International Journal of Marine Engineering Innovation and Research, Vol. 8(4), Dec. 2023. 636-643
(pISSN: 2541-5972, eISSN: 2548-1479)

Analysis of Solar Panel Energy Consumption on Tourist Boats in Labuan Bajo

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(Received: 17 November 2023 / Revised: 21 November 2023 /Accepted: 23 November 2023)

***Abstract*— Renewable energy is alternative energy that is currently being developed. In the current development of transportation, renewable energy is something that must be utilized properly in creating environmentally friendly modes of transportation. The use of renewable energy in the shipping industry plays a very important role in the era of the fossil fuel crisis. Research on this ship uses solar panels to convert solar energy into electrical energy, this energy can be used for ship navigation purposes. The ship's propulsion system uses an electric engine. The electric engine uses a battery that can be recharged when the ship is docked at the port. The solar panels used by Thin Film Solar Cells are lighter and have a high efficiency value. Total energy use for navigation is 799.6 kW. This ship uses 182 Thin Film Solar Cells with a capacity of 100 WP. This ship uses 4 batteries, where 1 main battery is used to drive the electric motor. Meanwhile, for backup energy storage, navigation uses 3 batteries.**

Keywords— Renewable Energy, Solar Panels, Electric Ship Design, Battery

I. Introduction

Indonesia is a maritime country where most of its territory is water and is a state asset that must be protected and preserved. With such vast waters, it is actually a large amount of capital if utilized and handled intelligently. So the experience must be carried out by someone who is experienced in that field.

Solar energy is an energy that is currently being intensively developed by the Indonesian government because as a tropical country, according to him, Indonesia has good solar energy potential [1].

The main component in a PLTS system is a solar panel which is an assembly of several solar cells. Solar cells are composed of two semi-conductor layers with different charges. The top layer of the solar cell has a negative charge while the bottom layer has a positive charge. The cells are installed parallel and in series in a panel made of aluminum or stainless steel which is protected by glass. or plastic according to [2].

Photovoltaic cells (also known as solar cells) are used to convert solar radiation into electrical energy [4]. PLTS (Solar Power Plant) is an electricity generator that uses sunlight through solar cells (Photovoltaic) to convert solar photon radiation into electrical energy. The main component in a PLTS system is a solar panel which is an assembly of several solar cells. The solar cells are composed of two semi-conductor layers with different charges. The top layer of the solar cells has a negative charge while the bottom layer has a positive charge. The cells are installed in a parallel position and series in a panel made of aluminum or stainless steel protected by glass or plastic [2].

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The solar panels used and available on the market are as follows:

a) Monocrystalline Silicon
It is an efficient solar panel produced with the latest technology & produces high electrical power per area [3]. According to [4] monocrystalline solar cells show a high efficiency version of all silicon solar cells, but the production of monocrystalline silicon is very expensive.

b) Polycrystalline
It is a solar panel that has a random crystal arrangement because it is manufactured using a casting process. This type requires a larger surface area compared to the monocrystalline type to produce the same electrical power. This type of solar panel has lower efficiency than the monocrystal type, so the price tends to be lower according to [3]. According to [5] Polycystalline is made from large square bars of liquid silicon blocks that are cooled and solidified. Poly-Si cells are cheaper to produce than single crystal silicon cells, but less efficient.

c) Thin Film Solar Cells (TFSC)
Thin Film Solar Cell (TFSC) / Thin film solar cells are a promising approach for terrestrial and space photovoltaics and offer a variety of options in terms of design and device manufacturing [6]. According to [7] Thin film solar cells provide the most promising option to significantly reduce the cost of photovoltaic systems. Compound semiconductor thin films such as CulnSe2-based alloys, and CdTe thin film solar cells.

II. Method

The analysis of renewable energy-based electric boat tourism planning in this research can be described in the form of a flow diagram of thought which is arranged sequentially in the following flow diagram:

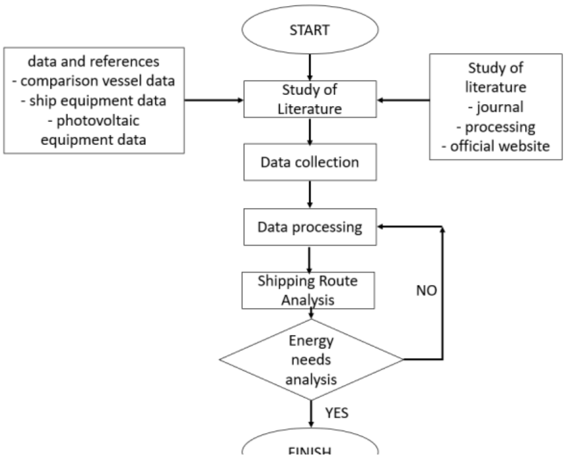

Figure 1. Flow of Thought for Research on Photovoltaic-Based Tourist Ships

Photovoltaic Calculation Methods :

A. Determine the battery capacity used

1. In calculating the average electrical energy needed per day. The average electrical energy per day is calculated by recording the loads used on the electric ship as follows:
   - Collect data on the power rating of each equipment in watts
   - Calculate the number of types of equipment that have the same power rating and the same parts or functions (Example: a living room lamp consists of two lamps and the same power, so in this case the number of equipment is 2 units)
   - Collect data on the time or duration of use of each electrical load in one day (for example, the living room lights are only on for 6 hours in one day)
   - Calculate the average daily electrical energy of all equipment

$$\frac{Electrical\ Energy\ Per\ Week}{7}\ (Wh)...............(1)$$

2. Converting average electrical energy units per day into ampere-hour units (Ah). Conversion of average electrical energy units per day (Wh) into Ampere-hour units (Ah) can be done by first determining the battery voltage in the PLTS system. will be used, so that if the battery voltage has been selected and determined for the system used, the average ampere-hour required in one day can be calculated.

$$\frac{Electrical\ Energy\ per\ Day}{Battery\ Voltage}\ (Ah)......................... (2)$$

3. Calculate the average Ampere-hour. This PLTS system is becoming common because the electricity loads used in the wider community are AC electricity loads, for this reason the electrical energy produced by batteries needs to be converted into AC electricity using an inverter which of course has efficiency in its use. Inverter efficiency values generally vary from 75% to 95%, the higher the load in accordance with the inverter's capabilities, the higher the efficiency. This is due to the process of changing the waveform by the electronic components in the inverter. However, if the average value is taken, the inverter efficiency is estimated to be 85%. In this case the average ampere-hour per day after taking into account inverter efficiency is as follows:

$$\frac{Ampere-hour\ average\ per\ day}{Efisiensi\ Inverter}\ (Ah)....................(3)$$

4. Determine the number of solar panel modules needed in the PLTS system.
   Determining the number of solar modules depends on the average daily energy requirements required by the electricity load, weather conditions, the location of the solar cell modules, whether there is shade, and the specifications of other equipment in a PLTS system. There are several formulas that are often used to determine the number of solar modules to be used and sometimes these formulas involve certain constants and certain data from weather conditions. In this research, the calculation of the number of solar modules used is based on the following simple calculation:

$$\frac{Average\ energy\ per\ day\ required\ by\ electrical\ loads}{Average\ energy\ produced\ by\ photovoltaics\ per\ day}..(4)$$

B. Solar Panel Selection

The following is a table of solar panel specifications used on the market:

TABLE 1.
PHOTOVOLTAIC SPECIFICATION

Item	Mono. Crys	Poly. Crys	Thin. Film
Voltage	18,0 V	17,5 V	18,0 V
Current Pmax	5,56 A	5,71 A	6,1 A
Weight	7,75 kg	7,55	
Dimension	1.200 x 550 x 35 mm	1.085 x 675 x 25 mm	864 x 5,63 mm
Efficiency	16 – 19 %	13 – 17 %	18,56 %

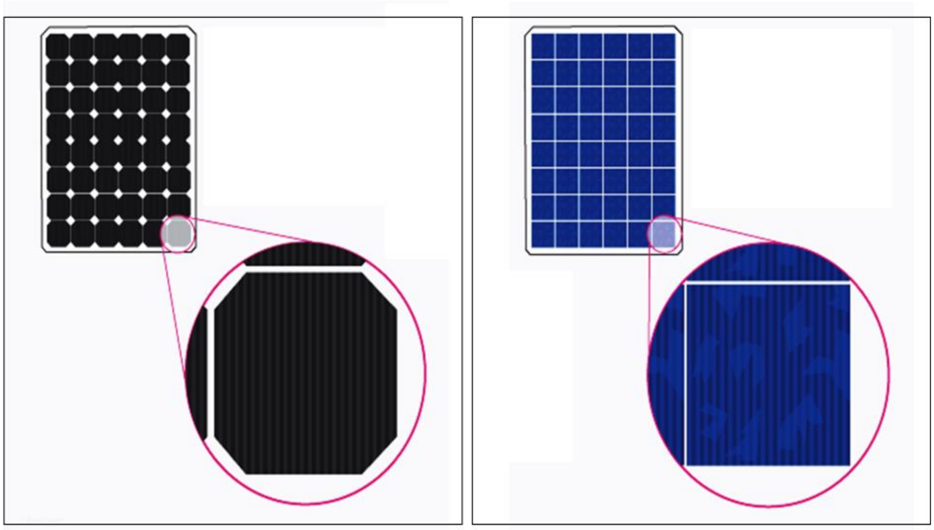

Figure. 2(a). Monocrystalline Silicon; **(b)** Polycrystalline Silicon [9]

Figure. 3. Thin Film Solar Cells [9]

III. RESULTS AND DISCUSSION

1. Equipment Data Collection Analysis

The ship equipment used on this ship needs to be calculated to determine the power load that will be released during operation. This ship's equipment is based on existing international standard rules. The following is the power of the ship's equipment that will be used in this research:

From the results of the research [8] that has been obtained, namely a ship speed of 12 knots, it can be seen which ship engine will be used. So you can know the design dimensions and layout of the rooms on the ship. In this research, the type of ship designed is a catamaran or double hull ship. The engine used is Twin Screw or two driving engines which are placed on the right and left of the stern of the ship. From the data that has been obtained, the following are the results of the design of the ship engine specifications used:

From the analysis results above, it was found that the type of machine used was 2 x EP – 7000 with a total weight of 2 x 335,658 kg. Each engine can produce 2 x 70 HP / 2 x 52 kW of power. Researchers took the range above by considering several aspects of the load that will be carried by the ship. From the results above, researchers used Lithium Iron LiFe MgP04 type batteries due to their lighter weight and relatively slightly smaller dimensions compared to Type AGM Lead Acid Batteries.

2. Photovoltaic Determination Analysis

In this section, researchers optimize the size of the design ship that has been obtained in terms of the Photovoltaic used, the weight of the Photovoltaic, the price of the Photovoltaic, the weight of the electric motor battery, the power of the electric motor, the volume of space for the battery load used.

a) Photovoltaic Optimization

The optimization carried out is by optimizing several types of photovoltaic that will be used for ship navigation purposes to find out what type of photovoltaic can be used most optimally.

From the data grouping above based on power, PV area, PV weight and price. Then proceed with calculations for the needs that have been determined based on the data obtained in table 1. The results of the data optimization analysis above show that each solar panel has its own advantages and disadvantages

TABLE 2.
ENERGY CONSUMPTION OF SHIP EQUIPMENT

Name	Equipment	No	Energy Consumption (Watt)	Total Daya (Watt)
Communication	Radio (JSS-2150)	1	150	150
Gyro Compas	(*Start Up*) *Sensor Unit*	1	140	140
	Distribution Unit	1	36	36
	Operator Unit	1	6	6
	Per Analogue Repeater	1	7	7
Radar	Furuno 1715	1	450	450
Navigation Light	*Red* (*Port Side*)	1	2,6	2,6
	Green (*Start Board*)	1	1,6	1,6
	Stern	1	1,8	1,8
	White (*Light Sea*)	2	2,3	4,6
			TOTAL	799,6

TABLE 3.
OPTIMIZING THE USE OF 100 WP PHOTOFOLTAIC FOR SHIP NAVIGATION

Item	Mono X1	Poly X2	Thin Film X3	
Power	72	58,5	83,25	≥799,9watt
Size	0,66	0,732375	0,486432	≤65 m^2
Weight	7,75	7,5	2,5	≤600 kg
Price	1500000	750000	2000000	

Boat size ranges (see note 1 below)	38' - 56'
Horsepower diesel equivalency	70 h.p.
Suggested horsepower replacement range	45 - 85 h.p.
Miles per gallon equivalency	33 mpg
Length	35"
Width	18.82"
Height	19.25"
Weight	650 lbs

Cruising speed 60%-80% of hull speed	6 - 8.5 knots
Cruising time 60%-80% of hull speed	6 - 2 hours
Cruising range 60%-80% of hull speed	35 - 17 nm
Recharging time for standard charger (shore power-50% depth of discharge)	4 - 5 hours
Recharging time for quick charger (shore power-50% depth of discharge)	3 - 4 hours
Number of 12 volt 8-D batteries (245 Ah)	9 batteries
Battery bank voltage in total	108 Vdc
Amps (maximum)	262 amps
Kilowatts (max full power from batteries)	28.2 kW
Number of chargers required	2 charger
Charger	Elcon PFC4000
Quick charger (optional)	Elcon PFC5000

Figure 4. Main Engine Specification

TABLE 4.
RESULT OF OPTIMAZION OF PHOTOVOLTAIC USED

Data	Monocrystalline	Poly	Thin	Information
Power	864	819	832,5	kWh
Total PV	12	14	10	Unit
Size	7,92	10,25	4,86	m2
Weight	93	105	25	kg
Price	18.000.000	10.500.000	20.000.000	Rupiah

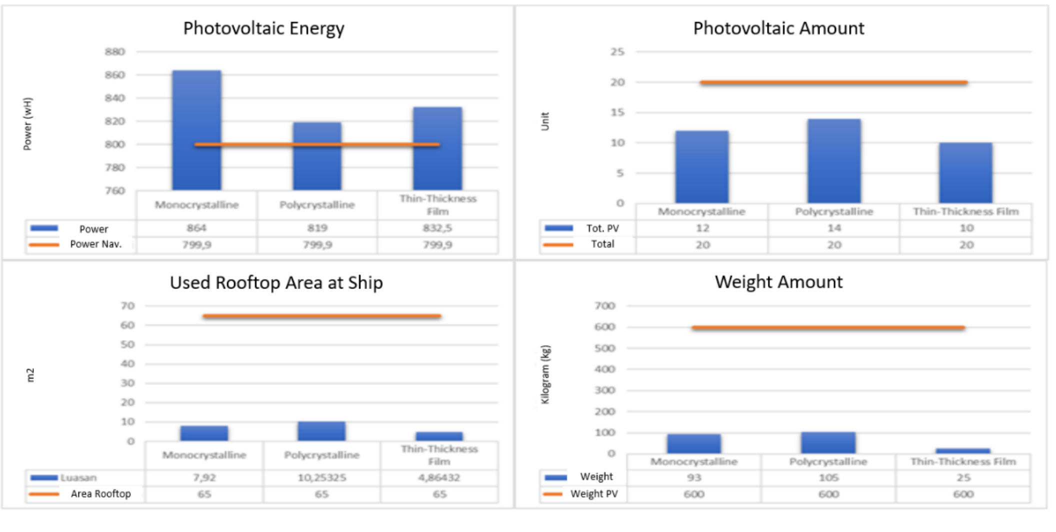

Figure 5. Photovoltaic Optimization Chart for Ship Design

TABLE 5.
OPTIMIZING THE USE OF ELECTRIC MOTOR BATTERIES

No	Item	R800 (M48189P3B) X1	R800 (M48218P5B) X2	R1000 (M48218P5B) X3		
1	Power	137	156,4	189,9	≥	466,96 kwh
2	Weight	1126	1118	1338	≤	6000 kg
3	Volume	0,92872	0,92872	1,3728	≤	22,62 m3

TABEL 6.

Item	R800(M48189P3B) X1	R800(M48218P5B) X2	R1000(M48218P5B) X3	Ket.
Power	548	469,2	569,7	kWh
Tot. Battery	4	3	3	Unit
Volume	3,71488	2,78616	4,1184	m3
Weight	4504	3354	4014	kg

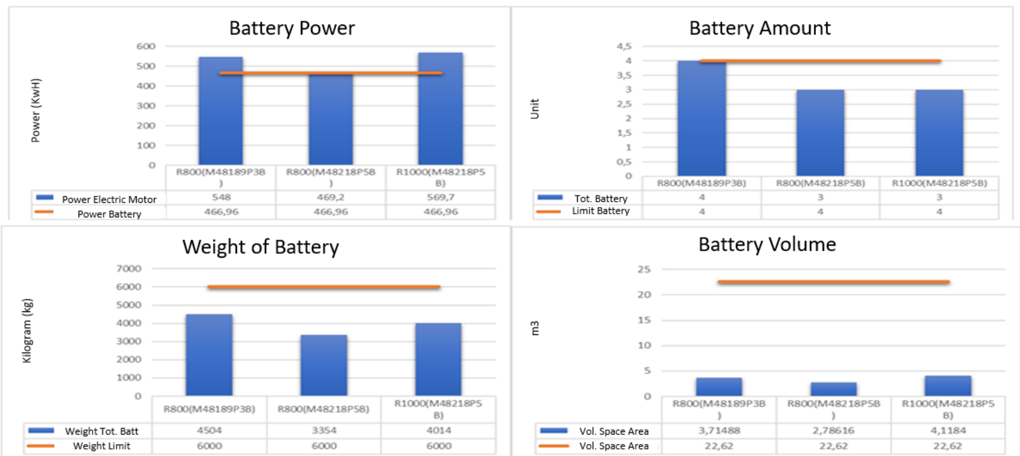

Figure 6. Electric Motor Optimization Graph

Based on the graphic results above, the photovoltaic with the greatest power is Monocrystalline Photovoltaic because the power produced is sufficient for ship navigation power. Based on the weight and number of photovoltaics used, it is also relatively lower. However, researchers use thin-thickness film type photovoltaics because of their lighter weight and higher efficiency.

3. Analyze Battery Usage

The optimization carried out is analyzing the types of batteries that can most effectively be used to drive electric motors.

From the data grouping above based on power, number of batteries, volume of loading space and weight. Then proceed with the calculation for the needs that have been obtained, in table 6.

From the graphic results above, it can be concluded that in this study the battery type R800 (M48218P5B) has optimal power and is sufficient to meet the power requirements of the driving engine of 466.96 kWh with a volume of 2.78616 m3, a weight of 3354 kg and the number of batteries used 3 batteries.

4. Calculation of the Number of Photovoltaics for Navigation

In this research, photovoltaics were only used for electrical equipment and ship navigation. This analysis was carried out because the power load on ship equipment and navigation is not as large as the power load on electric motors. The ship navigation electrical system uses solar energy as the main source of battery charging for ship navigation. Based on the optimization results, the solar panel (Photovoltaic) used is Monocrystalline. In this research, solar radiation only had a period of 4 - 5 hours with a solar panel efficiency of 16% - 19%. Researchers use Polycrystalline Photovoltaic because it has a relatively cheaper price. The following is a calculation of the number and area of Photovoltaics used:

Is known :

- Photovoltaic TFSC = 100 wp
- Solar Panel Efficiency = 17 %
- Illumination Efficiency Time = 4 – 4.5 hours
- PV dimensions = 1,065 x 540 x 3 mm

• Number of PVs for navigation power

Total PV = 799.6 watts / (100wp x 17%)
= 47.03 => 50 Units (to meet power)
PV energy = 50 units x (100wp x 17% x 4.5h)

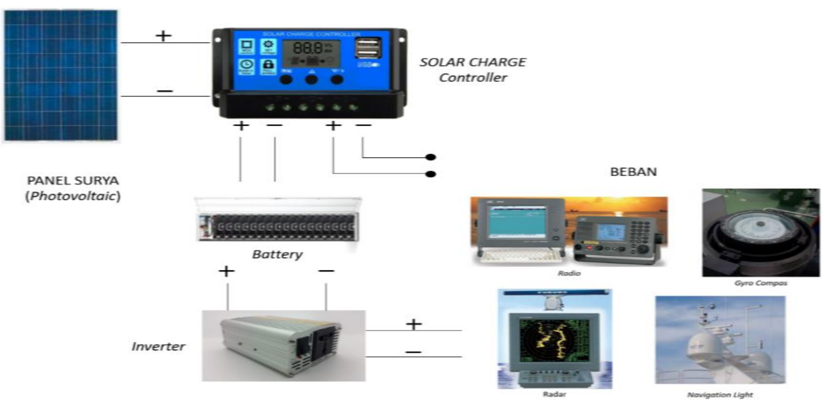

Figure 7. Electrical Scheme for Designed Ship Navigation

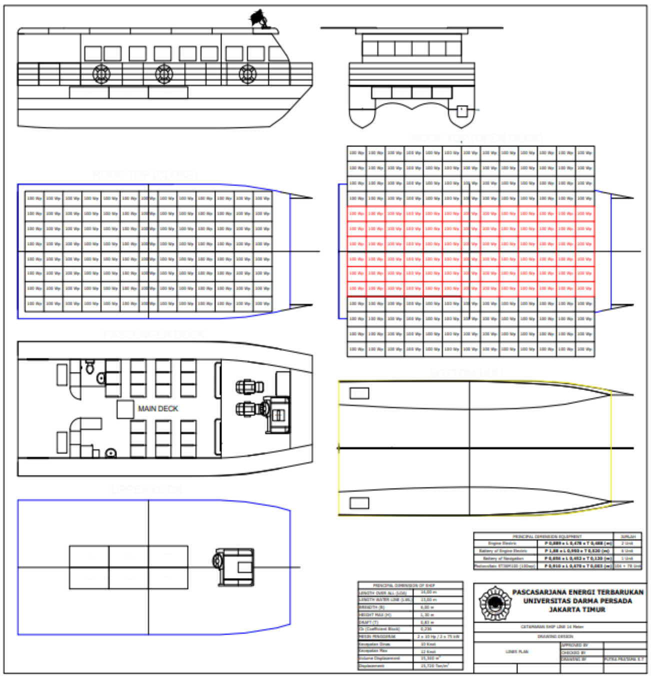

Figure 8. Design sketch of electric ship electric loading space

= 3,825 wH => 3,825 kWh

• Total Navigation Energy

Total = 799.6 watts x 4.49 hours

= 3,590.204 Wh => 3.56 kWh

To be able to meet the total navigation energy produced, researchers utilized the entire roof top area of the ship, 12.17 m long x 5.46 m wide = 66.45 m2. Of the total area, researchers used 100 wp Photovoltaics as many as 104 units + 78 units (Inside of Roof Top) to meet the Total Navigation Energy.

The figure 8 is a sketch of the cargo space analysis for the design ship based on the analysis results [9]. From the results of this analysis, the loading space for batteries, photovoltaic, seats, main engine and navigation equipment meets the loading space sketch that has been analyzed. In this research, the rooftop of the ship was designed as a double rooftop which can be opened wide so as to increase the amount of photovoltaic used. This Double Rooftop is designed to be operated when the ship is docked at any port, so when the ship is loading and unloading or waiting for tourists to travel, this double rooftop can open and catch sunlight for the operation of the ship's navigation system.

IV. Conclusion

From the results of the analysis that has been carried out, the conclusions regarding the use of solar panels on this tourist ship. The type of solar panel used is Thin Film Solar Cell, with a capacity of 100 wp. The number of solar panels used is 182 units. From existing ship designs. This ship uses 4 batteries, of which 1 main battery is for driving the electric motor. Meanwhile, for backup energy storage, navigation uses 3 batteries.

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