

# SOLAR BASED ELECTRIC POWER GENERATION FOR HOUSEBOATS

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**Abstract** – Inland vessels, such as houseboats, traditionally rely on diesel generators to meet their onboard electrical demands which leads to fuel consumption and emissions. This study focuses on the design of a battery pack that can replace the conventional diesel generator in a houseboat with Li-ion batteries that can cater for all auxiliary equipment and devices on the vessel. The study has assessed the feasibility and identified the benefits of the proposed transition from conventional fossil fuel-based power generation system to an all-electric solution for inland vessels. Electric power is generated onboard using the solar photovoltaic system, which is a renewable energy source. The proposed design of battery pack includes estimation of electrical load of the vessel, required battery capacity, voltage and other parameters; selection of a Li-ion cell for the battery pack; and assessment of space and weight considerations, safety and reliability. The study has also addressed aspects on reduction of emissions and reduction of fuel cost that can be achieved by using the proposed system.

**Key Words:** Solar Powered Houseboat, Renewable Energy, Photovoltaic system, Battery Management System, Hotel Loads, Li-Ion Battery, Inland Vessel, Electrical Power Generation

## 1. INTRODUCTION

Houseboats form an essential part of tourism in various states in India, especially in Kerala, as they provide a unique and scenic travel experience. Conventionally, these boats depend on diesel generators to supply electric power to various electrical equipment and devices onboard, such as lighting, air conditioning and galley equipment. Even though diesel generators are capable for providing the required electrical power, they have several disadvantages as described below:

- (i) Environmental impact: Diesel engines emit greenhouse gases, which contribute to air pollution and climate change. The noise pollution and vibrations from generators can also disrupt the natural environment and disturb wildlife. Fuel leakages to the inland waters can result in pollution and it can adversely affect the aquatic life.
- (ii) Economic impact: The cost of diesel fuel has increased in recent years, placing a financial burden on

houseboat operators. Furthermore, diesel generators require regular maintenance, adding to operational costs.

- (iii) Reliability and convenience: Diesel generators require fuel storage, regular refuelling, and operational space, which can be inconvenient and prone to disruptions to their routine operations.

Given these factors, there is a necessity for a sustainable, reliable, and cost-effective alternative to diesel generators for supplying the power to the auxiliary systems of a houseboat. The integration of renewable energy sources, particularly solar power, offers a promising solution to address these issues.

The main objective of this study is to design a battery pack powered by solar energy to replace the conventional diesel generators used on houseboats for powering the auxiliary systems. This solar-powered system aims to:

- (i) Reduce emissions: By replacing diesel with solar energy, the system will reduce the carbon footprint and pollutants released into the atmosphere and water.
- (ii) Lower operational costs: Solar energy is a free resource, and with the correct system setup, the dependency on costly diesel fuel will be minimized, reducing long-term costs.
- (iii) Enhanced reliability and convenience: With a solar-powered battery pack, the need for regular refuelling and generator maintenance is eliminated, offering a more autonomous and user-friendly solution.

Solar energy is a clean, renewable resource that can provide substantial energy. By placing solar panels on the houseboat roof, the vessel can harness sunlight throughout the day to charge the battery pack, hence replacing the conventional diesel generators and it reduces the emission of harmful gases. The reduction in fuel consumption and emissions aligns with global sustainability goals and enhances the eco-tourism appeal of houseboats.

## 2. PROPULSION AND ELECTRICITY GENERATION

For houseboat propulsion system, diesel based internal combustion engines are widely used. Engines used in trucks

are modified and it is commonly used as the engine for houseboat's propulsion system. A Diesel Generator set (DG set) is usually used to meet the hotel loads, i.e. the electrical energy demands for the electrical appliances and equipment. A DG set includes a diesel engine coupled with an alternator to produce electricity. Therefore, for both the propulsion system and hotel loads, the primary source of energy is fossil fuel. The use of fossil fuels contributes to emission of greenhouse gases into the atmosphere and results in significant carbon emissions from houseboats. Additionally, DG sets are very noisy and requires regular maintenance and refuelling. The study proposes the design of a solar powered battery pack to implement a fossil fuel-free and battery-based power distribution system for all hotel loads in houseboats through imparting solar system and replacing diesel generators.

### 3. ELECTRICAL SYSTEM DESIGN

The detailed design of the proposed electrical power generation system for the houseboat is described in the following sections.

#### 3.1. System Architecture

The proposed system is designed to replace the conventional diesel generator with a Li-Ion battery pack and solar as the primary source of energy. The solar panels are placed on the roof top and the power from solar is used for hotel loads and to charge the battery pack. A block diagram of the proposed system is shown in Fig-1.

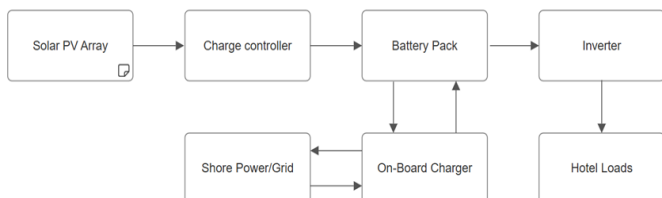


Fig -1: Block diagram of the proposed system

The above block diagram shows the general stages in power conversion required to implement the proposed system. The solar PhotoVoltaic (PV) array produces Direct Current (DC), which is then Boosted into required voltage necessary to charge the battery by the charge controller. For hotel loads, Alternating Current (AC) is required. From the battery pack, the DC is converted into AC by an inverter. During rainy seasons and cloudy days, the sunlight reaching the solar panels may not be sufficient to run the system. So, during these times, the battery pack can be charged using shore power with the help of an onboard or offboard charger.

#### 3.2. Electrical Load Analysis

Common electrical loads in a houseboat include lighting, fans, air conditioning, water pumps, kitchen appliances

(electric stoves, kettles), entertainment systems, navigational equipment etc. The total load and power consumption varies between different types of houseboats. A two Bedroom, one Hall and one Kitchen (2BHK) houseboat has been selected for the case study. The general arrangement of the houseboat is shown in Fig-2.

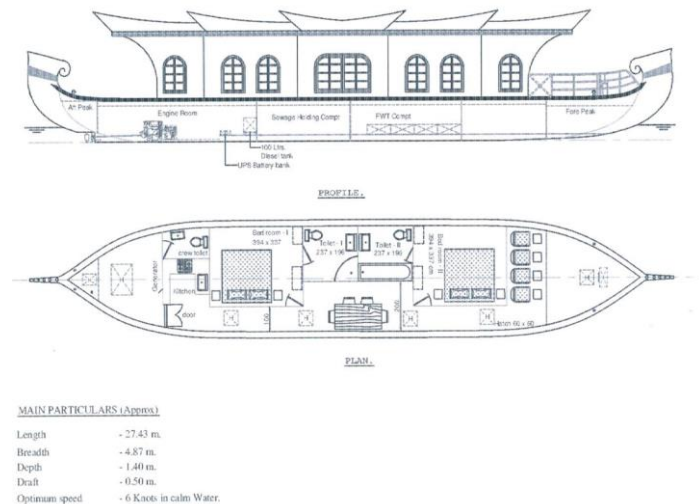


Fig -2: General arrangement of a 2BHK houseboat [1]

All the electrical appliances are assumed to be of the best quality and of high efficiency. In order to achieve this, appliances with 5-star ratings have been selected. In addition, Brushless Direct Current (BLDC) fans have been considered to be used onboard since these need to be of only half of the power rating of corresponding conventional fans. Table -1 indicates the electrical load chart which takes into account all the estimated electrical loads and its power ratings of the equipment onboard the houseboat.

Table -1: Electrical load chart

Sl No	Appliance	Quantity (a)	Power rating (W) (b)	Total power (W) (c)	Daily usage (hours) (d)	Daily energy consumption (Wh) (f) = (c)x(d)
1	LED light	20	10	200	6	1200
2	Fans	4	30	120	12	1,440
3	TV	2	40	80	4	320
4	AC	2	1,200	2,400	5	12,000
5	Fridge	1	200	200	24	4,800
6	Water pump	1	800	800	1	800
TOTAL						20,560

Total daily energy demand is the sum of daily energy consumption, and it is estimated to be 20,560 Wh from Table -1.

### 3.3 Size of Solar Panel

The required number of solar panels depends on the daily energy demand of the houseboat and therefore it varies between different houseboats. The number of panels that can be accommodated on the roof of the houseboat is also limited. Based on the load chart shown in Table -1, the number of panels required is estimated as follows:

It is assumed that the solar panel needs to produce 30% more energy than the required value of 20560 Wh/day in order to compensate for the energy loss in batteries and connecting wires. Therefore, energy to be generated by the solar panel becomes 26,728 Wh/day. A parameter known as Panel Generation Factor (PGF) has to be considered for calculating the size of solar panel. Several factors such as temperature variance, dust accumulation, ageing, inverter efficiency and battery efficiency affect the performance of the solar panels. A de-rating factor of 0.77 has been assumed [2] to take into account the above factors and also a minimum solar irradiance of 5.5 has been considered [3].

$$\begin{aligned} \text{PGF} &= \text{minimum solar irradiance} * \text{de-rating factor} \\ &= 5.59 * 0.77 = 4.304 \end{aligned}$$

$$\begin{aligned} \text{Size of solar panel required} &= \text{Energy (in Wh) per day to be generated} / \text{PGF} \\ &= 26,728 / 4.304 \\ &= 6210.03 \text{ W} \end{aligned}$$

Therefore, after compensating for all the losses in the system, such as losses in generation due to dust, inefficient sunlight and losses in electrical conversion stages, a solar panel system rated for 6210 W is proposed to be constructed. To meet this capacity requirement, solar panels having a peak power of 550Wp per panel, have been selected. Therefore,

$$\begin{aligned} \text{the required number of PV modules} &= \text{total required panel size} / \text{rated peak power of a PV module} \\ &= 6210 \text{ W} / 550 \text{ W} = 11.29 \approx 12 \text{ panels} \end{aligned}$$

Based on the above, twelve solar panels are proposed to be provided. Therefore, the total available capacity of solar panels together becomes 12 x 550 W = 6600 W.

### 3.4 Space Requirement of the Panels

It is necessary to identify adequate space on the exposed roof area of the houseboat in order to install the twelve solar panels. From the general arrangement of the vessel, shown in

Fig -2, it is found that a total roof area having 18 m length and 3.5 m breadth is available.

$$\begin{aligned} \text{Total roof area available} &= 18 \times 3.5 = 63 \text{ m}^2 \\ \text{Area of one PV module} &= 2278\text{mm} \times 1134\text{mm} \\ &= 2.583 \text{ m}^2 \\ \text{Area required for twelve PV modules} &= 12 \times 2.583 \\ &= 30.996 \text{ m}^2 \end{aligned}$$

Therefore, the twelve solar panels can be efficiently accommodated on the roof top of the houseboat. The orientation layout of the panels shall be such that there are two solar panels in the athwartship direction and six panels in the fore-aft direction, as shown in Fig -3.

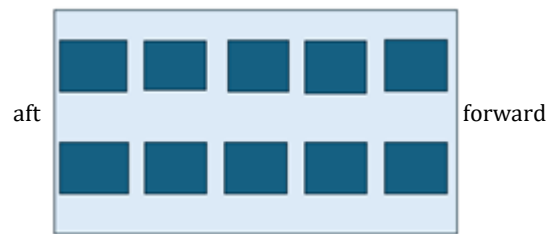


Fig -3: Plan view of solar panel arrangement on rooftop of the house boat

The panel are to be placed such that the weight of the panels are evenly distributed over the roof top. Adequate inclination shall be provided for the solar panels for maximum output generation and it will depend upon the shape and slope of the roof. Each panel would weigh around 28 kg. Therefore the total weight of twelve panels will be 336 kg.

The mass of 336 kg would impart a significant amount of load on the rooftop. Typically the strength of materials used to construct roof of the houseboats are low; therefore additional load bearing structures like stiffeners and pillars are to be additionally fitted to strengthen the roof of the vessel. Addition of such large weights on houseboats roof can adversely affect its stability and therefore the effect of the weight on the transverse stability is to be given due consideration.

### 3.5 Design of Battery Pack

For constructing the battery pack, Li-Ion cells are chosen. Lithium batteries are available with different chemistry, some of them are Lithium Titanium Oxide (LTO), Lithium Iron Phosphate (LFP), Lithium Nickel Manganese Cobalt Oxide (LMO) and Lithium Nickel Cobalt Aluminum Oxide (NCA).

After comparing the safety and performance of the different lithium chemistry, it is found that LTO and LFP are clearly better options. Fig 4 shows the comparison of various

Li-Ion batteries with respect to their performance and safety [4].



Fig- 4: Comparison of safety and performance of different Li-Ion batteries [4]

Following assumptions have been made for selecting the required capacity of the battery pack.

- (i) Battery efficiency is assumed to be 95%
- (ii) Depth of discharge is assumed to be 80%
- (iii) Number of cloudy days is assumed to be 2

Battery voltage levels are chosen based on the wattage capacity of the panels, as given below:

- a) 12V for up to 500 W capacity
- b) 24V for up to 1000 W capacity
- c) 48V for up to 2000 W capacity

Since the estimated capacity of panels is above 2000 W, a 48V system has been adopted for the battery pack and this would also facilitate optimal charging of the battery.

Based on assumption (i) given above, the battery has an efficiency of 95%. Therefore, to compensate for the 5% losses in battery, battery must supply 5% more than the total daily energy demand of 20,560 Wh, i.e. a total of 21,642 Wh/day. Based on assumption (ii), the depth of discharge is 80%, that is the battery can only be used up to 80% of its capacity, therefore battery bank must be able to supply 20% extra, i.e. a total of 27,052 Wh/day.

Since there is a possibility of charging the battery using shore supply during emergencies or during cloudy days, battery bank can be designed up to a rated capacity of 27,052 W.

Corresponding capacity of battery in Ah

$$= \text{battery bank size (W)} / \text{voltage}$$

$$= 27052W / 48V = 5635 \approx 570 \text{ Ah}$$

It is proposed to use cells with the individual cell specification of EVE 3.2V 105Ah LiFePO<sub>4</sub>. The battery pack

can be constructed by combinations of series and parallel connections of the cells to achieve the desired voltage and current.

- (i) Series configuration: 15 cells each with 3.2 V in series to achieve a nominal 48V.
- (ii) Parallel configuration: To achieve the total battery capacity of 570 Ah, it is required to provide 570Ah/(105Ah per cell) i.e 5.42 cells. Therefore, it is proposed to use six cells in parallel.
- (iii) Therefore, total number of cells required to meet the daily load demand is given by 15 (in series) x 6 (in parallel) i.e. 90 cells.

Total weight of ninety cells is estimated to be less than 200 kg. Since the total mass of batteries of 200 kg together with the mass of panels of 336 kg is much smaller compared to the total weight of the vessel and since it is going to replace the diesel generator set on board, the effect on draught is considered to be negligible.

### 3.6 Selection of Charge Controller

The charge controller for the battery is to be specified in terms of current and voltage. It is recommended to operate the charge controller at a current of 30% more than the short circuit current of the PV array. Since the battery voltage has been selected as 48V, the voltage rating of charge controller has also been selected as 48V. The short circuit current of each panel is 13.9 A [6]. Since 6 panels are proposed to be connected in parallel, the total short circuit current of the PV array becomes 83.4 A. Accordingly a charge controller rated 48V, 110 A capacity has been chosen which is rated more than 30% of the short circuit current of 83.4 A. Rating of inverter is found using the following formula:

Rating of inverter

$$= (\text{Connected load in VA} \times \text{Safety factor})$$

$$/ \text{Efficiency of inverter}$$

$$= (4750 * 1.2) / 0.9 = 6.33 \text{ kVA}$$

Based on the above, a 7 kVA, 48/230 V single phase sine wave inverter has been chosen.

### 4. BREAK EVEN ANALYSIS

The proposed system can become completely autonomous after its implementation. There won't be much operating costs during its lifetime. The only requirement would be cleaning solar panels once every two or three months. For the solar panel the manufacturer would normally give 30 years of performance warranty. For the battery pack, the cells would have 4000 cycles of life, which would extend to many years even if the battery is charged and discharged on a daily basis.

Two litres of diesel would be required per hour for running the hotel loads in a houseboat and about twenty-two litres of diesel would be used on a day [5]. The total cost of diesel consumption for operating the hotel loads is approximately ₹ 2000 per day. Considering the diesel price of ₹ 95 per litre and an annual operation of 350 days, the total operational costs amount to nearly ₹ 7,00,000 per year.

The estimated cost for procuring and installing the proposed system is about ₹ 6,00,000 [6]-[8]. Accordingly, the payback period for the proposed system will be less than a year, making it a highly economical and sustainable alternative to existing arrangement with DG sets. After the payback period of one year, the maintenance requirements of the solar power system would continue to be minimal and there won't be any further recurring diesel expenses for powering hotel loads. This can lead to significant long-term savings and a reduction in carbon emissions, contributing to both economic and environmental sustainability.

Also, the solar energy produced by the houseboat during non-operational period could be fed to the KSEB electricity grid, which in turn will generate additional income for the houseboat owners. Also, the proposed system is environmentally friendly as there is no pollution, noise and vibrations when compared to diesel generators that produce noise pollution and vibration and thereby adversely affect the comfort of people onboard. The proposed system is completely autonomous, unlike diesel generators, since there is no need for refueling and routine maintenance for the proposed system.

## 5. CONCLUSION

It is concluded that integrating a solar-powered lithium-ion battery system into houseboats can provide a sustainable and efficient alternative to conventional diesel generators. The study has analyzed the energy requirements of a typical 2BHK houseboat and proposed an environment-friendly design consisting of a 48V, 570Ah LiFePO<sub>4</sub> battery pack supported by a 6.6 kW solar PV array. The design has taken into consideration the structural feasibility, energy efficiency, and system reliability. Economically, the system can eliminate the recurring fuel costs associated with diesel generators and it can provide a return on investment within a short period. Furthermore, the proposed system can operate with less noise and low-maintenance, and it will conform to the eco-tourism goals by reducing emissions and enhancing passenger comfort. The proposed approach not only addresses sustainability concerns but also sets a replicable model for clean energy adoption in inland water transport.

## 6. FUTURE WORK

In the future, the proposed solar-powered lithium-ion battery system can be further enhanced by extending its application beyond powering hotel loads to supporting full electric propulsion of the houseboat. This would enable

complete elimination of fossil fuel dependency, making the vessel entirely electric and emission-free. By integrating a larger capacity battery system with suitable electric motors for propulsion, the houseboat can achieve silent and efficient navigation, which is particularly beneficial in ecologically sensitive backwater regions. Additionally, incorporating smart Energy Management Systems (EMS) can help optimize power distribution between propulsion and hotel loads, ensuring efficient energy use. Hybrid energy systems combining solar with shore charging or auxiliary renewable sources like wind can also be explored for increased reliability. Incorporating bidirectional charging and grid-tie capabilities would allow excess solar energy generated during idle periods to be fed back to the utility grid, creating an additional source of revenue for houseboat operators. Furthermore, advancements in battery technologies such as solid-state batteries could enhance energy density, safety, and lifecycle. Expanding this model to larger houseboats or small passenger ferries could significantly reduce fossil fuel dependency in the inland water transport sector. Lastly, real-world pilot implementations and long-term performance assessments can help refine the system design and promote wider adoption of clean energy solutions in tourism and transportation.

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