Design and Analysis of a Hybrid Power System for McCallum, NL, Canada

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***Abstract* — Although solar power plants have several advantages over conventional power generation methods, the main issue is the need for land, which is used for agriculture globally, as well as the expense. With the help of a floating solar photovoltaic (FSPV) system, the problem of land constraints can be solved. FSPV can be put in any water section, which will boost generation by utilizing the cooling impact of water while also lowering the cost of the land. In this research, an on-grid FSPV system is designed and analyzed for McCallum, NL, Canada. The designed system can reduce remote site diesel consumption by 70%.**

***Keywords* — Cost Analysis, Floating Solar System, Feasibility Analysis, Hybrid Power Plant, McCallum.**

I. Introduction

Energy is a crucial factor in generating wealth, social development, and improved quality of life in all developed and developing countries [1]. Global energy demand is likely to grow faster than population growth. Almost 80% of the world's energy demand is being fulfilled by fossil fuels [2]. As a result, the reserve of fossil fuels is reducing rapidly and fossil fuel consumption increases carbon emission, which escalates the average temperature of our surroundings. In this situation, experts are paying attention to renewable energy resources, resulting in carbon emission reduction, and reusing natural energy resources to generate electricity. Renewable energies are energy sources that are continually replenished by nature and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy sources are not only limitless energy sources in the future but also environmentally friendly and environmentally sustainable due to the ongoing depletion of fossil fuels and the rising energy demand. Power generation using fossil fuels majorly contributes to Carbon dioxide (CO_2) emissions which is very harmful to the environment.

In this context, alternative energy sources named Solar, Wind, Hydro, biomass, and geothermal are getting more priority to replace that fossil fuel-based power generator.

By doing this, we can reduce the environmental effect, i.e., the greenhouse gas emission by 50% [3].

By using these alternative energy sources, we can supply electricity to remote communities. There are some inaccessible areas in the whole world where the grid connections are almost impossible to reach. The area which we have selected is one of them, which is surrounded by the Atlantic Ocean. This area is known as McCallum which is a part of one of the four Atlantic provinces of Canada, Newfoundland, and Labrador. It is located on the southern shore of this province. There is a small community of 73 people in this area [4]. Most of them use Ferries, Speed boats and Seaplanes as the modes of their transportation. As this place is totally isolated from the mainland, they do not have grid connectivity. Though they have their own fossil fuel-based generator, this is not enough to meet up their daily needs. There is a hospital which runs only for two days a week due to lack of electricity. This kind of uncertain situation is harmful for that community. Moreover, due to unstable sources of electricity, most of the families struggle to do their household activities.

To overcome these problems, alternative energy sources can be a better option. Working along with the fossil fuel-based generator, we can reduce the energy shortage and provide clean energy to that community. Considering the location, we could use the wind turbines. However, for the gusty wind in the seashore area, these turbines may get damaged. Moreover, there is no water flow from upstream and no chance of building dams. That is why constructing a hydropower system will be much more expensive for this small community. The geothermal and bio-gas process will not be that much effective for this location. For these reasons, we can only consider solar power to generate alternative energy for that community.

Solar power is now a significant source of renewable energy. It is utilized for various purposes, including commercial applications, solar heaters, and pumps. Solar electricity helps to alleviate the paucity of integrated grid power. The area which we have chosen is surrounded by tall mountains. No availability of plain surface hinders setting up conventional solar panels. In this prospect, a floating solar photovoltaic (FSPV) system will be a better option for the selected site.

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II. Literature Review

Technological change is inevitable as it continues to grow and touch every big infrastructure of the world. Floating solar power plant is an innovative approach of using photovoltaic modules on water infrastructures to conserve the land along with an increase in efficiency of the module. Shatil *et al.* [5] designed a floating solar panel for Chalan Beel, Bangladesh. They investigated installing floating solar panels in Chalan Beel, Natore, Rajshahi. The comparison of the ground-mounted panel and floating panel based on electrical factors such output power and cost are also seen throughout the experimental setup. After the analysis, it is found that the energy conversion cost in the floating panel set up is 0.57 cents/kWh, which is acceptable. Sachin *et al.* [6] reviewed some of the floating PV plants installed in India. This paper focuses on the floating PV technology, describing the types of floating PV plant along with studies carried out on some floating solar plants. Additionally, the feasibility of putting in 1 MW floating PV plants at the Kishore Sagar and Kota barrages in Kota, Rajasthan, is shown. The two plants' potential energy output, water conserved from evaporation, and a decrease in CO_2 emissions are all calculated in this study. A 1 MW floating plant at the Kota Barrage may generate 18,38,519 kWh of electricity annually, conserve 37 million liters of water, and lessen CO_2 emissions by roughly 1,714 tons. A 1 MW floating plant in Kishore Sagar Lake may generate 18,58,959 kWh of electrical energy annually, conserve 37 million liters of water, and lessen CO2 emissions by roughly 1,733 tons. Oufqir *et al.* [7] outline a model and control scheme for a solar-powered freestanding microgrid.

To test the effectiveness of the Microgrid, the photovoltaic panel, converters, and a storage device were researched and modelled. An MPPT (Maximum Power Point Tracking) algorithm, which manages the boost converter, extracts the best solar energy. On the other hand, the battery and the bidirectional DC-DC converter ensure that the DC bus voltage is stabilized and that the load is continuously supplied with electricity. A transformer and a DC-AC inverter provide power to the AC load. To create an effective microgrid, it is crucial to establish reliable control loops for these power converters. The simulation results shown in this work, performed in the MATLAB/Simulink environment, demonstrate that the proposed standalone photovoltaic system guarantees a constant frequency and RMS load voltage with a good THD value under various operating conditions (solar power and load variation). Temiz *et al.* [8] designed and analyzed a floating photovoltaic based energy system with underground energy storage

options for remote communities. The resilient solar energy-based system with energy storage options proposed in this study is specially engineered to produce electricity, heat, cooling, hydrogen, and ultimately ammonia. An ion exchange membrane electrolier, a pressure swing adsorption air separator with an ammonia reactor, and a heat pump are all integrated into the floating photovoltaic plant. Pumped hydro storage, high grade heat storage, medium-grade heat storage, and cold storage are the subsurface energy storage possibilities. The suggested system aims to utilize the underground storage infrastructure of defunct mines as well as floating photovoltaic plants on defunct lake surfaces. Challenges and opportunities towards the development of floating photovoltaic systems is presented by Kumar *et al.* [9]. This study presents an overview of various design and construction tactics, along with offshore PV technology

and the status of FPV systems. The specific design and structure of the FPV affect its output power generation, durability, and investment cost.

III. Methodology

A. Site Information and Resources

Before installing any renewable energy generating system in a specific place, the weather data and geographical conditions must be considered. The selected area for this project is McCallum, a local service district designated place in the Canadian province of Newfoundland and Labrador. As it is a hilly area [10] and there is a random possibility of having excess and unusual wind flow, installing wind turbines is not a prudent decision because the setup of a wind energy system may damage due to storms. Considering the solar energy system, we need a flat surface to install the solar photo voltaic modules. For this, the problem is the same. There is not enough flat surface to install the solar system due to the hilly structure of that area.

Besides, the area is not suitable for building a water dam for constructing a hydropower plant.

Fig 1. McCallum on the map of Newfoundland.

Due to these circumstances, the only usable part of that area is the water surface. So, a floating solar photovoltaic system is the perfect choice for that area. Floating solar is a concept that extends the theory of Solar Power Generation only, and through some structural modifications, we aim to obtain higher efficiency of the plant.

There were some limitations in going to the place and analyzing the solar irradiance data.

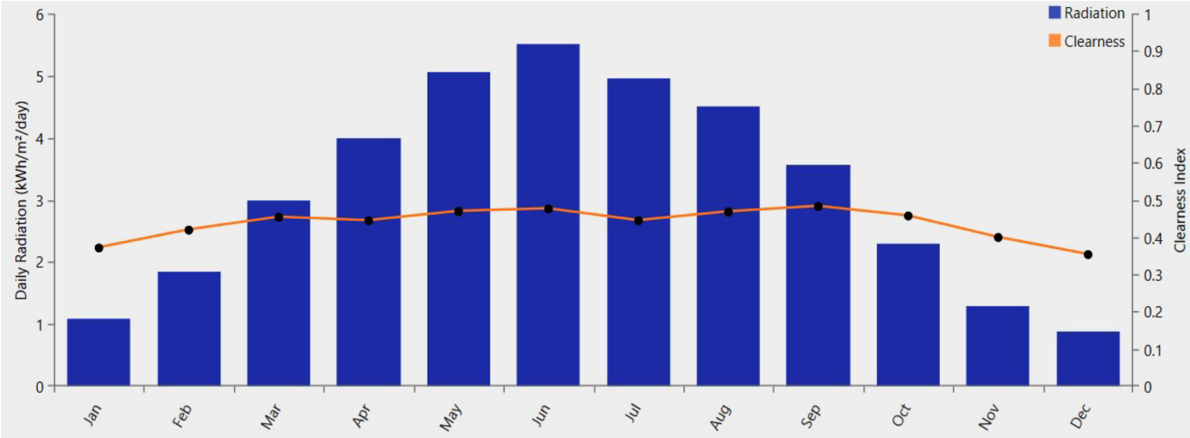

Fig. 2. Monthly Average solar GHI data of McCallum, NL.

However, we relied on "NASA – worldwide resource (Power) database" to collect up-to-date solar irradiance of this location and necessary diagrams. We observed the weather information from the past few years and presented an average data of Global Horizontal Radiation of past 22 years in this paper.

In the bar chart of Fig. 2, we have presented the average solar irradiation data on monthly basis for this location. This figure shows that, in the month of June, the daily solar radiation is 5 kWh/m^2/day which is the maximum comparing other months. Though in the winter season, the radiation goes down to 1 kWh/m^2/day, but this is enough to keep our microgrid operational for backup supply.

B. Diagram & Components of Solar-Powered Microgrid System

A Floating Solar system will consist of components given in Fig. 3.

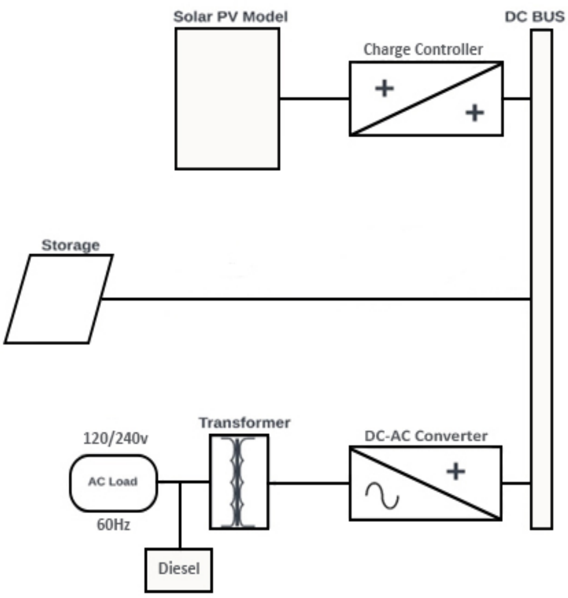

Fig. 3. A Schematic diagram of proposed floating solar system.

The diagram above depicts a simplified block diagram of a floating solar energy system for our proposed location. The solar panels will power the battery storage system. A charge controller regulates the battery input and output voltage and current from the solar panel in real-time. As a result, it keeps the batteries at their highest possible charging state while protecting them from being overcharged by the source and over-discharged by the connected load. Overcharging causes the charge controller to lose extra load. In case of overcharging, the charge controller will dissipate extra load through a dump load. Finally, DC power will be converted to AC power by a DC-AC converter before being distributed to all houses via a transformer. A diesel generator provides system backup power.

C. PV Configuration and Structure

1) Passivated Emitter and Rear Cell (PERC) panels

PERC solar panels are an advancement over conventional monocrystalline cells. This relatively new technology adds a passivation layer to the cell's rear surface, which improves efficiency in various ways.

- It returns light into the compartment, increasing the amount of solar energy absorbed.
- It inhibits the flow of electrons in the system by reducing the natural tendency of electrons to recombine.
- It allows for the reflection of longer wavelengths of light. Light waves longer than 1,180 nm cannot be absorbed by silicon wafers and instead pass through, heating the cell's metal back sheet and reducing its efficiency. The passivation layer reflects higher wavelengths, preventing them from heating up the back sheet.

2) Pontoon/Floating structure

A floating construction is called a pontoon. The buoyancy of a pontoon allows it to hold a hefty load while floating on water. The framework is built so that it can support several panels. PV modules can be installed thanks to a floating framework as shown in Fig. 4.

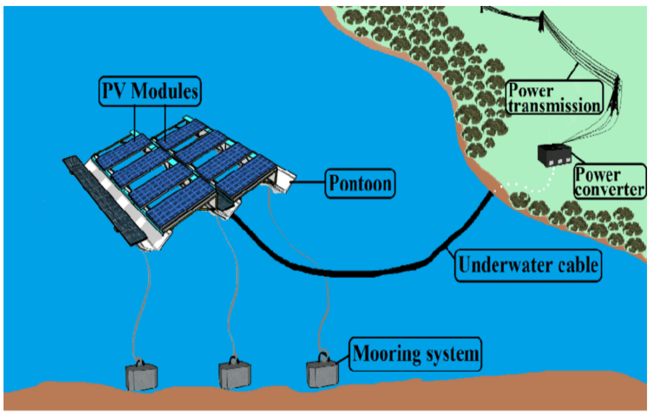

Fig. 4. Proposed structure for the floating solar system.

3) Mooring structure

A mooring structure is a permanent structure used to anchor floating structures. The anchoring prevents floating objects from moving freely on the water. Without anchoring the floating construction to the shore, an anchor mooring secures its location in relation to a spot on the waterway's bottom. This enables regulating water level changes while keeping its position facing south.

4) Solar module

Solar Modules are PV generation devices that are mounted on top of the floating system and resemble electric junction boxes. A single solar module can only generate a certain amount of power; therefore, most setups use numerous modules. Typically, a photovoltaic system consists of a panel or array of solar modules, a solar inverter, and occasionally a battery, solar tracker, and interface cable [11]. The floating solar systems have primarily utilized crystalline solar PV modules. The design of a floating platform, the distance between the water's surface and the PV array, and other factors all play a significant role in how much energy may be produced [12].

5) Power Generator

Our proposed system is coupled with three generators. These are 150kW diesel generator and already installed at our proposed site. Only one 150kW diesel generator will be needed after the installation of PV system.

6) Inverter

An inverter converts DC to Alternating Current (AC). The efficiency of the inverter plays a significant part as a less efficient inverter will result in some losses of energy in the system. So, while choosing an inverter, it is crucial to select an inverter which is having the highest efficiency rating in the market.

7) Charge Controller

A charge controller constantly regulates the battery output voltage and current from the FLPV. Thus, it maintains the batteries at their highest possible state of charging while protecting them from being overcharged by the source and from becoming over-discharged by the connected load. Maximum Power Point Tracking (MPPT) is one of the widely used charge controllers. One of the noticeable features of this controller is it can handle higher voltage input from the generation source than the battery bank's voltage.

8) Battery Bank

A battery storage system is used when solar system is out of operation or to adjust load consumption. Due to the scheduled maintenance works of the system, a battery storage system will act as a backup supply for the connected load. Normally, there are two types of batteries used in the energy storage system.

1. Absorbed Glass Mat (AGM)
2. Flooded Battery

AGM batteries are certainly a good choice in terms of maintenance as it does not require watering service. But considering the application of this project (i.e., Backup power applications) and battery longevity flooded batteries are typically the best choice and more cost-effective than AGM batteries.

IV. Equations for System Sizing

A. PV Module Mathematical Modeling

The basic equation of a PV cell can be represented as (1).

$$I_{pv} = I_{ph} - I_d - I_{sh} \quad (1)$$

where,
I_{ph} is the current of the PV cell, Id is the diode current,
I_{sh} is the current in shunt resistance R_{sh}.

The current of the PV cell is proportional to the irradiance (G), given in (2).

$$I_{ph} = [I_{cc} + K_i(T - T_n)] * \frac{G}{G_0} \quad (2)$$

I_{cc} is the light-generated current of a nominal operating condition, K_i is the temperature co-efficient, T_n is the nominal temperature, T is the actual temperature, G is the irradiance of the surface, and G_0 is the nominal irradiance. nominal temperature, T is the actual temperature, G is the irradiance of the surface, and G_0 is the nominal irradiance.

The equation of I_d current can be represented as (3).

$$I_d = I_0(Exp[\frac{V+(I \times R_S)}{A \times V_{th}}] - 1) \quad (3)$$

The thermal potential (Vth) is given by (4).

$$V_{th} = \frac{K \times T \times N_S}{q} \quad (4)$$

where,
k is the Boltzmann constant ($1{,}381.10^{-23}$J/K),
N_s is the number of series-connected cells,
q represents the electron charge (1.6×10^{-19}).

The reverse saturation current I_o is calculated using (5).

$$I_0 = I_{on} \times \left(\frac{T}{T_n}\right)^3 \times e^{\left[\frac{q.Eg}{A.k}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right]} \quad (5)$$

where, E_g represents the bandgap of the semiconductor (1.12eV), A is the diode ideality factor (1< n < 2), I_{on} is the reverse saturation current in standard temperature conditions, calculated using (6).

$$I_{on} = \frac{Icc}{e^{\left(\frac{Vco}{Vth * A}\right)} - 1} \quad (6)$$

The current I_{sh} in parallel resistance is found using (7).

$$I_{sh} = \frac{R_S . I_{pv} + V}{R_{sh}} \quad (7)$$

R_s is the series resistance, and R_{sh} is the parallel resistance.

1) Load Estimation

To design an appropriate battery storage system first we need to estimate the yearly electric consumption of our proposed remote community. The total electric consumption in a day of any given load can be calculated using (8) [13].

$$Wt = N1 \times W1 \times Hd \quad (8)$$

where W_t is the total wattage which is derived from the multiplication of the number of any given electrical appliance N_l, wattage of that appliance W_l and the number of operational hours of that component H_d.

Hence by the addition of Wt of different equipment used in the house, we can figure the electric consumption at any given time.

2) Storage System Estimation

As per the estimation of the load, we can determine the total storage capacity of the battery bank by using (9).

$$Weu = Wt \times Nd \quad (9)$$

where, Weu is the wattage required for emergency use and Nd is the number of days for that emergency use.

Considering the DoD effects on the battery, (9) can be derived using (10).

$$Weu = Wt \times Nd/\,\%\;of\;DoD \quad (10)$$

The efficiency of the battery also depends on the room temperature as well. Thus, we have to compensate for that in (11) [13].

$$Weu = Wt \times Nd \times Tf/\,\%\;of\;DoD \quad (11)$$

Here, Tf is the temperature factor of the battery bank at a particular room temperature.

The required ampere-hours required of the battery banks for the above number of days is (12).

$$Ab = \frac{Weu}{Bv} \quad (12)$$

where Bv is the battery voltage.

The total number of batteries needed is found using (13).

$$Nb = \frac{Ab}{Ah} \quad (13)$$

where Ah is the ampere-hours of a typical battery.

Therefore, an appropriate management strategy system is required to control the charging and discharging of the battery bank system [14]. The state of charge is given in (14).

$$SOC = \frac{Bc}{Bm} \quad (14)$$

Here, SOC is the state of charging, Bc is the capacity of the battery at a particular time and Bm is the total capacity of the battery banks.

The Depth of Discharge is given in (15).

$$DoD = 1 - SOC \quad (15)$$

The Depth of Discharge is used to estimate the total storage capacity of the battery bank mentioned in equation (10).

V. Calculation Methodology

The calculation of the whole system will be done based on the above equations. The flowchart of calculation is shown in fig 5. The calculation starts with the estimation of total electric consumption of that rural community per day. We have collected the annual energy consumption data of that area from Newfoundland and Labrador Hydro and calculated approximate daily consumption [15]. After that, solar irradiance data has been analyzed and we have found floating solar system as a suitable process for alternative power generation. The entire system has been designed initially in the HOMER Pro optimization tool. Then we will design the same system using PVWatts simulation software and compare their simulation results.

Our focus is to minimize the use of fossil fuel and fulfil the shortage from PV generation plant. That's why we are comparing the results from different simulation tools and find out most feasible solution for this location.

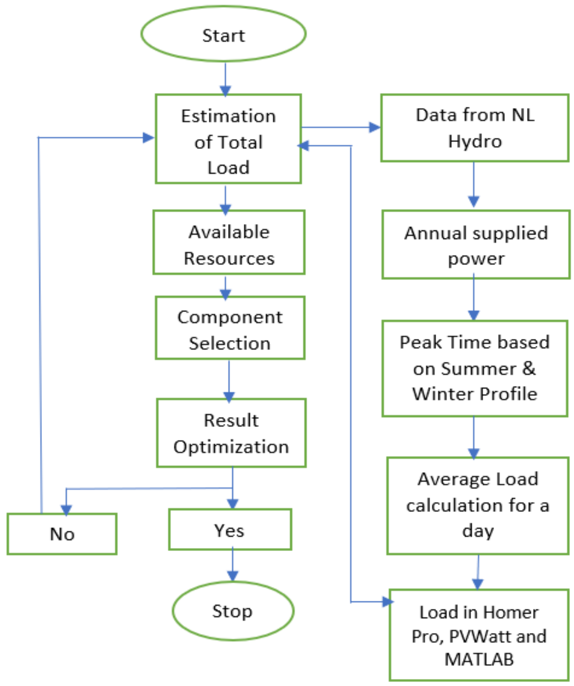

Fig 5: Calculation Algorithm.

VI. Data Collection

A. Load Estimation

As our proposed location, McCallum, is an isolated remote area having a small group of population, most of the electric load demand is for the residential load. We have collected the present load demand information from the Generation & Consumption Data for Newfoundland and Labrador Isolated Electricity Systems [16]. According to that data,

Annual load demand = 359990kWh/yr.

So, approximate daily load consumption = 986kWh

Maximum peak load- 149kW.

However, currently this demand is being fulfilled by three diesel generators and yearly fuel consumption is about 128,959 liters.

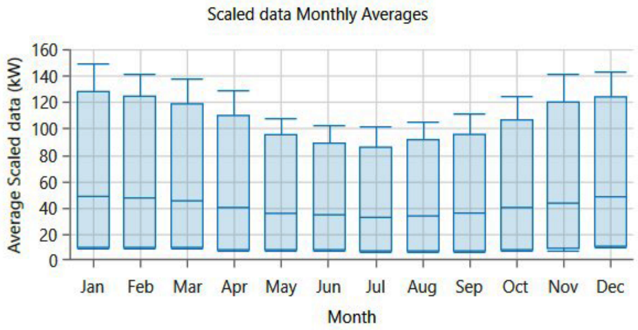

Fig. 6. Per month average load profile of McCallum, NL.

B. Solar Data

The solar irradiance and temperature data has been obtained from the NASA Prediction of Worldwide Energy Resource (POWER) database in Homer. The annual average solar irradiance in this area is 3.17kWh/m^2/day. Irradiance is generally high during summer with the highest in July and the lowest in January.

And the annual average temperature in this area is 4.41^{0}C having the peak in summer. However, the peak rise of temperature is in the month of August and lowest in February.

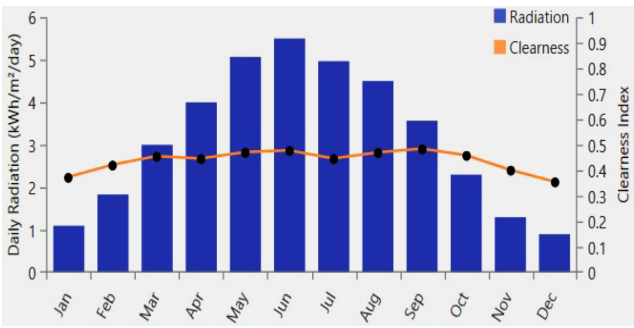

Fig. 7. Average Solar irradiance data in every month.

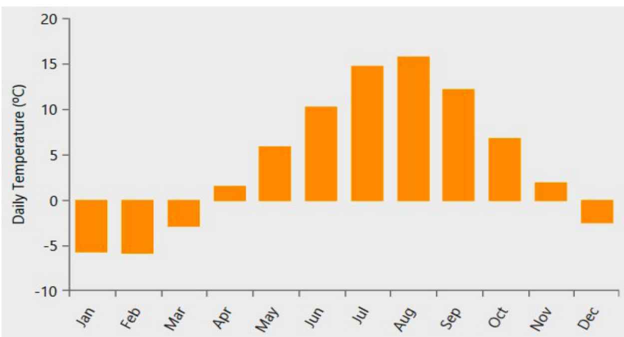

Fig. 8. Average temperature in every month.

C. Solar PV Panel

For generating renewable energy in this area, we are planning to place the solar panels on top of floating structures or pontoons. Detailed information about our selected solar panel is given in Table I.

TABLE I: PV PANEL SPECIFICATIONS

Company name	Canadian Solar Co. Ltd.
Name	Can315CS6U-315P
Rated Capacity (kW)	0.315
Operating temperature	43.9^{0}C
Module efficiency	13%
Cell alignment	72 (6 × 12)
Temperature coefficient	-0.409600
Lifetime (years)	25

D. Generator Information

In our proposed location, there are three 150kW diesel generators already in operation. Annually this system consumes 128,959 liters of fuel. This fuel is carried out by ship from another location. We are considering this system along with our proposed renewable energy system to set up a hybrid power generation system. Currently, site has three diesel generators. After the addition of PV system, only one 150kW diesel generator will be needed.

E. Battery Information

For the storage and distribution of electricity generated from PV panels, we have added batteries. Detailed information about batteries is given in Table II.

TABLE II: BATTERY SYSTEM SPECIFICATION

Company Name	Trojan SAGM
Name	SAGM 12 105
Nominal Capacity (kWh)	1.39
Ampere-hour	116
Voltage (V)	12
Maximum Charge Current (A)	21
Maximum Discharge Current (A)	263

VII. SIMULATION RESULTS

A. Homer Simulation

HOMER, a computer model, developed by National Renewable Energy Lab (NREL) and distributed by homer energy, was used to design the energy storage. system. The proposed energy storage system has been designed in Homer.

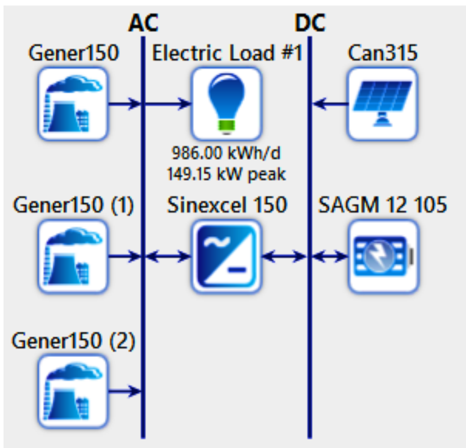

Fig. 9. Homer diagram of proposed system.

The components have been selected as per the above sizing estimations. Homer Pro results are shown in Table III.

TABLE III: ANNUAL POWER GENERATION FROM HYBRID SYSTEM

Production	kWh/yr	%
Canadian Solar315CS6U-315P	365,350	76.4
Generic 150kW SD150	112,594	23.6
Total	477,944	100
Quantity	kWh/yr	%
Excess Electricity	81,917	17.1
Unmet Electric Load	0	0
Capacity Shortage	10.7	0.00300
Quantity	Value	Units
Renewable Fraction	68.7	%
Max. Renew. Penetration	822	%

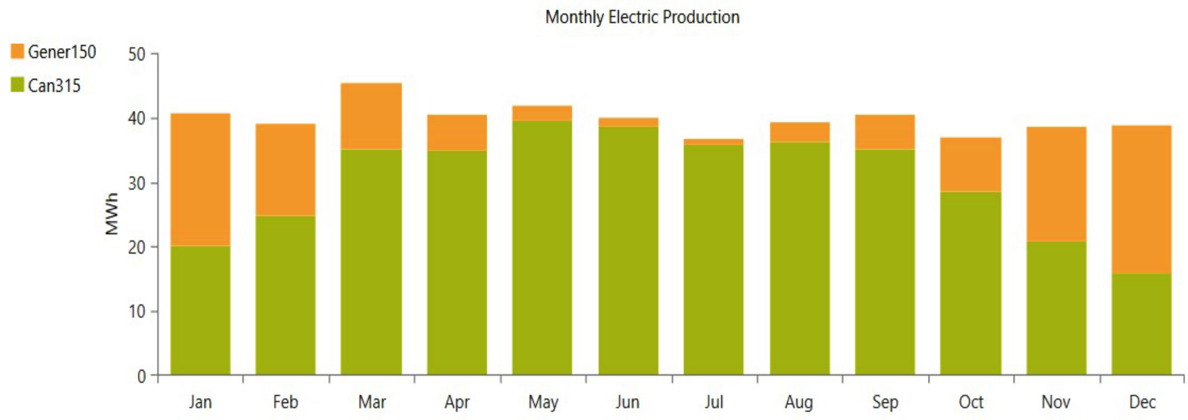

Fig. 10. Monthly energy generation from Generator (Orange) and PV system (Green).

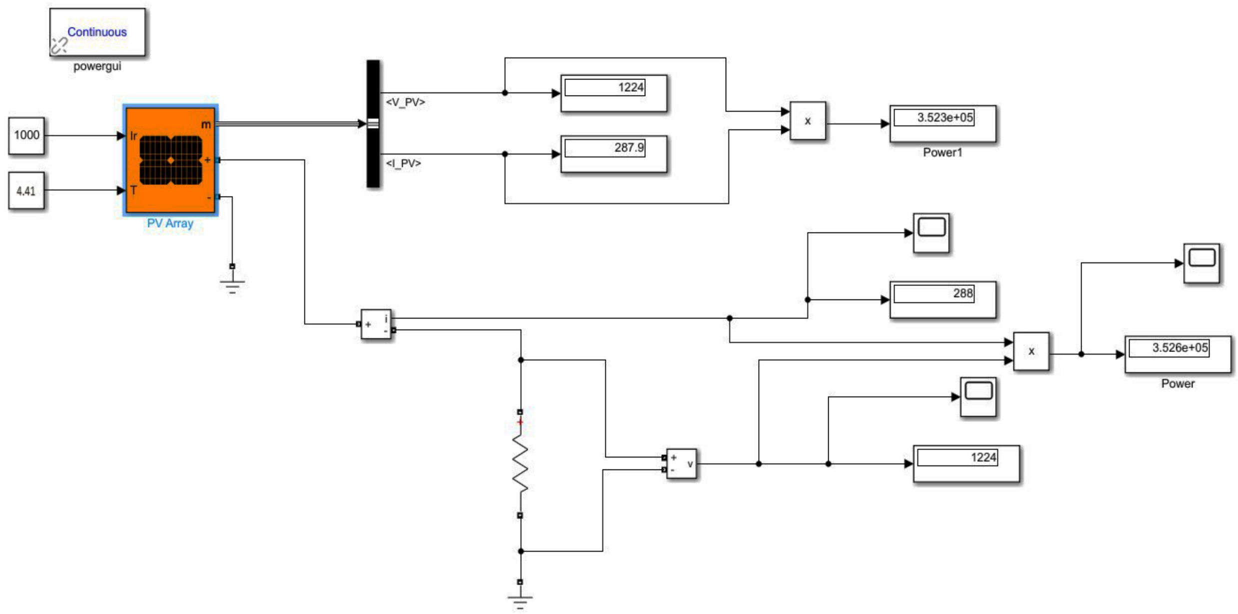

Fig. 11. Simulink diagram of our proposed PV system.

So, from the homer simulation we find that, the system is producing 477,944kWh electricity per year. Out of this total production 365,350kWh/yr. is producing from the PV modules that is 68.7% of the total generation and the rest from the generator. That means almost 70% fuel consumption of diesel generator would be saved with the new FSPV energy generation plant. Some results are shown in Fig. 10.

A. PVWatt Simulation

PVWatts is a helpful map-based free online tool for analyzing solar sites in the US and abroad. It can provide information on the annual global energy output of PV systems connected to the grid in the USA or in other countries. It may also provide hourly PV energy output values for numerous sites. International solar maps are also available from PVWatts. The NREL developed this robust and user-friendly tool (US National Renewable Energy Laboratory).

Here, we use this tool to verify the PV module output that is found from the Homer simulation and that is 365,350kWh/yr. So, the specified location was selected at PVwatts to collect the weather resources and then system design information has been provided as same as the solar system size 321kW, shown in the Homer simulation result. After that, it gives us the result that is shown in TABLE IV.

TABLE IV: SIMULATION RESULTS FROM PVWATTS

Month	Solar Radiation(kWh/m^2/d)	AC Energy(kWh)
January	1.52	13,471
February	2.23	17,765
March	3.73	32,369
April	4.76	38,729
May	5.19	42,372
June	5.35	41,662
July	4.91	38,989
August	4.82	38,381
September	3.88	30,416
October	2.74	23,066
November	1.67	13,849
December	1.36	11,768
Annual	3.51	342,837

It shows the total yearly generation is 342,838kWh which is slightly less than the Homer result, but this 6% difference is negligible as we considered many losses factor here like snow effect and others. However, Homer shows a little bit excess energy that we may consider as different types of system loss.

B. MATLAB Simulation

The system, which was designed in HOMER, we tried to implement in MATLAB Simulink to analyze the output and the dynamic analysis (Fig. 11).

Here, we have defined our system equipment as same as our HOMER simulation and considered the average temperature 4.41^{0}C for this simulation. After simulation, we've found the annual power generation is 352,600kW/yr. Which is almost similar to the annual generation of HOMER and PVWatts system. Detailed Simulink model still needed to work and will be completed soon.

Hence, it can be said that, considering weather data and solar irradiance of McCallum, we can produce almost 365,350kWh energy per year from the PV power generation system we have designed, which can backup up to 68.7% yearly consumption of that area.

VIII. Achievements and Experiences

Although the project initial cost is high, there is no fuel cost in FSPV system and the LOCE is 0.4433 which is reasonable enough. Besides, the new system will cover almost 69% of annual load demand that results a huge savings of diesel generator's fuel cost. Moreover, there are others benefits of FSPV system those are listed in below-

i. Higher power outputs because of improved converting performances caused by decreased thermal wandering
ii. A zero-land requirement; land may be valuable real estate for agricultural purposes or in areas with significant demand for energy, such as towns and large cities. Greater power efficiencies are possible with floating photovoltaic technology because there are fewer restrictions on component spacing.
iii. Greater power efficiencies are feasible with floating photovoltaic technology since there are fewer restrictions on component spacing.
iv. In addition to the previous point, many of the world's largest towns have been built along the coast, where there may be many possible sites to install on and possibly enough grid infrastructure nearby.
v. Besides, safeguarding the water's surface may stop potentially hazardous algal blooms from photosynthesis.
vi. It is easier and less expensive to combine cleaning equipment and a cooling veil when there is water nearby; however, this may be difficult in saltwater locations.

Additionally, ongoing research shows that the Albedo impact has a negative influence on the environment and increases ambient air temperature changes for ground-mounted solar systems but has a positive impact for floating photovoltaic systems.

A. Drawbacks

However, there are several obstacles and difficulties that prevent the use of this technology in the maritime environment:

- During their operational life, which is typically 25 years, marine FPV plants are subjected to significant wind and wave loads. Extreme environmental events, wear on joints and connections, saltwater corrosion, UV deterioration, and biofouling must be endured by them.
- The PV modules are constantly moving, which could lead to microcracking and dealignment, two conditions that reduce output. Nevertheless, Refs. [16,17] modelled the losses caused by the realignment of the panels and found that the cooling impact of the marine environment more than offset them.
- Other marine activities like fishing or navigation may be hampered by these plants.
- Some advantages of freshwater FPV plants, like as limiting evaporation losses, reducing algae development, preventing eutrophication, and having significant synergy with hydroelectric power, are overlooked. This seldom has any bearing on marine applications.
- The lack of design standards, rules, and laws is indicative of poor technological development.

IX. Conclusion

One of the major challenges of setting up any isolated renewable project is to manage its huge installation cost because after the commencement of the operation, there are no fuel costs involved. So, the effectiveness of this project depends on whether the authority keeps the construction cost within the limit. A hybrid FSPV energy system is only practical for a location when the area offers enough solar resources, and the grid connection is not available or can only be made through an expensive extension. Otherwise, the whole project will cause a significant upfront cost which will be hard to recover. As our proposed location has an average solar irradiance of more than 3kwh/m^2/d in a year, the location is not bad for any solar system for extracting higher solar energy and specially for a place like this where no other option is available. But the irradiance goes down in winter season when the load demand reaches in peak making the project less feasible. Although the overall project still costs more than \$2000,000, in twenty years of successful implementation of this project will bring energy independence from the utility grid and help to maintain clean energy throughout the year. However, accurate load forecasting and the O&M cost of the floating solar system are crucial before the implementation of the project. Inaccurate load forecasting and unplanned breakdown of the FSPV could expand the NPC and LOCE more than originally anticipated.

X. Future Works

i. Need to develop more detailed system design using Simulink.
ii. An elective system protection circuit should be designed for minimizing the system loss and save the equipment.
iii. To get maximum output from PV modules, tracking system might be considered though it is complicated for FSPV energy system.
iv. More details analysis required to minimize the initial capital cost.
v. Need to work for developing the proper monitoring and maintenance system.

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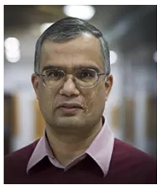

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