PV generator.

The structure of the hierarchical control system includes four (4) levels. Each one has precise control task depending on its hierarchical position:

a. Switching Control (SC): implements the modulation technique to each converter and the generates the signal to apply the wishes ideal states.
b. Automatic Control (AC): applies the control algorithm to meet the current or voltage reference.
c. Power Control (PC): calculates the power reference for each source according to the sensed values and the selected operating mode from the Mode Control level
d. Mode Control (MC): decides the operating mode for the whole PV generator according to the availability of the PV production, the states of each PV power station unit and the actual power dispatched to Grid

Two (2) sources are considered: the PV panel (PV), and the Grid connection (GC). Two power electronic converters are used to regulate the power exchanges among them. Then in the control system, two Switching Controls (SCs), two Automatic Controls (ACs) are used for the control of the two sources, a common Power Control (PC) and a common Mode Control are used for the power dispatching among the difference sources. The hierarchical control structure, switching master controller diagram and general schematic of PV power station unit can be seen in the figure below:

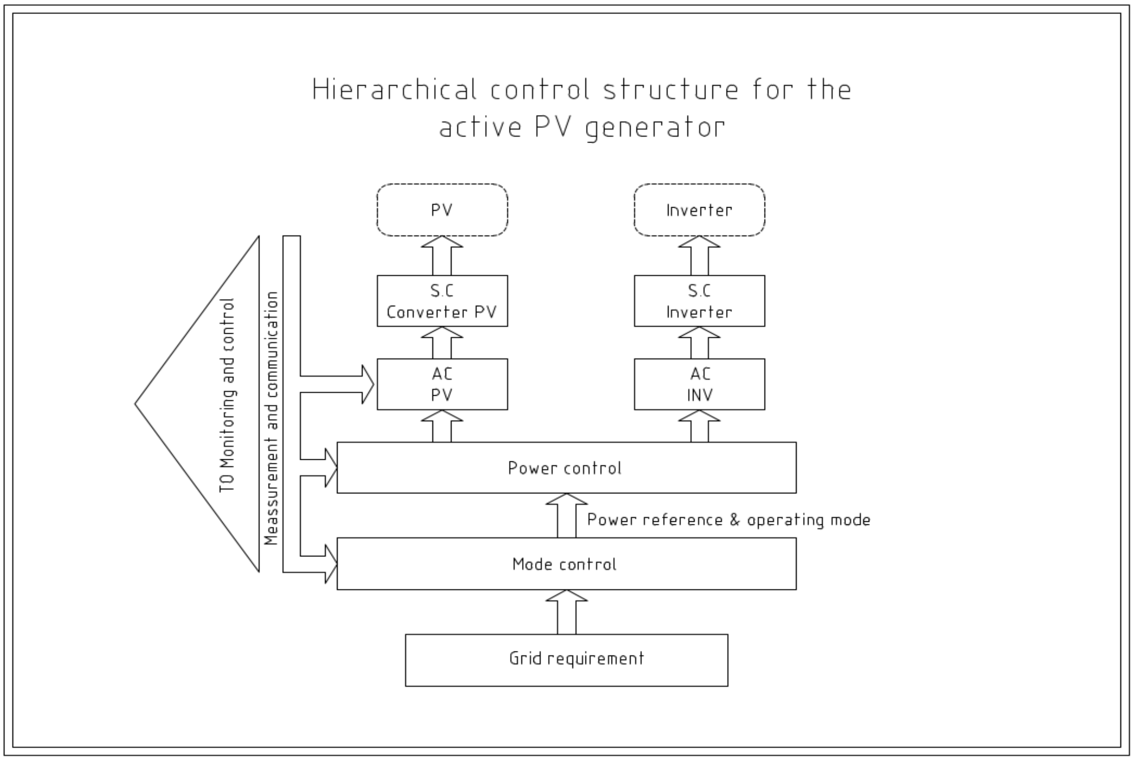



*Figure 3-32: Hierarchical Control Structures*

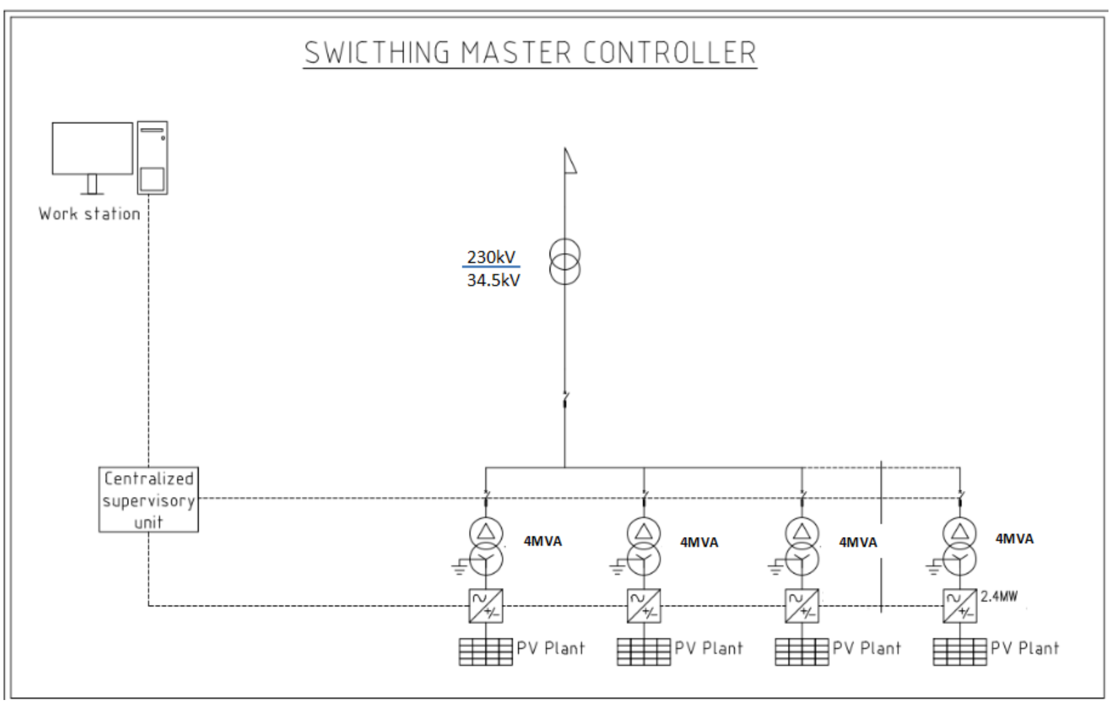



*Figure 3-33: Switching Master Controller Diagram*

### 3.6.2 PV - SCADA System Structure

The Supervisory Control and Data Acquisition (SCADA) system is located in the central control room of the plant to perform monitoring of plant-wide equipment, 35 kV distribution equipment as well as data processing to create a complete database for operation management.

The PV - SCADA system consists of the following equipment, systems and equipment:

- Two (02) operational stations, each consisting of one (01) computer, two (02) displays, two (02) keyboards and two (02) mice to fulfil the supervisory requirement of the power plant.
- One (01) technical station, one of which consists of one (01) computer, one (01) display, one (01) keyboard and one (01) mouse, and the other station uses laptop. Technical station for system maintenance and management.
- One (01) server reports historical data to save data in the long term and create the report.
- Two (02) incident printers for data and breakdown.
- One (01) color laser printer for copying images displayed from the operator station, printing all reports and other print jobs.
- Two (02) optical communication networks high-speed (100Mbit / s) single-loop for data communication.
- One (01) GPS clock for time synchronization function.
- One (01) set of equipment for all control rooms, such as tables and plugs for fitting all system equipment and components, including operator's chairs.

PV - SCADA system equipment is arranged to facilitate the operation of monitoring control, operation data management and system maintenance. All software and programs required for system operation and maintenance must be provided at the technical station a copy of all software is stored in a CD or DVD, all software included in the documentation relating to the block diagram, program list, and instruction manual. Language must include a number of functional modules, each containing a graphic symbol and programmed by connecting graphical symbols.

### 3.6.3 Recording Incident and Data

The PV - SCADA system shall record the incidents and data as follows:

a. Automatically printing saved data

Voltages, currents, frequencies, active power, reactive power, power (Wh and Varh), temperature, etc. must be periodically printed on the report to record data according to the daily and monthly reports form. The data logging function must be designed to allow manual printing of data on the printer to record data when the operator require.

b. Automatically printing operation records

Whenever the unit, self-consuming and switching on-off operating system, and the operating mode is changed, the time (days, hours, minutes and seconds), the name of the device being operated, and the operation status is automatically printed on the incident printer. Operational log lists are implemented in order of operation over time.

c. Automatically printing the incident record

In the event of an incident or trouble, the time (date, hour, minute, second), the related device name, and the relay or device number are automatically printed on the incident printer.

The incident log list must be executed in the order in which the problem occurred

### 3.6.4 Daily Compilation and Monthly Report

The PV - SCADA system should be equipped with a daily and monthly report preparation function for plant operation management.

Daily and monthly reports should be prepared as follows:

- Daily report for array output power and yield.
- Daily report for power and transmission power
- Daily report of capacity and power consumption of self-consuming supply system
- Daily reports on the number of times the switchgear system operates and the operating time of the self-consuming equipment.
- Monthly report of operating hours, inverter output, and yield.
- Monthly reports on the operation of the system of switching and operating the self-consuming equipment.
- Monthly report on temperature.
- Monthly report on incidents and troubles of equipment.
- Unlimited record of number of times the system operates and the operating time of the self-consuming equipment's.

Data logging for daily reports is printed hourly, data logging for monthly reports must be printed daily, power data related to daily and monthly reports, including accumulated daily and monthly power. Postponing or skipping this recording may be done by the operator.

Report format should be submitted to the Project Manager for approval.

Daily and monthly reports are stored on the DVD-R drive when the operator requests. Reports are stored in the server for storing historical data for at least sixty (60) days for the daily report and twelve (12) months for the monthly report.

# 4 ENVIRONMENTAL AND SOCIAL CONDITION

## 4.1 General Condition

The Agno River basin is the 5th largest basin in the country whose upland watersheds and vast alluvial plains are surrounded by mountain ranges belonging to the Cordillera, Zambales and Bataan Mountains. The river basin which covers principally the provinces of Pangasinan and Benguet is the area's food and fiber basket and is considered one of the richest ecosystem in the country. In total, the San Roque Reservoir has an area of 12.8 $km^2$. At the time of commencing this Feasibility Study, the reservoir is also utilized by San Roque Hydro Power Plant with a total installed capacity of 435 MW.

In terms of the development of SRPC 150MW Floating Solar PV Power Plant, it is anticipated that a series of environmental and social components will be affected by the activities of the plant.

Activities that may potentially affect the surrounding environment include the utilization of some reservoir surface area for floating PV equipment, as well as the main construction of Floating Solar PV system and its supporting infrastructures. The environmental components to be affected include but not limited to increased density of dust, changes to the natural ecosystem of the river, decreased ambient air quality and noise pollution during construction, decreased water quality in the surrounding water bodies, and impact on surrounding biodiversity.

During operation phase of the floating solar PV plant, it is anticipated that the solar PV system will not emit a significant amount of pollutant. The most important impact has to do with the food chain or the natural river ecosystems in which the floating PV block/island will limit the solar energy entering the ecosystems below it.

This environmental and social study section of this feasibility study is conducted based on existing data and reports reasonably available to the Consultant and visual inspections during the site visits.

## 4.2 Environmental Regulation

### 4.2.1 National Law

Below are the National Laws and Departments relating to this Project:

- **Presidential Decree 1586 Environmental Impact Statement (EIS) Statement of 1978** to facilitate the attainment and maintenance of rational and orderly balance between socio-economic development and environmental protection;

  (1) Administrative Order No. 42 (series of 2002) providing for "Rationalizing the implementation of the Philippine Environmental

Impact Statement (EIS) system and giving authority, in addition to the Secretary of the Department of Environment and Natural Resources, to the Director and Regional Directors of the Environmental Management Bureau to grant or deny the issuance of Environmental Compliance Certificates"; and

(2) DENR Administrative Order No. 30 (series of 2003) providing for the "Implementing Rules and Regulations for the Philippine Environmental Impact Statement (EIS) System".

- **Republic Act 9275 Philippine Clean Water Act of 2004** The law aims to protect the country's water bodies from pollution from land-based sources (industries and commercial establishments, agriculture and community/household activities);
- **Republic Act 9003 Ecological Solid Waste Management Act of 2000** the law aims to adopt a systematic, comprehensive and ecological solid waste management program that shall ensure the protection of public health and environment;
- **The Indigenous Peoples' Rights Act of 1997** An Act to recognize, protect and promote the rights of Indigenous Cultural Communities/Indigenous Peoples, creating a National Commission on Indigenous Peoples, establishing implementing mechanisms, appropriating funds therefor, and for other purposes.
- **Presidential Decree No. 1067 December 31, 1976** a decree instituting a water code, thereby revising and consolidating the laws governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources;
- **Republic Act No. 7160 - An Act Providing For A Local Government Code Of 1991, where Book 1 Section 290 provides for:**
  Amount of Share of Local Government Units. - Local government units shall, in addition to the internal revenue allotment, have a share of forty percent (40%) of the gross collection derived by the national government from the preceding fiscal year from mining taxes, royalties, forestry and fishery charges, and such other taxes, fees, or charges, including related surcharges, interests, or fines, and from its share in any co-production, joint venture or production sharing agreement in the utilization and development of the national wealth within their territorial jurisdiction.
- **Energy Regulation No. 1-94 - Rules and Regulations Implementing Section 5 (I) Of Republic Act No. 7638,** Otherwise Known as the "Department Of Energy Act Of 1992"
- **National Irrigation Administration**
- **Department of Environment and Natural Resources**

### 4.2.2 International Regulatory Framework

#### 4.2.2.1 Equator Principles

Equator Principles (EPs) are the environmental and social risk management framework voluntarily implemented by 83 financial institutions (Equator Principle

Financial Institutions). The main purposes of these frameworks are to provide a minimum standard for due diligence to support responsible risk decision-making in project financing. These principles are applied to all new project financings across all industry sectors with total project capital expenditures of USD 10 Million or more. There are 10 principles (EP 1 to 10) which are:

a. Review and Categorization;
b. Environmental and Social Assessment;
c. Applicable Environmental and Social Standards;
d. Environmental and Social Management System and Equator Principles Action Plan;
e. Stakeholder Engagement;
f. Grievance Mechanism;
g. Independent Review;
h. Covenants;
i. Independent Monitoring and Reporting; and
j. Reporting and Transparency

#### 4.2.2.2 IFC Environmental Health and Safety (EHS) Guidelines

The IFC EHS Guidelines are technical reference documents with general and industry-specific issues associated with private sector projects. These guidelines cover the performance standards which are generally acceptable to IFC and considered to be achievable in new projects at reasonable costs by available technology. The International Financial Institutions (IFI) are commonly referring to these requirements to ensure that a project has implemented Good International and Industry Practices. The applicable IFC guidelines for the Project are as follows:

- IFC Performance Standards;
- IFC's General EHS Guidelines;
- IFC's EHS Guidelines for Electric Power Transmission and Distribution

The guidelines also specify limits for environmental emission and pollution sources as well as certain aspects of occupational and community health and safety. The applicability of IFC Guidelines should be tailored to the hazards and risks established for each project. Technical recommendations should be based on the professional opinion of qualified and experienced persons. When local regulations differ from the IFC Guidelines, best practice dictates that the Project will aim to achieve whichever is more stringent.

## 4.3 Baseline Information

### 4.3.1 Project Description

SRPC 150MW Floating Solar PV Power Plant (the "Project") has a capacity of 150 $MW_{AC}$. The plant consists of 684 floating PV blocks with 260kWdc per block which forms Islands of 4.68MWdc (Type 1) and 2.34MWdc (Type II. There are also supporting facilities, such as transformer shelters, 34.5 kV collector bus, laydown area, and plant switchyard 230 kV. In total, the Project occupies about 661 Ha of water surface area and about 5.5 Ha of the on shore area near the reservoir.

### 4.3.2 Land Classification

The Project Site is mainly located on the surface of San Roque reservoir and is part of the Agno River Basin, and some supporting facilities on nearby area which is being owned by NPC. Most of the Agno river basin area (not reservoir area) is classified as forest lands (i.e. forest reserves, reservations, national parks, unclassified public forest), with only less than half of the area classified as alienable and disposable. The dominant land in the river area covers are annual crops. This is followed by wooded grasslands, open forests , grasslands , and shrublands . Land cover change analysis from 2003 to 2010 indicated the increasing urbanization of agricultural areas in the ARB and the shifting of farming preference to perennial crops. . During the EIA process to be done in the next stage of the project development, the study shall also consider the context of the Proclamation 2320 (series of 1983):

"Establishing as watershed forest reservation for the purpose of protecting, maintaining or improving its water yield for hydroelectric, irrigation and other ecological enhancement purposes and providing restraining mechanisms for inappropriate land-use and forest exploitation, the parcel of land situated in the municipalities of Tuba, Itogon and Baguio City, Province of Benguet and the Municipalities of San Manuel and San Nicolas, Province of Pangasinan, island of Luzon, Philippines."

### 4.3.3 Aquatic Ecosystem

Due to its unique biogeographic position, the Agno River Basin is rich in both floristic and faunal diversity. The river basin is part of the Greater Luzon Terrestrial Biogeographic Region and straddles three terrestrial biogeographic sub-regions (i.e. Central Cordillera, Central Luzon Lowlands, and the Zambales-Bataan). It is also bounded by two biodiversity corridors – Cordillera Terrestrial Biodiversity Corridor and the Bataan-Zambales Terrestrial Biodiversity Corridor.

According to the report Climate-Responsive Integrated Master Plan for Agno River Basin, there are more than 500 species of bryophytes, pteridophytes, gymnosperms, and angiosperms have been identified in the Agno River Basin in at least 8 different vegetation types. This includes numerous indigenous species; Northern Asiatic floristic species; and endemic species, some of which are Luzon-restricted, regionally-restricted, or locally-restricted species. Locally, endemicity for flora in the river basin are high. Although faunal assessments in the river basin were not as extensive as flora, at least 150 migratory and resident species of birds, amphibians, reptiles, and mammals were identified in the Agno River Basin. This includes numerous vulnerable species, some of which are site-restricted.

The biological diversity of the Agno River Basin is also evidenced by the presence of numerous conservation and special interest areas. This includes four Conservation Priority Areas, two National Parks, a Resource Reserve, two

Watershed Forest Reserves, a Protected Landscape, two Key Biodiversity Areas and two Important Bird Areas.

It is suggested that during conduct of EIA for this project, the impact of the Project to the surrounding biodiversity, including migratory and natural resident birds, should be considered as well as consideration in the study the context of Proclamation 2320 (series of 1983).

## 4.4 Potential Impact to be Considered

### 4.4.1 Water

Construction and operation of a floating Solar PV plant could potentially have adverse impacts to the quality of ground and/or surface water in the area. These contaminants could occur as a result from leakages and spill of a hazardous substance such as construction materials, fuel (diesel or petrol), lubricants and cleaning agents. Other potential impacts to be considered during this phase are suspended sediment to nearby surface water from the construction activities.

Unlike other conventional power generation technologies such as coal and gas-fired power plant, solar PV plant does not require water during its process to generate electricity. Most of the water consumptions are for the construction of the plant only. After the construction only a small amount of water is needed for daily domestic usage during operation and maintenance/cleaning of the PV modules.

Some negative environmental impacts might also occur when the floating solar PV blocks are installed on a natural reservoir/river body and cover the majority of the reservoir. The important impact to be considered has to do with the food chain of the river ecosystems. Since the solar energy penetration to the lake is limited by the floating PV blocks, the underlying water ecosystem (*such as aquatic microbial ecosystem*) might be affected in terms of its metabolism. This could potentially change the natural ecosystems since some of the species rely on it. However since the PV islands cover only less than 15% of the total reservoir at high to normal water level, this issue will not be applicable for the SRPC project. Studies have found that as long as the floating solar plant occupy not more than 40% of the water surface the river/reservoir biodiversity ecological stability will be maintained and undisturbed.

The discharge of wastewater shall comply with the Department of Environment and Natural Resources on domestic wastewater quality standards.

Water quality monitoring data should be collected and presented as baseline information for conducting EIA study. The baseline data should be collected within the Project area and also within the potentially impacted surrounding residential area.

#### 4.4.2 Noise

The impact on ambient noise can be described as any unpleasant or loud sounds that occur during the construction, operational, maintenance and decommissioning activities. The main sources of noise during the construction phase of the Project could potentially be generated by the activity of the construction equipment and vehicles. These noises could cause nuisance to those settling close to the Project site.

A floating Solar PV plant does not have any moving part while generating electricity. Therefore, there is no noise associated with the generation of electricity by the power plant.

The Project shall comply with the existing national regulations.

#### 4.4.3 Air Quality

Ambient air quality monitoring at sensitive receptors may be required as a part of the EIA baseline studies. The sensitive receptors will be established as part of the Terms of Reference (ToR) for EIA. The results will be compared against the air quality standards from the Department of Environment and Natural Resources.

The source of emission to the ambient air during the construction phase mainly come from the mobilization of the power plant equipment and construction materials, access road and supporting facilities construction and land preparation activities. The emission from these sources could come in the form of dust, particulate matter (PM) and vehicle exhaust/combustion gas. These emissions will only affect the local construction site area and the duration will be in a short-term. The ambient air quality during these activities will be monitored to ensure that the construction phase complies with the applicable standard.

There is no source of air pollution associated with the operation of the Solar PV system. However, during the maintenance of PV modules and other equipment, there could be a potential of dust accumulated. Appropriate protective equipment such as mask and safety glasses are suggested to be used by the maintenance worker.

#### 4.4.4 Solid Waste

During construction and operation of the power plant, some amount of solid and hazardous waste may be generated. Typically, solid wastes during construction comprise of office waste, construction waste (e.g., wood, material leftovers, concrete scrap, etc.) and some hazardous waste such as oil and solvents used in construction activities.

During operation of the power plant, most of the solid wastes comprise of domestic waste, used oil or solvent from operational vehicles and broken or replaced components (e.g. PV modules, inverters, power electronics part).

Most of the solid materials (e.g. concrete and brick walls, steel, glass mirrors, electrical cables, pipes, pumps) can be recycled and/or sold as scrap or used for other purposes such as road construction. The hazardous waste such as lubricants and fuel could be delivered to the authorized facilities for further processing. The used PV panels could be collected and recycled as a raw material to produce new components for PV, or if not recycled, these components need to be processed by an authorized facility since they contain hazardous materials.

A waste management system shall be implemented on the Project site to comply with the Philippines solid and hazardous waste storage and disposal regulations.

### 4.4.5 Landscape and Visual Amenity

Potential visual impacts to the surrounding environment associated with the construction activities will include visual change as a result of installing the floating PV block on the surface water area; vegetation clearing for the balance of systems area; ancillary buildings and laydown area; construction of new roads; soil stockpiles from excavation activities; power lines constructions, increased traffic (heavy equipment and transport vehicles); project worker presence and dust emissions.

For the Solar PV systems, the PV panels would likely to bring the most significant to the landscape and visual amenity of the surrounding area since it will occupy a large area. The contrast between the surrounding land/surface water and panel field could be prominent, in form, color, line and texture. In order to minimize the glint and glare from the PV panels, it is suggested that the panels that will be used for the plant shall have low reflectivity.

### 4.4.6 Biodiversity

Potential impacts to the natural ecology can include loss of natural habitat and disturbance or displacement of certain vegetation and wildlife species. The ecological baseline surveys need to be undertaken where there is a potentially sensitive habitat associated with this Project.

Other impact could also occur from other associated facilities such as overhead transmission lines, substation/switchgear, new access road and lighting.

It is important to collect site-specific baseline information on biodiversity during the EIA studies in order to ensure the most appropriate site and site layout is selected to minimize any adverse impacts on local biodiversity.

## 4.5 Socio-economic Aspects of the Project

The following socio-economic aspects are observed for the Project Site:

In terms of local economy, the prominent economic activities found in this area around the reservoir is farming.

- San Roque Reservoir surface area is considered as natural river reservoir and is owned by the Philippine government, all permits shall be processed either by the local or central government.

The Project site does not appear to be of archaeological value, national heritage and historic building.

- This project will require a large amount of capital investment and may bring positive economic opportunities to the communities surrounding the Project site and the wider area. The local sourcing of material and labor shall be maximized and could potentially give some positive local economic benefits.
- The increase in number of workers could also have the potential to cause disturbance within the local community, particularly in the form of conflict resulting from non-local workers being appointed.
- There is also a potential of increasing road traffic during the lifecycle of the Project, especially during the construction phase. These activities may potentially increase the risk of accident.
- In a wider perspective, this project could contribute to meet Philippine's Renewable Energy generation target.

A social baseline survey needs to be undertaken during EIA study to understand the socio-economic key-features within the Project area which will be used as a baseline to assess the potential impacts of this Project to the social and economic aspects and also prepare the necessary mitigation/management measures.

The detailed design should have no negative impact on the social economic activities such as fishing, broom making and agroforestry and shall accommodate sufficient navigational routes within its layout.

## 4.6 Socio-Environment Feasibility of Project

The Project activities have the potential to have both positive and negative impacts on the environment and socio-economic aspects. It is expected that the Project shall follow and comply with the requirements of applicable Philippines and International standards. According to the Consultant's assessment, the Project is considered feasible from socio-environment perspective. However, the EIA or monitoring and management plant studies will be needed to demonstrate that the Project can comply with the applicable requirements.

In addition, stakeholder engagement with affected communities is also an important aspect of the socio-environment study to disclose Project information, to collect affected communities' views on the Project and to gather social data to be used in the social impact assessment. It was also noted that the San Roque Hydroelectric Power Plant has been helping the NPC in rehabilitating and protecting the watershed that has now increased both flora and fauna.  Hence, continuous investments must be made in improving vegetation quantity and quality and wildlife conservation.

# 5 HIGH LEVEL MANAGEMENT ASPECT FOR CONSTRUCTION AND OPERATION AND MAINTENANCE (O&M)

## 5.1 Project Schedule

The Consultant assumes the 150MWac Floating PV Solar project will be implemented on Engineering, Procurement, and Construction (EPC) basis. It is foreseen that the plant will be supplied by a single EPC contractor. This is generally also the preferred solution in order to reduce various construction risks.

This project schedule is an estimation only and based on the Consultant's experience on the similar floating solar project in the Asia region. The final detailed project schedule is expected to be provided by the EPC contractors.

### 5.1.1 Key Milestones

The key milestones are:

- Permitting Process and PPA Signing : T0 + 6 = T1
- EPC Contract Signing and NTP : T1 + 3 = T2
- Commencing the construction of FPV : T2
- Commercial Operation Date of FPV : T2 + 20

More detailed activities planned during the construction stage is discussed in later section.

### 5.1.2 Pre-construction Schedule

Consultant is proposing above project schedule to ensure timely completion of the total 150MWac capacity of Solar PV floating system to be operation 18 to 20 months after the PPA is signed.

In total, 6 months have been reserved for the development phase (including permitting process), for finalizing the PPA and other contracts, for both the project capacities.

### 5.1.3 Construction Schedule

The total construction schedule from NTP to COD of the plant is estimated to be 20 months which includes the installation, commission and testing of the Solar PV and floating system. The relative long duration is due to the challenges of the construction period, due to the fact that no reasonable sized assembly area is available which has direct access to the reservoir. Due to this the islands need to be preassembled in one area and then final assembled on the reservoir itself.

Main construction activities for this project will include:

- Preliminary works, including development order, bathymetry survey and soil investigation, flood study, bathymetry, and environmental assessment;
- Engineering and design for electrical transmission system and solar PV and floating system;
- Procurement and shipment for Balance of Systems, solar PV and floating system;
- Construction activities, including:
    - Reservoir: installation of anchoring and mooring system, erection of solar panels and inverters on floating system, cabling, floating system mooring and anchoring;
    - Land: preparation of ramping area, onshore piling, construction of facilities and infrastructure (main and temporary), piling and foundation work (for transformer cluster and switchyard), erection and installation work for electrical systems, solar PV, SCADA system;

The Consultant envisages that the installation of anchoring, erection of solar panel and floating system and fastening work will be conducted in parallel, island by island.

- Testing and commissioning, including interconnection of Solar PV to the grid, grid code test and performance test.

It should be noted that Philippines is a developing solar market with only limited experience in large scale floating solar PV, hence the construction and commissioning of the project shall be given adequate provision and be well-planned and monitored to meet the scheduled COD. The indicated 18-20 month construction schedule is well longer than for a solar based 150 MW PV solar plant, but this is due to the challenges specifically applicable for the SRPC project such as anchoring/mooring, the very limited access to the reservoir and the need to partial pre-assemble the PV module islands in a different location than beside the reservoir.

## 5.2 Construction Water

Fresh water for the Project construction can be from the reservoir itself or from the ground water if available. For this purpose, any specific permission if required, needs to be taken by EPC contractor.

## 5.3 Construction Power

The Project construction can use the power supplied by the nearby 13.4 kV system from the SRPC or a portable diesel generator. However, EPC contractor will need to verify whether the currently available power source within this area will be sufficient for the construction or any additional temporary power generator will be needed. Any specific permission if required, needs to be taken by EPC contractor.

## 5.4 Availability of Construction Material

The construction of FPV system will require a significant amount materials. The EPC Contractor shall be responsible for supplying at its own cost and relate to construction works include supplying good quality material required during the construction phase.

## 5.5 High Level Operation and Maintenance Management

Operation and Maintenance Management will focus mainly on the following:

- Spares Inventory
- PV Panel Cleaning
- Control and Operation
- Security
- Reservoir Maintenance
- Equipment Maintenance

### 5.5.1 Spares Inventory

The facility shall have ample inventory of spares for the Operation & Maintenance for the first 5 years. The supply of these spares can be included in the EPC contract. Among the major equipment that shall have spares are the PV modules, Inverter parts, transformer parts, floaters, mooring cabling, etc.

### 5.5.2 PV Panel Cleaning

PV panel cleaning is required to maintain the PV effectiveness in terms of capturing/absorption of the solar irradiation and thus maximize the energy yield. PV panel cleaning can be done by a third party service provider and is done on an interval based on the requirement for cleaning (determined through the observation of actual energy production if consistently does not match with the actual energy resource available).

### 5.5.3 Control and Operation

Control and Operation can also be done by the Owner’s own team. They must be knowledgeable of the FPV plant operations as well as maintenance. The Owner can also enter into an agreement with a competent O&M service provider to oversee the operation and control activities. Among the things to focus on operation are the monitoring and ensuring of the energy production of the plant, energy sales, and coordination with grid provider with regard to power dispatch on a day to day basis.

### 5.5.4 Security

The Owner shall also look into consideration the provision for adequate security for the FPV plant to protect the assets and the day to day operation within the plant boundaries. Security personnel can be provided by third party security providers.

### 5.5.5 Reservoir Maintenance

The key success of the FPV plant is a well maintained environment of the reservoir. Preventing debris from upstream of the reservoir to enter the FPV area will become a major challenge. Debris being brought by the water current from upstream of the reservoir are threat to the FPV blocks and their mooring system if they are not addressed and intercepted before it reaches the reservoir. These debris will clog the water flow within the reservoir and will damage the FPV blocks and the mooring systems. With this, the Owner shall arrange with the EPC contractor in the early stages of design to address the issue and design for a debris collection system which shall be managed by a separate maintenance contractor.

### 5.5.6 Equipment Maintenance

Major equipment such as the Inverters, Transformers, PV modules, Switchgears , floaters and mooring systems shall be regularly checked for damages and malfunctions. Adequate spares as recommended by respective suppliers shall be adhered to and provided by the EPC contractor before handover of the Plant to the Owner. These spares must be replenished on a timely manner in order for the spares to be available at all times. The Owner shall ensure that adequate warranties are included in the agreement with the equipment supplier or with the EPC that covers from simple repairs, technical advisory/assistance to full product replacement.

# 6 CONCEPT LEVEL COST ESTIMATES AND HIGH LEVEL TECHNICAL INPUT FOR CLIENT FINANCIAL MODEL

## 6.1 General

The Consultant has conducted an independent cost estimation for the Project. The estimation provides key technical cost inputs to be used in the financial model, namely the Capital Expenditures (CAPEX) and Operational Expenditures (OPEX).

The Consultant highlights that there are no utility-scale Floating Solar PV projects in Philippines. Hence, the Project costs in this section are estimated based on the Consultant's experience with other projects in the same region (i.e. South East Asia) with similar scale and nature, as well as prices obtained from publicly available data.

It should be highlighted that the actual Project costs may deviate from the estimated values in this section, strongly subject to commercial packages offers by suppliers, the actual technology selection of the key equipment, finalized design of the Project, as well as the risk appetite of the selected contractors and fluctuating material and commodity prices.

The costs for solar PV in this section are estimated based on the capacity of 178 MWp / 150 $MW_{AC}$ Floating Solar PV Plant.

## 6.2 Capital Expenditures

As described above, the CAPEX of solar PV is estimated from the Consultant's in-house database and involvement in projects in the same region. The total CAPEX estimate for the Project is shown in the following table.

*Table 6-1: Total Capital Expenditure (in MUSD)*

| Capital Expenditure (in MUSD) | Base Case (Exc. VAT) | Portion |
|---|---|---|
| EPC Cost (excluding item listed below) | 176.04 | 92.62% |
| Land Cost | 0.56 | 0.29% |
| Project Development and Owner's Cost During Construction | 0.9 | 0.47% |
| Commissioning and Testing | 2.64 | 1.39% |
| Contingency | 9.05 | 4.76% |

| Capital Expenditure (in MUSD) | Base Case (Exc. VAT) | Portion |
|---|---|---|
| Insurance During Construction | 0.88 | 0.46% |
| TOTAL (in MUSD) | **190.1** | **100%** |

### 6.2.1 EPC Cost Breakdown

The EPC cost is estimated based on other similar sized plants in the region adjusted for Project specific costs. The actual EPC cost may deviate from the estimated values by the Consultant, strongly subject to commercial packages offers by the EPC contractor.

The estimated total EPC cost for 178 MWp / 150 $MW_{AC}$ floating solar PV (with mono C-Si module type and central inverter technology) can be seen in the following table.

*Table 6-2 EPC Cost Breakdown (in MUSD)*

| EPC Cost Breakdown | Base Case (excl. tax) | |
|---|---|---|
| | MUSD | MUSD/MWp |
| PV Plant | | |
| Solar PV Modules | 44.5 | 0.250 |
| Inverters | 9.79 | 0.055 |
| Floater/Mounting Structures | 26.7 | 0.150 |
| Anchoring and Mooring | 30.62 | 0.172 |
| Balance of System (other equipment, civil, labour, etc.) | 48.06 | 0.270 |
| Engineering, Administration, and Management Fee | 16.376 | 0.092 |
| TOTAL (Exclude Tax) | 176.04 | 0.989 |

### 6.2.2 Land Cost

The land cost considered as a part of the Capital Cost comprises of land acquisition cost (for the transformer shelters and plant switchyard) and land lease cost for floating PV block laydown area during construction. The estimated land acquisition and lease cost are based on the other projects in Philippines. As the TA understands the land to be used is in the possession of NPC. If there are no land cost (lease) involved these cost can be eliminated.

### 6.2.3 Special Facilities

From the three options available for the power evacuation, *the Consultant made a capital cost estimate for the interconnection of new Floating Solar PV plant to existing Nagsaag Substation (PES-III)*. The cost breakdown can be seen in the following table. For the purpose of financial analysis, it is assumed that the transmission line cost is attributed as Component *Special Facilities*.

*Table 6-3 Special Facilities Cost Estimation (3 options)*

| Connection Option | Component | Cost (in MUSD) |
|---|---|---|
| PES-I | Connection to existing SRPC-Hydro 230kV Switchyard (Bay extension and new FPV plant substation) | 4.0 |
| PES-II | Provision of Switching Station to tap to existing transmission line plus plant substation | 12.0 |
| PES-III *(used for LCOE calculation)* | 230kV Transmission Line to Nagsaag Substation (10km) and Plant substation at SRPC Compound | 13.5 |

### 6.2.4 Project Development and Owner’s Costs During Construction

The Owner will incur costs during construction such as:

- General and admin costs (bank fees, service expenses, transportation services, donations, utilities, auditing fees, freight and import duties, etc.);
- O&M team mobilization fee;
- Company overhead and advisors’ fees (which includes fees of establishing an office, presenting to the public, hiring skilled staff such as accountants and project developer. In addition, various advises fees will be required including lawyers, engineers, insurance advisors);
- Some consumables prior to COD not included in the EPC Contract;
- Vehicles and some heavy equipment.

Based on other similar scale Projects, the Consultant has estimated a cost of approximately 903,000 USD.

### 6.2.5 Commissioning and Testing

Solar PV system require testing for performance and safety verifications. The level of testing required will depend on local regulators, the Owner desires, and quality commitments of installation and maintenance contractors. For this Project, the Consultant estimated that this cost is 1.5% of total EPC cost (before tax) which is approx. 2.64 MUSD.

### 6.2.6 CAPEX Contingency

Typically, the Consultant expects to see a contingency provision during the construction stage to mitigate risks and to cover the possible variations and cost increases due to technical reasons. These include potential underestimated costs, cost not fully covered under the insurances, cost arising from delayed or expediting works and the risk of currency rate movement. The CAPEX contingency is estimated at 5% of total capital cost (excluding the contingency itself) based on the Consultant’s Experience.

### 6.2.7 Construction Insurance

Typically, the Project will be required to take out insurance during the construction period. In this case an allowance of 0.5% of the EPC price has been allowed although the final cost should be agreed with the insurance advisor.

## 6.3 Operational Expenditures

Similar to the CAPEX, OPEX estimation is based on the Consultant’s in-house database. OPEX estimated herein is in real terms (before inflation and depreciation factors). The O&M components for solar PV plant is not depending on how much energy generated by the plant, therefore all O&M cost is considered as fixed O&M cost per year. The total OPEX estimate for the Project is shown in the following table.

*Table 6-4 O&M Cost Breakdown*

| Fixed O&M Breakdown | Base Case |
|---|---|
| | MUSD/year |
| General O&M | 1.73 |
| General, admin & Others | 0.29 |
| Salaries and Benefits | 0.38 |
| Outsourcing for PV Cleaning | 0.18 |

| | |
|---|---|
| Spare Parts and Consumables | 0.88 |
| Plant Insurance Cost | 0.84 |
| TOTAL | 2.57 |

### 6.3.1 General and Administrative Costs

The general and administration (G&A) cost given above is an estimate based on the Consultant's in-house knowledge and experience.

The G&A costs includes bank fees (if any), service expenses, landscaping and janitorial services, office maintenance and management services, freight and import duties, security expenses, public relation services, legal services, transportation services, donations, utilities, auditing fees, entertainment, safety equipment, recreational expenses, offices equipment expenses, education/occasional training, EIA monitoring and other miscellaneous expenses.

### 6.3.2 Salaries and Benefits

The Project is assumed to be owner-operated. The human resources cost has been estimated by the Consultant based on local salaries and local practices for similar projects in Philippines.

The cost includes salaries and wages, bonus, overtime, travelling expenses, shift premium, social security, training expense, health insurance premium, staff uniform and medical check-up expenses.

The human resources costs are based on some 50 personnel. The breakdown of this personnel can be seen in the following table.

*Table 6-5 Staff Positions and Numbers*

| Staff | No. |
|---|---|
| Plant Supervisor | 1 |
| HSE & Admin | 3 |
| Operator & Technician | 16 |
| Helper (e.g. cleaning, janitor) | 2 |
| Security | 24 |
| TOTAL | 50 |

### 6.3.3 Outsourcing for PV cleaning

The Project assumes that the PV cleaning will be done by third parties workforce supplier (outsourcing). The Consultant estimated that for 178MWp PV plant, the outsourcing for cleaning the module costs 182,000 USD/year.

### 6.3.4 Spare Parts and Consumables

This cost covers routine and preventive maintenance items including consumables (bulbs, cables, gaskets, seals, cleaning equipment, filters, etc.).

### 6.3.5 Insurance

Insurance cost is estimated at about 0.5% of the EPC cost for PV plant per year. This covers the O&M period insurances for general liability, component breakdown and business interruption for the power plant.

## 6.4 Major Maintenance Reserve Account

During the operational phase of the Project, capital investment is required to ensure that the Project is able to continue operating as planned. The MMRA is designed to accumulate funds for major maintenance of key equipment without incurring negative cashflow to the project.

For Solar PV systems, PV inverters usually have shorter life than the other PV main components. Likelihood of replacing/refurbishing inverters over the 25 years (PPA term) is high. Therefore, for this Project, the Consultant assumes that the MMRA for PV plant is 2% of the inverter cost per year of operation. MMRA is accumulated over 10 years or during extended warranty period.

# 7 HIGH LEVEL MARKET ANALYSIS

This section covers a high-level market analysis of relevant price benchmarks for the electricity market in the Philippines and a high-level calculation of the levelized cost of energy for the floating solar project.

## 7.1 Price Benchmarks

There are various potential revenue streams for a generator in the electricity market in the Philippines. The following sections discuss the bilateral contract market, the Wholesale Electricity Spot Market (WESM), and the upcoming Green Energy Auction Program (GEAP).

### 7.1.1 Bilateral Contract Market

Most electricity in the Philippines, 80-90%, is sold via bilateral contracts, or Power Supply Agreements (PSAs) with distribution utilities and retail electricity suppliers.

In recent years, there are various circumstances that have been putting downward pressure on PSA prices of solar power projects with distribution utilities, including retail competition, the decreasing costs of solar equipment, and the mandatory Competitive Selection Process (CSP) imposed by the DOE. PSAs with distribution utilities are also subject to regulation and approval by the Energy Regulatory Commission (ERC). Latest ERC-approved PSA rates for solar developers range between 4.69 – 5.39 Php/kWh for a 20-year contract period. However, there is currently stiff competition as recent solar PSAs filed have rates as low as 2.35 Php/kWh. Table 7-1 shows the summary of recent solar PSAs in the Philippines.

*Table 7-1 Summary of recent solar PSAs*

| ERC Case No. | Date of Application | Status of Application | Price | Contract term |
|---|---|---|---|---|
| 2019-023RC (SPTC – MERALCO) | March 2019 | Initial order | 2.3456 Php/kWh (subject to 16% annual escalation starting on the 11$^{th}$ contract year) | 20 years |
| 2017-094RC (SPTC – MERALCO) | October 2017 | Initial order | 2.9999 Php/kWh | 20 years |
| 2017-014RC (SPTC – MERALCO) | February 2017 | Approved | 5.39 Php/kWh (subject to 2% annual escalation) | 20 years |
| 2017-012RC (PFBS-MERALCO) | February 2017 | Approved | 4.69 Php/kWh (subject to 2% annual escalation) | 20 years |

Aside from the bilateral contracts market with distribution utilities, generators can also sell to retail electricity suppliers which are licensed to sell in the retail market. Retail competition has been introduced in the Philippines for large end-users, and demand threshold was lowered to 500kW effective February 2021. Additionally, renewable energy generators through renewable energy suppliers can also sell to small end-users with demand greater than 100kW under the upcoming Green Energy Option Program (GEOP).

Unlike PSAs of distribution utilities, retail contracts are not subject to individual scrutiny and regulation by the ERC and, hence, information on pricing of RES contracts with solar power projects is not readily available. However, indications are that this market has been successful at setting up a competitive environment, with generators in fierce competition and the resulting prices being lower than typical PSA prices.

### 7.1.2 Wholesale Electricity Spot Market

The WESM is a real-time gross pool market with five-minute pricing based on demand and supply. The rest of electricity, 10-20%, is sold in this market. Under the rules, solar power plants are provided must dispatch status and only required to submit projected generation. This means that they are the first to be scheduled for dispatch and, if necessary, last to be curtailed. Figure 7-1 illustrates the annual progression of the average WESM prices[1] in Luzon. The LWAP ranges from a low of 1.7 PHP/kWh in 2009 to a high of 6.3 PHP/kWh in the following year. Prices over the last three years have averaged 3.5 PHP/kWh. Prices in 2020 were depressed due to lower demand resulting from the impact of the pandemic.

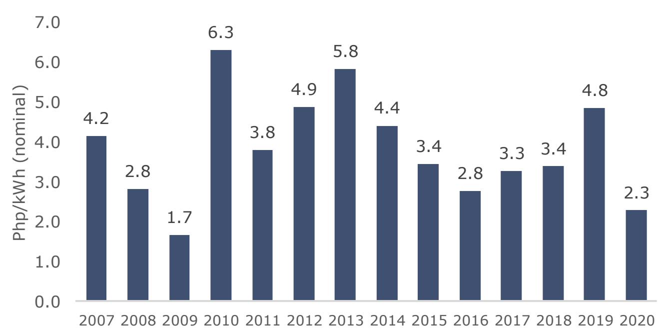



Figure 7-1: Average annual WESM electricity prices for Luzon

[1] Prices shown are Ex-Post Load Weighted Average Price (LWAP) as a simple average across the calendar year or month.

Figure 7-2 shows the monthly capture price for a typical solar power plant in Luzon against the average WESM prices in 2019. Capture prices are calculated as the average WESM price weighted by solar generation. In general, solar capture prices are higher than the average WESM prices as solar generation is highest during peak hours, which have higher spot market prices compared to off-peak hours. The April 2019 capture price is highest due to high spot market prices brought by a combination of unplanned plant outages, hot weather, and delay in the entry of new baseload plants.

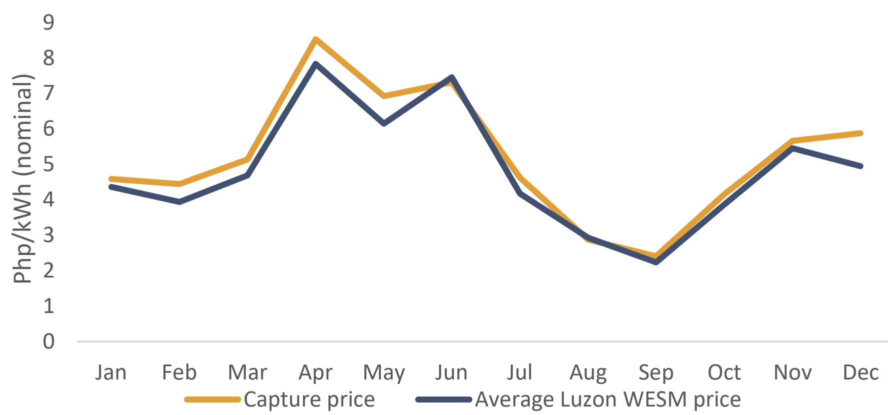



*Figure 7-2: Average monthly solar capture prices and average monthly WESM prices for Luzon*

### 7.1.3 Green Energy Auction Program

In July 2020, the Department of Energy (DOE) promulgated the guidelines for the GEAP in the Philippines. The GEAP aims to support development of RE projects under a centralized competitive process and assist Renewable Portfolio Standards (RPS) mandated participants in complying with their RPS requirements through increasing RE supply and renewable energy certificates (RECs) in the market. For the first auction, DOE is targeting a total of 2,000 MW of capacity divided across different technology types and major grid for the period 2023 to 2025. Based on the latest DOE simulation of potential GEAP volume for 2023-2025, solar auction volume is 900MW for Luzon, 260MW for Visayas, and 100MW for Mindanao.

The first auction was originally planned to be launched in June 2021 but it was deferred to October 2021 as DOE was still in the process of compiling data. However, it was deferred again recently due to ongoing discussions with stakeholders and planned revision of the guidelines.

## 7.2 Levelized Cost of Energy

The Consultant developed a high-level calculation of the levelized cost of energy (LCOE) of the floating solar power plant. The LCOE is calculated as the net present value of the total cost of building and operating the power plant divided by the net present value of the total electricity generation over its lifetime. The total costs associated with a project generally includes the capital investment, maintenance and operations expenditures, and, if applicable, fuel expenditures. Since the project is a solar power plant, the LCOE does not include fuel and variable O&M costs. Lastly, the LCOE calculation uses the weighted average cost of capital (WACC) as the discount rate to incorporate expected returns to cover the financing of the project.

The calculations take as input the cost estimates proposed in Section 6.2 and applicable WACC summarized in Table 7-2.

*Table 7-2 Summary of assumptions for LCOE calculations*

| Parameters | Value |
|---|---|
| Plant capacity | 150 MW |
| Plant lifetime | 25 years |
| Total generation over plant lifetime (P90 probabilistic solar yield) | 6,048,757 MWh |
| Debt-to-equity ratio | 70%:30% |
| WACC (real, pre-tax) | 7.00% |
| Capital expenditure (CAPEX) | 1,361.66 USD/kW |
| Operation expenditure (OPEX) | 18.44 USD/kW/yr |

Table 7-3 shows the estimated levelized cost of energy using the assumptions above. An equivalent value in Philippine peso is also shown using the 2020 annual average US dollar-Philippine peso foreign exchange rate from the Bangko Sentral ng Pilipinas.

*Table 7-3 Breakdown of estimated levelized cost of energy*

| Tariff breakdown | Value (USD/MWh) | Value (PHP/kWh) |
|---|---|---|
| Levelized CAPEX | 70.99 | 3.52 |
| Levelized OPEX | 11.20 | 0.56 |
| LCOE | 82.19 | 4.08 |

Compared to the solar PSAs in Table 7-1, the estimated LCOE for the floating solar project is higher than the base price of recently filed solar PSAs, which are below 3 Php/kWh. However, accounting for the escalation provisions under those contracts would make the price gap smaller across the duration of the contracts. The estimated LCOE is lower than the contract prices of older solar PSAs.

# 8 RISK ANALYSIS

The Consultant have observed few key issues to be considered while developing this project. The issues are marked with an appropriate level of risk, as shown in the below table.

*Table 8-1: Risk Matrix-Feasibility study of the project*

| No. | Subject | Risk Level | Implication | Mitigation | PIC |
|---|---|---|---|---|---|
| 1 | Capacity Approval by DOE | High | If the capacity allocated by DOE is less than the proposed 150MWac capacity, the project development approval may get stalled until the next notification | DOE to be informed in advance about possible project capacity and any suitable plan to check and accommodate the proposed capacity in their plan | Owner |
| 2 | RoW issues for Transmission line and Rights to use the Reservoir | Medium | RoW for transmission line will most likely pass through the private lands, there could be a possibility of potential RoW/Rights issues. This can become social impact and might delay or stall the project | Project Owner would ensure from local authorities to take prior approval for the use of identified areas of the TL route. Use of existing transmission line to be considered as technical preferred solution. | Owner |
| 3 | Selected Key equipment | Medium | The facts and figures presented in the study are as per the equipment selected at this stage. Will change once EPC tendering and construction phase starts.<br>Experience of EPC contractor and equipment suppliers with FPV and specific requirements needs to be scrutinized during selection. | As long as the EPC complies with the conceptual design and Minimum Technical Requirements and the performance estimated in the tender documents, the change in equipment will not have significant impact in production.<br>Selected equipment shall have appropriate IP ratings | EPC |

| No. | Subject | Risk Level | Implication | Mitigation | PIC |
|---|---|---|---|---|---|
| | | | | due to the project environment. Warranty of the selected equipment shall be made available for the project environment (floating PV) by the suppliers. | |
| 4 | Un-appropriate Electric Design | High | Any carelessness in designing the electrical scheme for this system could become hazardous , due to water and conductive environment. For ex: Cable insulation is essential to avoid cables contacting the water, causing short circuit to the system. | EPC shall have proven track record with FPV plants. EPC to comply with international acceptable standards and proven design methodology for FPV. | EPC |
| 5 | Conceptual Design | Medium | The design indicated in the report is indicative and for the purpose of conducting a feasibility study. It may change once EPC tendering and construction phase starts. | The detail design and engineering done by any party should comply with suitable and appropriate industry standards | Owner /EPC |
| 6 | Intermittent nature of Solar Radiation | Medium | Sudden drop or peak of solar radiation may affect the operation of the whole system. | SolarGIS is a popular and bankable tool and its solar resource is utilized in conducting the Feasibility study at this stage. Grid impact study must evaluate the ability of the grid to absorb variations | Owner /EPC |

| No. | Subject | Risk Level | Implication | Mitigation | PIC |
|---|---|---|---|---|---|
| | | | | and plant sizing should be made accordingly. | |
| 7 | Site Topography | High | It has been duly noted that the water level variation is very high, which goes up to 65m variation. This scenario is unique for floating projects of this type and scale and will have significant impact on detail design, construction management, construction schedule and commercial aspect | The detail design needs to be appropriately and carefully done by the EPC contractor, due to large water level variation. The selection of mooring and anchoring systems is very critical and must be suitable and strong for the project. Detailed design report and detailed design review meeting regarding anchoring to be hold points for the project in the design phase. | Owner /EPC |
| 8 | Water Quality for Module Cleaning | Low | Dirty water will spoil the Module surface and cause the energy generation | the quality of water to be checked in every cycle | Owner /EPC |
| 9 | Spare management for O&M | Medium | lack of appropriate spares, may cause loss in power generation in case of any preventive or corrective shutdown | Since the project site is based on a Reservoir, the spare management and storage is an important task. The spares are to be acquired as part of the EPC contract and maintained as per standard industry practice as well. | Owner /EPC |
| 10 | Construction management & Schedule | High | Lack of experience in development and construction of such large scale FPV project | It is recommended to<br>a. Write specific and appropriate qualification criterion for the selection of | |

| No. | Subject | Risk Level | Implication | Mitigation | PIC |
|---|---|---|---|---|---|
| | | | may lead to delay in schedule and also could have hazards | suitable equipment supplier Owner to approve each supplier before placing order<br>b. The EPC turnkey supplier must design the project complying to all necessary standards, specifically FPV<br>c. The risks in design and engineering should be timely discussed and resolved. Hold regular design review meetings for critical parts of the project.<br>d. The construction of the site should be done only by qualified technicians<br>e. Possible health hazard due to working on deep waters and MV and HV on water should be carefully studied and all possible EHS scenarios must be complied and followed<br>f. May allocate more contingency period in the implementation schedule | |
| 11 | Debris (trees, small woods from upstream of the reservoir) | High | The reservoir is prone to be the destination of debris being washed from the upstream. This will go right through the FPV blocks as well as through the underwater mooring | Project Owner to ensure in the detail planning that debris collection/screening system upstream of the reservoir (entrance of the reservoir) will be available. | Owner /EPC |

| No. | Subject | Risk Level | Implication | Mitigation | PIC |
|---|---|---|---|---|---|
| | | | cables. If this happens, it would be difficult to remove these debris and there will be high possibility of damage for the mooring cables, and consequently the FPV blocks. | The method/system of disposing of collected debris shall also be included in the planning | |
| 12 | Construction sequence and duration | High | There is no identified construction assembly area or launching area identified close to the reservoir. This will lead to double handling and pre-assembly in area's away from the reservoir. This is a new way of installing floating solar and might lead to additional cost and time for the construction. | As part of the EPC selection process, the EPC shall make a detailed write up on the step by step process of the parts arriving at site up to the parts having been installed on the reservoir. This write up shall play a major role in the selection of the EPC contractor. | |
| 13 | Potential failing of FPV mooring | Low | Can Impact integrity of the dam if the mooring components as well as FPV floating island components are swept/drifted to the dam | Proper design of mooring and selection of the right materials for mooring cables | |

# 9 SUMMARY & RECOMMENDATIONS

In all the above sections, the Consultant have carefully Collected, Analyzed and Generated the relevant results with respect to the feasibility of this project. The details with Consultant's views and comments are already included in each of the section and sub sections, however, the compiled notes are as given below:

- The Feasibility Study was conducted after reviewing the available inputs from documents provided by the Project Owner and the findings during the site visit. The Consultant was of the opinion that the provided documents contains some key information.
- For the power evacuation, AFRY believes that the most economical solution is to use the existing SRPC hydro-plant 230kV substation by extending the bay as the existing network can still accommodate the additional 150MWac to 165MWac of the FPV. But if there is any administrative, legal and control issues on this, the other options are to build a switching station so the FPV can connect to the existing transmission line, or the FPV plant can directly connect to the NGCP Nagsaag substation by building a new transmission line from the FPV plant substation. The cost of these options is the lowest for using the SRPC substation and the highest for a new transmission line directly to NGCP Nagsaag substation.
- The identified Reservoir is a natural body of water, however, considered as slightly complicated for developing a floating PV project. This is mainly due to the uneven bed bathymetry and huge water level variations. This has been conveyed by few suppliers who are working in this segment. However, Consultant have considered all the aspects and have successfully completed this feasibility study. The project will face a reasonable amount of challenges but is feasible.
- Due to the large variation in water level, the layout has been planned in such a way that the FPV blocks are positioned inside the available surface of the lowest water level but mooring length is designed so that it will have room to adjust its position when the water level goes up or down. This scenario is very unique, as very limited information were found on the public domain or from the leading suppliers which are close to the assumptions and facts of the subject plant. However, the indicative design and layout prepared shows clear idea about the feasibility and risks involved in the project. The Consultant highly recommends that the turnkey suppliers of these systems should be consulted with the accurate project information in the next stage of the project.
- The Project capacity for the first phase is considered as 150MWac to 165MWac at the evacuation side, whereas the DC capacity is optimized at 178MWp.The Equipment selected are indicative and purely for the purpose of feasibility study. Therefore the EPC later might like to optimize the design and cost based on their own patented technology or other preferences. The total FPV capacity (first phase plus the expansion) can reach up to 450MWp to 500MWp if the entirety of the reservoir will be utilized and consideration to use higher wattage PV modules of up to 700Wp (if available in the future), the possibility of using string inverters and optimization of the blocks and PV islands. The mentioned optimization can be done in the detailed FS or FEED.

- The Float has been arranged in such a way that they form clusters (like blocks) or islands and are replicated throughout the PV layout.
- For mooring, gravity anchoring has been selected for the feasibility study due to many reasons detailed out in the section.
- During the site visit it became clear that there is no construction/assembly area or launching alongside the reservoir. Most FPV projects are being assembled along the waterbody and then with a gentle slope pounced in to the water while the assembly progresses. This will not be possible for SRPC. This means a new assembly/construction method will need to be developed based on pre-assembly more away from the reservoir and then final assembly of the pre-assembled parts on the water. This is a further challenge for the project and its duration. Possible location of the assembly area is at the upstream of the spillway having an estimated available area of 4.7Ha. Earth works such as grading and tree cutting will be required so this area can be used for the assembly during the construction.
- The Energy yield assessment was performed and the following data was generated:

| Parameters | Values |
|---|---|
| Global Horizontal Irradiance (kWh/$m^2$-yr) | 1,886.10 |
| Initial PR | 81.12% |
| Initial specific yield (kWh/kWp-yr) | 1,559.19 |
| 1st year energy production (kWh) | 274,424,673 |
| DC Capacity Factor % | 17.62% |
| AC Capacity Factor % | 20.61% |

The above can be further optimized during FEED and detailed engineering.

Above are the key notes from the study conducted by the Consultant.

The Consultant opines that the Project has a lot of (technical) challenges but the project is Feasible provided that all the risks associated with the challenges are identified and  addressed and carefully studied and taken care of during the detail planning including sufficient design review meetings and reports by competent Consultants.

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