

500kWp Floating Solar Power Plant At Banasura Sagar Kerala – An Overview



Introduction



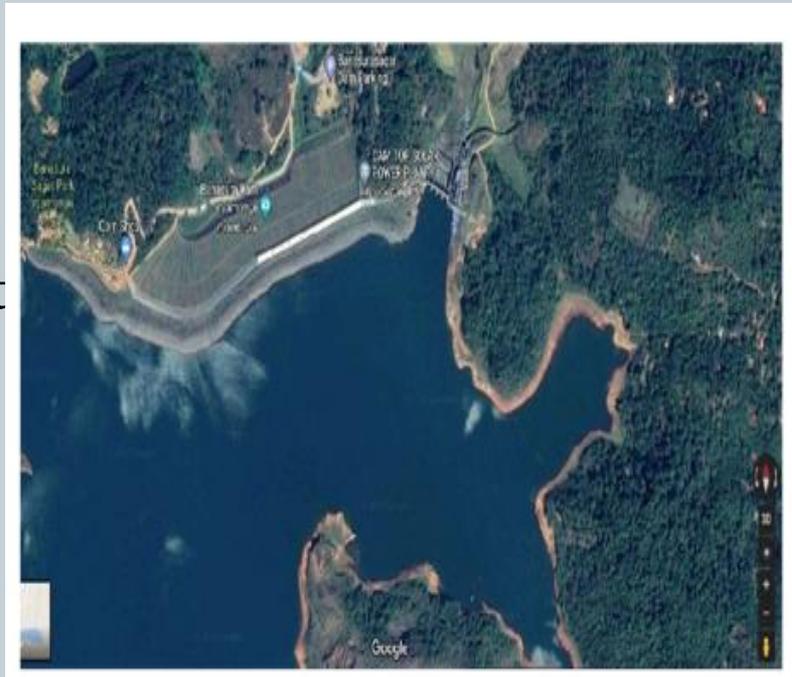
The Banasura sagar 500kWp Floating solar power plant situated in Kerala , the largest of its kind in India is commissioned recently in the Banasura sagar reservoir, an innovative project done by the Kerala State Electricity Board Ltd



Introduction

Project Location

The project is located in the Banasura sagar dam reservoir in the state of kerala , a dam originally constructed in the year 2005 for the purpose of the irrigation and reservoir in the Karamanthodu a tributary of Kabani river and later for Kakkayam Generating station of kerala State Electricity board ltd



Brief History of the project

Pilot floating solar project at Banasura sagar Dam

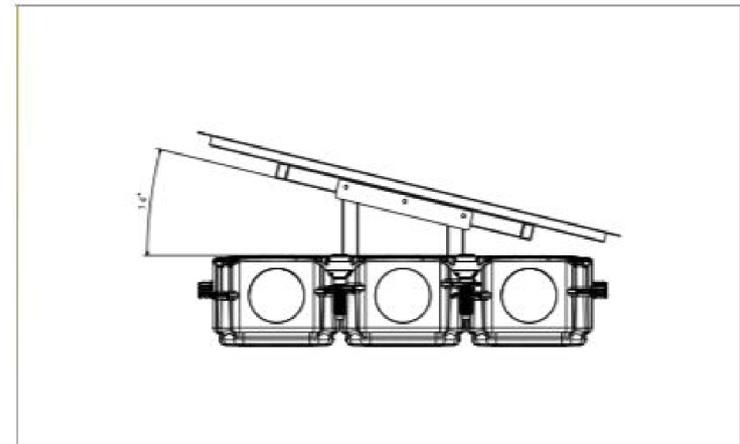
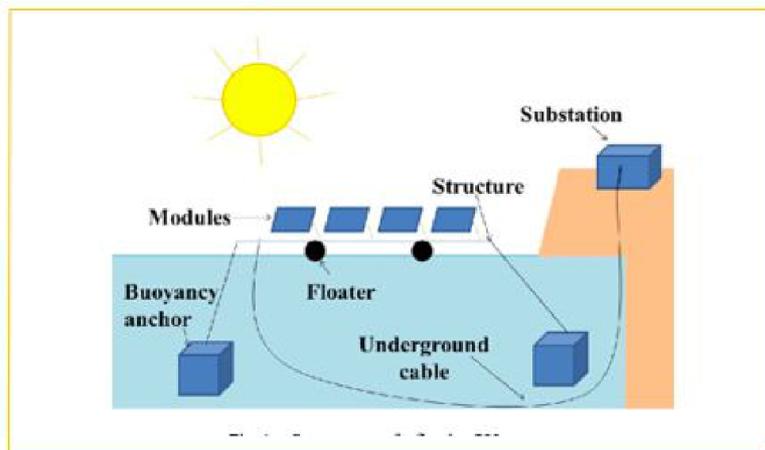
KSEBL has been considering Floating solar power plants from 2013 onward . Kerala State Electricity Board (L) has successfully tested and commissioned a 10 kW floating solar power plant using ferro cement platform as a start up project before taking up the 500 kW project



Introduction to floating solar power plants



Working Methodology – Floating Solar PV



A majority of the installations utilised a *floating pontoon* constructed either from fibre-reinforced plastic (FRP), Medium Density Polyethylene (MDPE) or Ferro-cement, High-Density Polyethylene (HDPE). The solar PV modules were supported on these pontoons through the use of metal structures and were inclined in a majority of cases to maximise the solar incidence.

Salient features of Floating Solar power plants



- Floating solar power plant is best suited where the land availability is an issue and the land cost is escalating .
- Conventional land based Solar power plant requires a large area about 4 to 5 Acres of land to produce 1 MW of Energy .
- Further this land can not be normally used for any other purposes . Also cleaning of the power plant requires more water which is also a problem considering the availability of water
- By using the floating power plant where the solar PV panels are placed over the float in the water body can address the issue of land , the water requirement for cleaning the PV modules .



- Floating solar power plant conversion efficiency is more compared to the plants installed at the land due to reduced temperature in the PV modules in floating environment .
- Another advantage of the plant is that it reduces the evaporation from the reservoir thereby conserving the water.
- The floating solar power plant can be installed in reservoirs , ponds and lakes and other water bodies including sea .

Components of floating solar power plant



Major Components of Floating Solar PV Plant



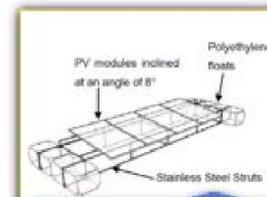
Solar PV Modules



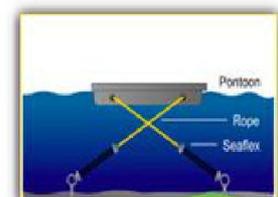
Central/String inverters



Module Support System



Pontoon/Floating Structure



Mooring System



Grid connect equipment



SCADA



Cables & connectors



Transformers

Major Components of the Banasura Sagar Floating power plant



- The float made up of ferro cement platform
- The Mooring and anchoring system
- The PV modules and panels
- The string inverter
- The low voltage AC cables and its protection
- The step up transformer and HV cables
- The HV cable Management system
- The Scada system
- The earthing and lightning protection
- Weather monitoring system



Floating plat form

- There are 17 plat forms made of Ferro cement which is used for placing the solar panels and inverter
- A central plat form for the substation and control room and Scada system
- The float is held in place by seaflex mooring and anchoring system.
- The total area of the float is 1.23 acres

Construction of the ferrocement plat form

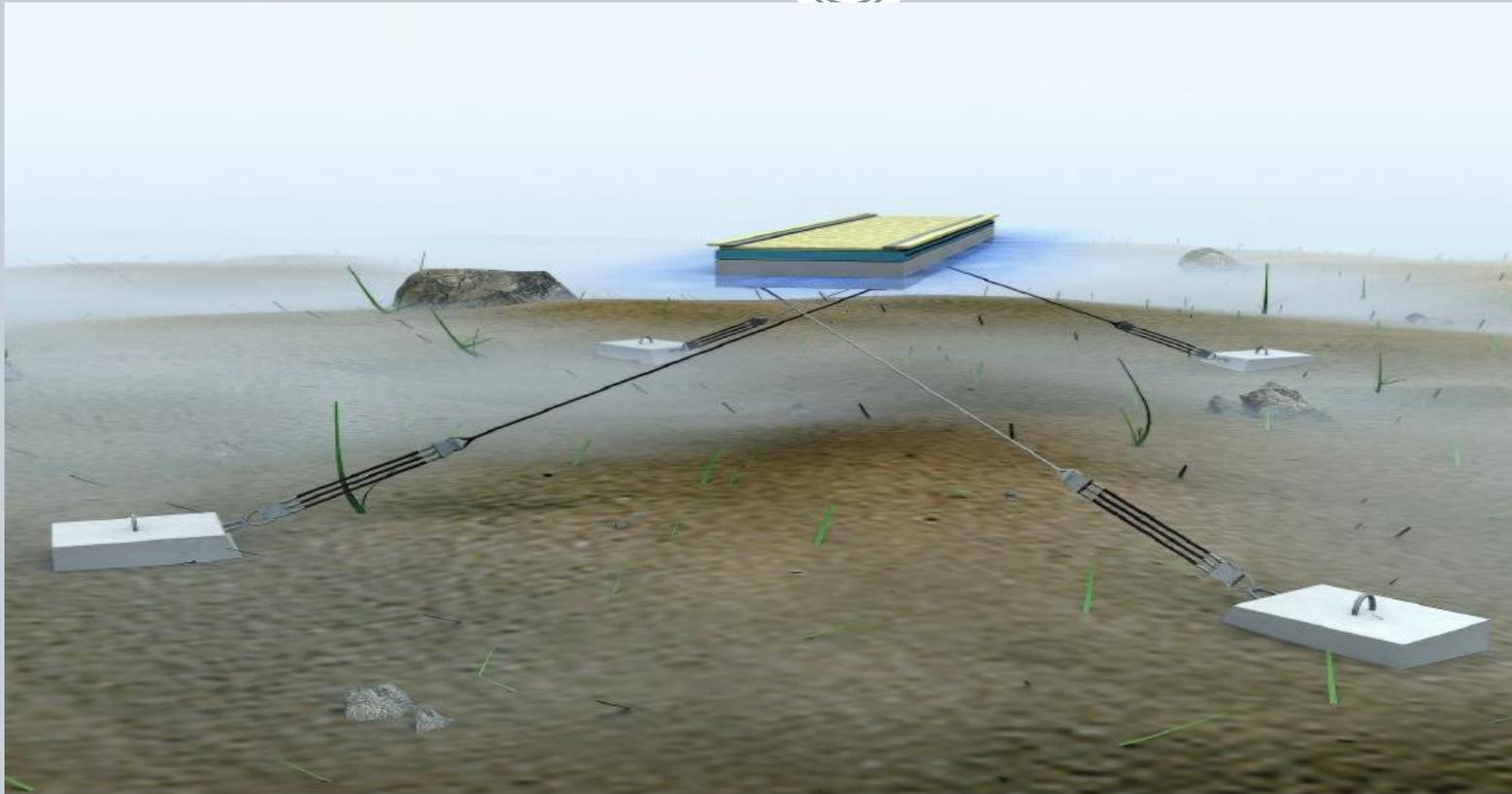
The platforms are constructed at the shore and later pulled to the location of the plant

Ferro cement platforms



The construction site of the ferro cement platforms

Mooring and anchoring system



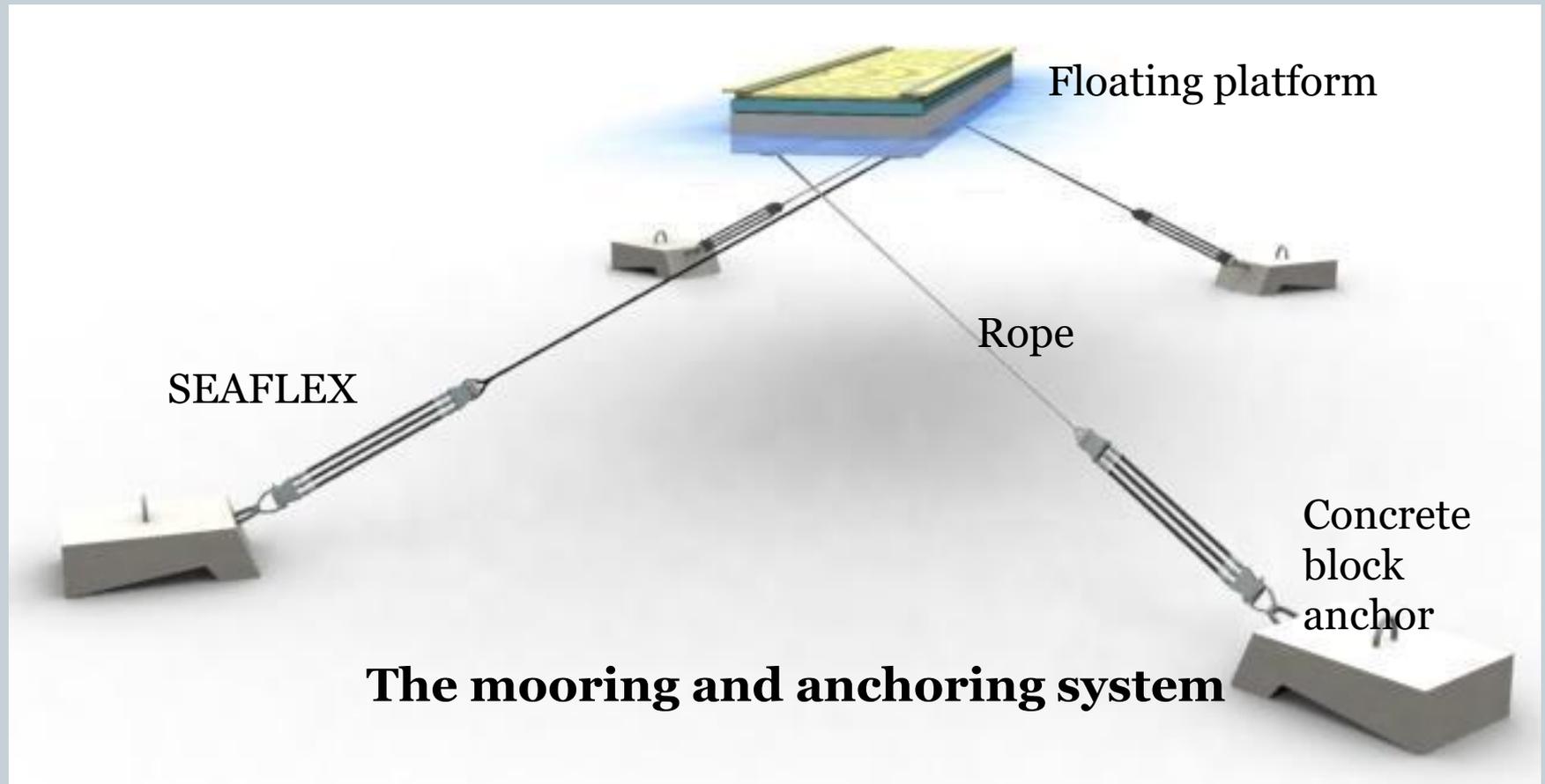
The Mooring and anchoring is used to keep the float in position against the external forces and water level variations

Mooring and Anchoring system



- This project uses the SEAFLEX mooring system which consists of a SEAFLEX and a rope to hold the float in position against external forces and water level
- The SEAFLEX is the active part of the mooring, adjusting for water level changes while also taking care of forces.
- SEAFLEX is always tensioned at lowest water level.

Mooring and Anchoring system



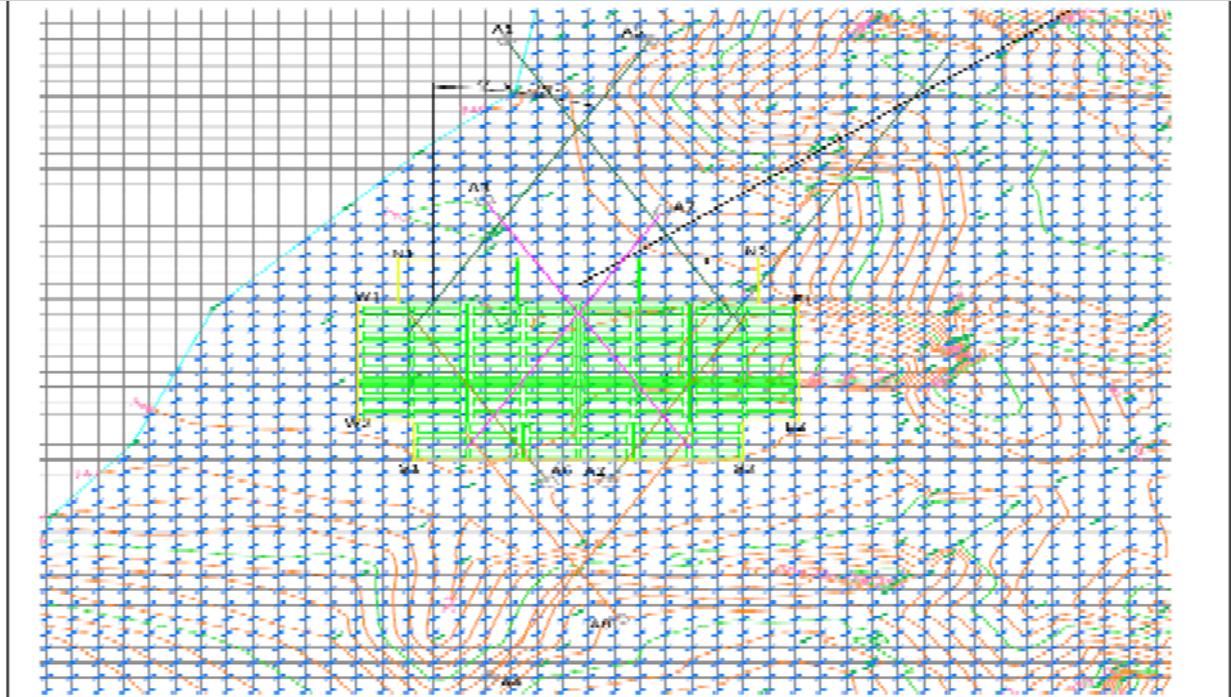
Mooring and Anchoring



Dimensioning Parameters

Location	Banasurasagar Reservoir, India
Max wind speed	32m/s at 10 m height
Depth at lowest water level	Avg. 15 m
Water level variation	Design Lowest Water Level: 755.5 ref. to MSL Total Water Level Variation: 20.74m
Wave height	0.3 m (H significant)
Current	- (No current)

Mooring and Anchoring system



Position of the anchors and mooring system as per design

PV Panel Placements



Placement of PV panels on the plat form

- The PV arrays are placed over the plat form in two ways
 1. on Ferro-cement Platform
 2. on Water Body



•PV PANELS ON FERROCEMENT



ON WATER BODY

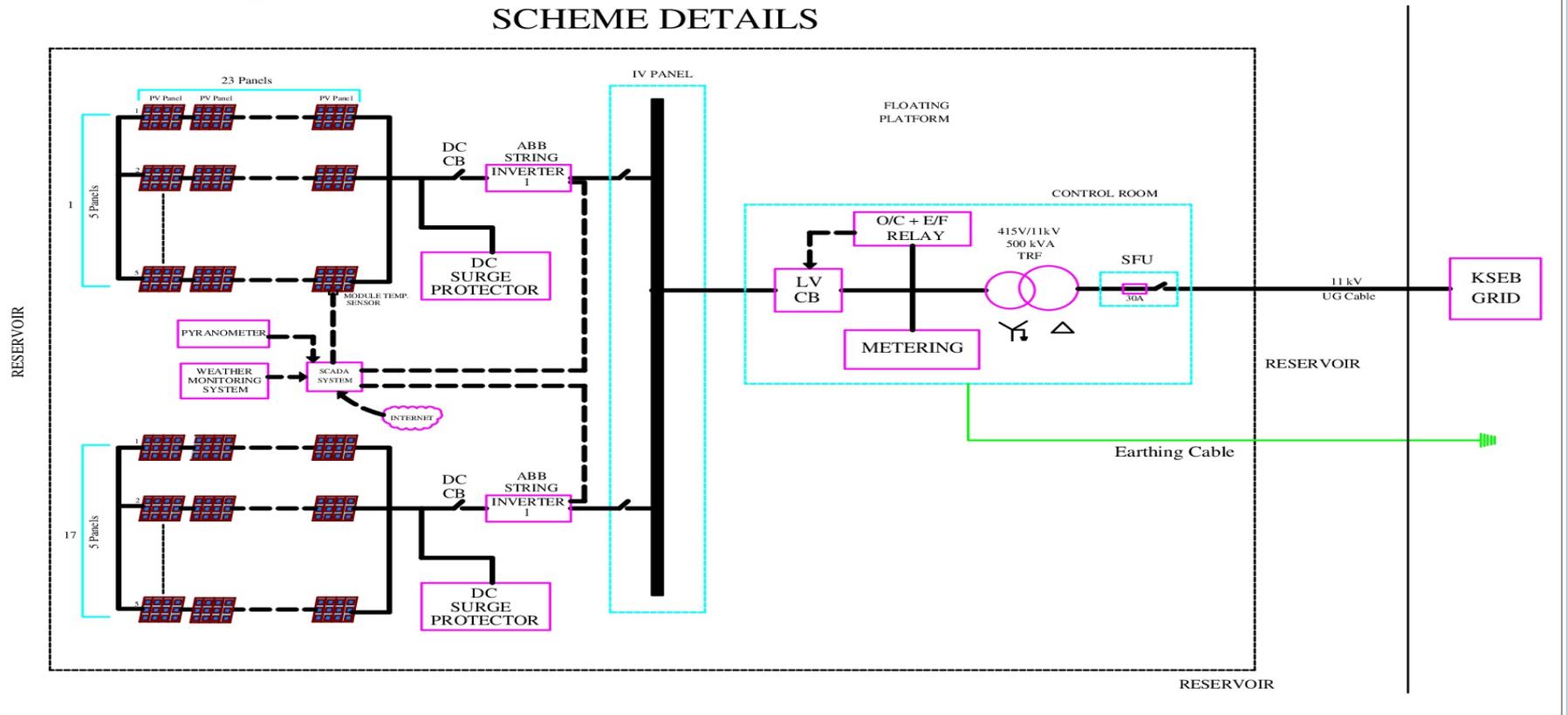
PV panel placement



- Even though the temperature of the panels are lower as it is on the floating water ,specific attention was given to place the panels directly over the water body by suitable design of the plat form as shown in the picture . Investigation is on for comparing the efficiency of the Floating PV plant with that of the nearby dam top solar power plant

Electrical schemes

KERALA STATE ELECTRICITY BOARD Ltd. 500 kWp BANASURA SAGAR FLOATING SOLAR PROJECT SCHEME DETAILS



Details of PV module



Electrical details of the PV module

Solar Panel – Radiant Solar RS260P – 60

	W	260
Maximum Peak Voltage, V_{mp}	V	31.60
Maximum Peak Current, I_{mp}	A	8.23
Open Circuit Voltage, V_{oc}	V	37.73
Short Circuit Current, I_{sc}	A	8.96
Maximum System Voltage	V	1000

Configuration of PV modules



String details

Number of String inverters	17
Number of strings connected to each inverter	5
Number of Modules connected in each string	23
Total DC voltage of string V_{dc} $= 37.73 \times 23$	$867.79V < 1000V$ (V_{dc_max})
Max Mppt Voltage $Mppt = 31.6 \times 23$	$726.80V > 610V$ (V_{start})
$I_{dc} = I_{sc} \times \text{Number of panels in parallel}$ (8.96×5)	$44.8A < 80A$ (I_{sc_max})
$I_{mppt} = V_{mp} \times \text{Number of panels in parallel}$ (8.23×5)	$41.15A < 58A$ (I_{mppt_max})

SOLAR PV ARRAY



Grid connectivity



11kV substation and Grid synchronisation

The 11kV substation with 415/11 kV 500kVA , Star- Delta Power Transformer is placed on the central platform and the grid synchronization is done in the float .

The power from the float is evacuated to the shore through a 11kV XPPE power cable specially designed for the application

Net metering is placed in the HV side of the plant

11kV cable Management system



- **Cable Management system**



- Special graded 11kV cable is used for the transmitting the power generated in the floating solar plant to the KSEB grid . A cable management system with pulleys are used for allowing the free movement of the cable when the water level in the reservoir is varying due to seasonal changes

String inverter



String inverter ABB PRO 33.0-TL-OUTD

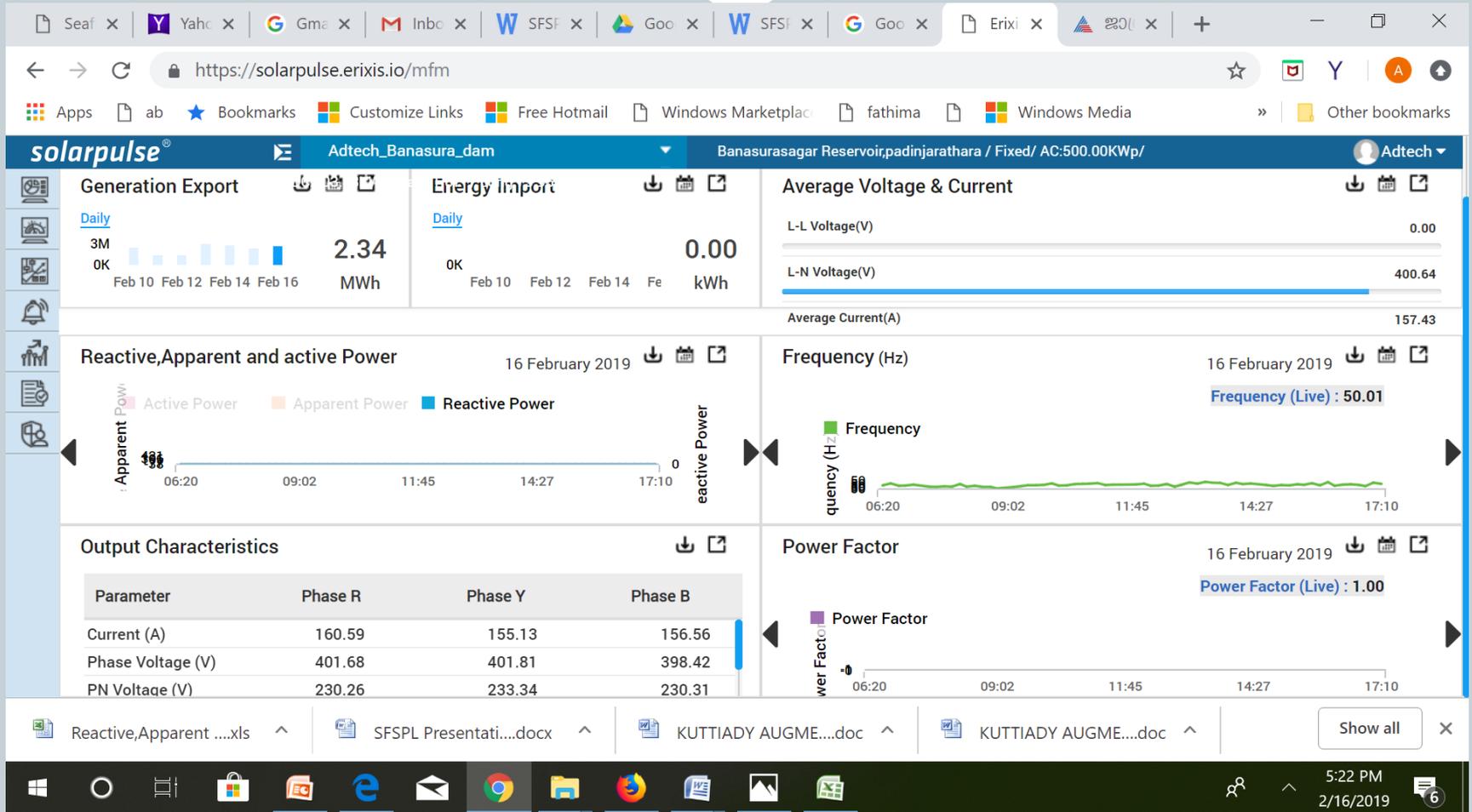
Absolute Maximum DC Input voltage, V_{max_abs}	V	1100
Startup DC input Voltage, V_{start}	V	610
Operating DC Input Voltage Range, V_{dc_min} to V_{dc_max}	V	580 to 950
Rated DC input Voltage, V_{dcr}	V	580
Rated DC input Power, P_{dcr}	W	33700
Number of MPPT		1
MPPT Input DC Voltage Range, V_{mppt_min} to V_{mppt_max} at P_{acr}	V	580 to 850
Maximum DC Input Current I_{dc_max} /for each MPPT, I_{mppt_max}	A	58
Maximum Input Short Circuit Current, I_{dc_max}	A	80

SCADA SYSTEM



- The Scada system in the plant is connected to the inverters , whether monitoring station and metering equipments, other monitoring devices . The scada system is having the facility for
- Device monitoring – Inverters , Metering and Weather station
- Alarms
- Trends
- Technical Reports and
- Executive reports

Scada system



SCADA SYSTEM SCREEN SHOT

Earthing



Earthing challenges

- As the substation used to step up the Voltage from 415 V to 11 kV for synchronizing with the KSEBL grid, the 11 KV grid the Earthing provided shall reduce the step and touch potential to a safer value so as to avoid any possible hazard to the operating personal in the Float .
- Presently there is no international or Indian standard that can be followed for the design of Earthing of floating solar plant with 11kV substation in the float ,
- There is certain risk of fault current to be allowed to flow through the reservoir water .
- However ,as per the IEEE 80005-1 ,the earthing method to be followed while the ship takes short stay in the port and it take power supply from the shore .
- This is achieved by earthing the metallic structure of the substation directly to the shore by using redundant Insulated cable

Relay and protection



Relay and protection

- 11 KV side of the plant is protected by the over current earth fault protection in the feeder connected to 33 kV Padinjara substation .
- Over voltage , under voltage, over frequency, under frequency protection and anti islanding protection working in the active mode is set in the Inverter which trips and disconnects the inverter with the grid in case of abnormal conditions
- LV side of the power transformer is protected by over current and earth fault protection which trips the LV CB in case of faults in the AC cable between Inverter and the Transformer

Conclusion



Conclusion.

- The details of the floating power plant and its installation on the ferrocement float has been discussed in this report. The solar plant and the 11 kV substation are placed over the ferro cement platform and the DC to AC conversion is done near the plant itself as a result of which there is savings in the cost of the DC cable
- As the power is converted to MV 11kV alternating current , the power loss is reduced in this typical design .
- The mooring and anchoring system used in this plant has proven to sustain in recent heavy floods in kerala
- Even though the cost of the ferro cement float is higher than that of HDPE panels , ferro cement plat form is made in the site itself which is certainly an advantage in difficult terrain
- In this typical design , the 11kV substation is placed over the float and the float has the flexibility to place bigger capacity transformers in case of future expansion

conclusion



- The floating plant requires less space compared to land based plants . The area requirement for the Banasura Project is app 1.23 acres for 0.5 MW where as the land requirement for equvalant land based system is 2 to 2.5 acres
- The floating solar environment especially in the reservoir will be comparatively cleaner than that of land based power plant and hence the maintenance cycle can be reduced
- There is no land cost or land development cost etc in floating solar power plant and the floating plant can be installed in short time comparatively
- The power evacuation cost of the floating plant in the reservoir connected with the hydro plant will be less as there will be nearby substations for the hydro plants

Conclusion



- The shadow in the reservoir will be comparatively low and hence the available power generation time in the floating solar will be more than that of land based pV plants
- Floating plants if used in the cooling reservoirs will have the advantage of less water evaporation and the better utilization of the available space
- The efficiency of the plant is directly related to the cleanliness of the modules . The PV modules can be easily cleaned in floating plants . Also the reservoir water can be used for cooling of the modules which in turn increases the efficiency

Future improvements and suggestions



Future improvements and suggestions based on the experince

- Even though the floating solar power plant efficiency increases with the reduced panel temperature , there is large difference noticed with ambient temperature and the module temperature especially during the peak time of the day . An automatic cooling system using the water in the reservoir that operates based on the temperature information from the sensor can be used to bring down the module temperature and the efficiency of the plant can be improved .
- The equipotential earthing achieved by connecting the metal parts of the floating solar to the remote shore is very vital for the safety of the operating personal . Hence by introducing an earthing monitoring system that can be connected to the Scada system , which monitors the condition of the earth can be used for further improving the safety of earthing
- Water level variation and flow velocity variations are important factors in mooring system design hence while identifying sites including dam reservoirs these factors have to be analyzed.

Future improvements and suggestions



- Earthing of the floating solar power plant especially when the substation is in the float need to be analyzed and designed to see that it meets all safety and protection requirements
- Banasura Sagar floating solar power plant is taken up as an innovative project as floating solar projects are relatively a new concept and hence project cost aspect need to be controlled in future projects considering other options for floats .