Analysis of Photovoltaic as Supporting Electric Power Supply on 02 Sultan Hasanuddin Training Vessel

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Abstract

This study aims to analyze the amount of electric power and the profit achieved under the installation of the Photovoltaic array. Solar panel tested was laid on the surface of the Training Ship 02 Sultan Hasanuddin. The technical analysis, namely the calculation of electrical power and economical use of Solar-Powered Electric to support the diesel-powered electric generator as the main source of electrical power. A comparison of power was made by measuring the electric current and voltage variable as well as the financial calculation between the diesel-powered and solar-powered electric generator. The financial calculation was analyzed by using NPV, IRR and PI methods. The results showed that since the power capacity of the Solar Panels was almost similar to the capacity of the Diesel Generator with the output power assumed to be similar, the Solar Panel that supports the Diesel Generator was more profitable than the use of Diesel Generators without supporting solar cells.

Keywords: Solar Cell, Diesel Generator, Technical Analysis, Financial Analysis

1.   Introduction

Energy is increasingly becoming a basic need of every human being. There was an increase in the number of the energy used for industry, commerce, domestic usage, farming and transportation. Untill the present time, the needs of energy has relied on petroleum, coal and natural gas as the primary sources. In fact, the natural oil is getting rare and more expensive. The energy crisis seems to be a real threat in the future. Thus, continuous searching of the alternative energy to meet the electrical energy demand should be developed.

A solar cell is a device that can convert the ray of sunlight into electrical energy under the principle of photovoltaic. Solar cells used the direct energy converter technologies. Electrical energy can be created without the help of fluid movements such as steam or gas. Solar cells also do not require the movement of machineries such as a *Rankine cycle* or *Brayton cycle*.

Indonesia is a country that is located in equator line, where, throughout the year, it is exposed to the intense sunlight . Therefore, the utilization of solar energy by using photovoltaic is in a great demand and begin to be developed in all area of the country by doing a lot of research and testing. One of them is the study of hybrid system combining solar cell and the main electric power sources. A hybrid system is one alternative that can be applied to the transport and industry sectors with high power usage. The hybrid system utilizes renewable energy as the source of backup energy (secondary) combined with the

main power source (primary). In the hybrid system, the renewable energy used can be derived from the energy of the sun, the wind, the waves and others that are combined with the main power source. This combination produces a power source that is efficient, effective and reliable to be able to supply the electrical energy needs in the transport sectors.

In relation to the development of alternative energy provision from the power generator besides the diesel fuel, the roof of the Training Ship 02 Sultan Hasanuddin PIP Makassar that has a flat surface area of 130 m^2 can be used to receive the energy from the sunlight. Therefore, this research made the plan for installing photovoltaic by utilizing the roof of the Training Ship 02 Sultan Hasanuddin as the area for mounting the solar panel.

2. Research Method

The data was collected for 7 (seven) days on the study object of Training Ship 02 Sultan Hasanuddin managed by Politeknik Ilmu Pelayaran Makassar. The data collection methods used in this research were observation, documentation and literature studies.

Material and Equipment used :
1) Solar Panel, with: Max. Power (Pmax) is 300W ; Nom. Power is ; 100 W ; Dimension 1956 x 992 x 40 mm.
2) Inverter : Power 3000W
3) Battery Charge Regulator: **1**50A Solar Controller PV panel Battery Charge Controller Regulator 48V for 7200W
4) Battery (Accu) : 70 Ah (Ampere Hour), 12 V (Volt)
5) Fluke 325 Clamp Meter
6) Solar Panel Cable
7) LED
8) Solder set
9) Connector

Data Analysis
1. The technical procedure includes the calculation of power and the total electrical energy produced*.* The field observations on the solar panels systems that were capable of charging the electrical energy based on the time provided for 10 hours from 7 a.m. to 5 p.m.
2. Financial : The investment costs between the installation of Solar Panel and the provision of Diesel Generator set as well as the achievement of expected benefits

This type of research is an *Experimental Research Development*.

The references for the technical calculation include :

The Calculation of Electric Power

The calculation of electric power can be done with the following approach **[6]**:

$$P = V \; x \; I$$

Where : P   = Electric power (watts)
         V   = Voltage (Volt)
          I   = Electric current (Ampere)

So the electric power required can be identified. The electric power formula used to calculate the amount of power can be formulated as follows:

$$P_{battery} = P_{total} \; x \; T$$

Where :
$P_{battery}$ = Power required (watt hour)
P_{total} = Total power(watt)
T = Time of use (hour)

From this calculation, the selection of the battery was adjusted to the specifications that exist in the market by considering the maximum power produced by battery to meet the needs of the battery. So it will formulas as follows [6]:

$$n_{needed} = \frac{AH_{needed}}{AH_{battery}}$$

$$AH_{needed} = \frac{P_{battery}}{V_S}$$

Where :
AH_{needed} = the needed power of battery (AH)
$P_{battery}$ = the needed power of system (watt hour)
V_S = the voltage of battery (Volt)

The calculation can be used to calculate the number of batteries that will be used to fulfil needs of solar power. The selection of the battery based on the specifications in accordance with the specifications that have been designed by the manufacturer of the battery and number of batteries required **[6].**

The Calculation of Panel Area
The panel area is the a surface where the *Solar Cells* will be placed. The wider the area available, the more solar cell that can be installed but the cost that will be incurred are also getting higher. The number of *solar cell* that can be mounted based on the following approach [7]:
n units of Solar Panel = the area available/A

Cost Analysis
The investation on *solar cell* system installation is a project or activity that involves *capital expenditure*, which is important economically because [9]:
1. The capital expenditures have long-term consequences. The capital expenditures will be latter forming activities of the company in the future and nature of the company in the long term.
2. The capital expenditure generally involves a very large number of money.
3. The commitment on capital expenditures is not easy to be changed.
In assessing the profit or loss of investment, there are several criteria to be used. The criteria for the assessment of investment can be classified into two groups. The first investment criteria based on the concept of advantage or profit is the *average rate of return / accounting rate of return.* The second investment criteria is based on the concept of *cash flow* that can be put in detailed as follows:

where : n_{needed} = unit battery needed
AH_{needed} = the needed power of battery (AH)
$AH_{battery}$ = the power output from battery (AH)

- The *cash flow* concept that disregards the time value of money or factor discount *(non-discount cash flow)* is the *payback period*.
- The *cash flow* concept that takes into account the time value of money or *discount cash flow*, as follows [4]:
  1) *The Net Present Value (NPV)*
  2) *Profitability index (PI)*
  3) *Internal Rate of Return (IRR)*

Therefore, it is required to perform the economic analysis on the investment of the installation of *solar cell* system in order to know the economical feasibility. The installation of *the solar cell* system can utilize the investment assessment criteria of the *Net Present Value (NPV).*

- **The *PayBack* Method**

This method tries to measure how fast an investment can recoup the fund used since the unit of result is not in the percentage, but in the unit of time (month, year, etc.). If the *payback* period is shorter than that implied by the *management*, then the investment project is said to be profitable, whereas if the payback period is longer, the project is said to be unprofitable.

Since this method measures time duration need to recover the funds invested, then the basis used is the cash flow, not profit. So it is formulated as follows **[4]**:

$$Payback = \frac{investment\ valus}{Cash\ flow}\ x\ 1\ year$$

1) **The Net Present Value (NPV) *Method***

This method calculates the difference between the present value of the investment with the received net cash inflow (operational and *cash flow*) in the future. To calculate the present value, it is required to determined first level of interest that is considered relevant. There are several concepts to calculate the ones considered relevant to this. Basically, that interest rate is the interest rate when we consider the investment decision is still separate from the decision of spending or when we begin to continue the investment decisions with the spending decisions. The relatioship existed here only affects the interest rate, not the cash flow. If the present value of the receiving net cash inflow in the future greater than the present value of the investment, then the investment project can be said to be profitable.

Whereas, if it is smaller (*NPV negative*), the project is not profitable. **[8].**

The basic formula of the NPV is:

$$NPV\ =\ investment\ value\ -\frac{cash\ inflow}{(1+i)}$$
$$+\frac{cash\ inflow}{(1+i)^2}+\ldots\ldots\frac{cash\ in\ flow}{(1+i)^n}$$

Where : n = the number of years of depreciation of investments

The NPV calculation created by projecting the calculation of income and expenses that occurred during the 25 years (based on the use of interest rates (interest) of **11**% every year [5]

2) Internal Rate of Return (IRR) Method

This method calculates the interest rate by equating the present value of the investment with the present value of the receipt net cash inflow in the future. If the interest rate is greater than the level of relevant (level of profit required), then the investment is said to be loss-making. With interest rate of 11 % then : 16.11 % For Photovoltaic (accepted). #Num! For Diesel Generator (the value far away from the excel calculation and the result is rejected)

$$NPV = \frac{cash\ inflow}{(1+r)} + \frac{cash\ inflow}{(1+r)^2} + \frac{cash\ inflow}{(1+r)^3} + \ldots \ldots \frac{cash\ in\ flow}{(1+r)^n}$$

Where : n = the number of years of depreciation of investments [8].

3) *Profitability index (PI) Method*

This method calculates the interest rate by equating the present value of the investment with the present value of the receipt net cash inflow in the future. If the interest rate is greater than the level of relevant (level of profit required), then the investment is said to be loss-making or this method calculates the ratio between the value of net cash flows in the future with the present investment value. The Profitability Index should be greater than 1 to be considered worth. The greater the PI, the investment is more worth it [3]

3. Results and Discussion
3.1. The Output Analysis of Power and Energy on daily recording

Based on the results of the observation for 7 days by using 1 piece of solar panel, it revealed:

Table 1. Output Power (watt)

| No	Time	Total Power (Watt)						
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	7.00	150	149	147	151	154	158	158
2	8.00	167	167	167	170	170	170	172
3	9.00	173	173	173	186	185	189	189
4	10.00	183	182	193	191	191	191	192
5	11.00	190	190	200	200	194	194	197
6	12.00	200	200	200	200	200	196	233
7	13.00	200	197	195	192	192	192	191
8	14.00	187	186	185	184	181	184	184
9	15.00	183	182	172	173	173	170	170
10	16.00	173	170	167	157	153	150	150
11	17.00	153	157	147	145	145	135	142
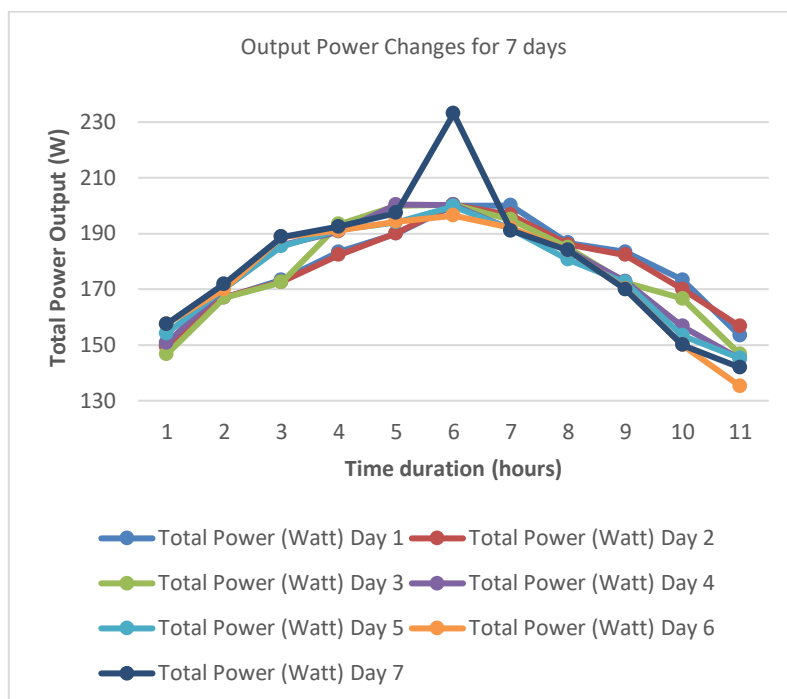
Figure 1. Output Power for 7 days

From figure 1. the visible increase in the output power of the solar panel was on day 7 (July 2020) at 12.00 p.m. which was equal to 233 watts. This was caused by the position of the sun that right above the surface of the earth.

Table 2. Total Energy Supply :

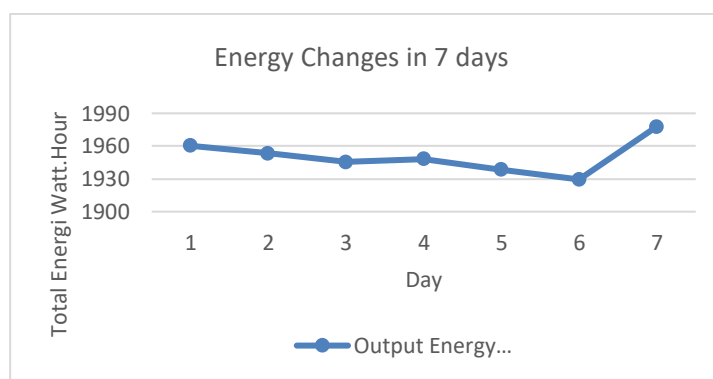| No	Date	Output Energy (Watt.Hour)
1	09-05-2020	1960
2	16-05-2020	1954
3	13-06-2020	1946
4	20-06-2020	1948
5	27-06-2020	1938
6	11-07-2020	1930
7	18-07-2020	1978
	Average / Day	**1951**

Figure 2. Total Supply Energy for 7 days

From figure 2., the visible increase in the amount of electric energy for 10 hours in day 7 (July 2020) was equal to 1.951 watts.hour.

The results obtained by installing 1 piece of solar panel as the initial planning in training ship 02 Sultan Hasanuddin for 7 days were :

1. The maximum power that can be generated was 233 watts at day 7 and at 12.00 p.m local time.
2. The average energy on daily basis was 1,951 watts.hour.

Since on the MT. Sultan Hasanuddin Vessel has a surface area of 130 m^2, while the cross-sectional area of each solar panel is 100 x 200 cm, so by taking into account the distance of the gap for each panel, then in this study, it was assumed that the number of solar panels used was 10 units. Based on that assumption, the value of the maximum power and the average energy per day will be multiplied by 10.

The Total Maximum Power per day for 10 pieces of solar panels was **2,330 watts** and the energy average was **19,510 watts.hour.**

The Calculation of the Cost of Investment for the 25 years usage duration

Cost of Investment for use in 25 years

Price list for the component and instalallation of Solar Panel

Table 3. Cost of Investment of PhotoVoltaic

No	Material / Equipment	Qyt	Unit	Price		Total
1	Solar Panel 300WP	10	Pcs	3.900.000	Pcs	39.000.000
2	Iron 50x50x4mm	100	Meter	129.950		12.995.000
3	Iron Hollow 40x60x2mm	50	Meter	180.000		9.000.000
4	Bolt M8x15mm	100	Pcs	500	Pcs	50.000
5	Bolt M8x60mm	60	Pcs	1.000	Pcs	60.000
6	Connector MC4	8	Pcs	45.000	Pcs	360.000
7	Connector MC4 Y	4	Pcs	155.000	Pcs	620.000
8	Cable	200	Meter	5.000	Meter	1.000.000
9	Aluminium rails 2.1m	10	Pcs	1.500.000	Pcs	15.000.000
10	End Clamp	10	Pcs	45.000	Pcs	450.000
11	Middle Clamp	6	Pcs	45.000	Pcs	270.000
12	The hooks rails	24	Pcs	60.000	Pcs	1.440.000
13	Installation budget	1	Pcs	10.000.000	Pcs	10.000.000
14	Accu	24	Pcs	1.200.000	Pcs	28.800.000
15	Battery Charge Regulator	1	Pcs	3.500.000	Pcs	3.500.000
16	Fluke Amper turn	1	Pcs	3.500.000	Pcs	3.500.000
17	Fluke Multimeter	1	Pcs	4.500.000	Pcs	4.500.000
18	Inverter	1	Pcs	4.500.000		4500000
	TOTAL					135.045.000

Table 4. Price list for Component and Installation of 3000 W Diesel Generator

No	Remark	Price (Rp)
1	**Cost of Initial Investment**	
	Diesel Generator 3000 W	8.800.000
	Installation of Diesel Generator	2.000.000
	Total	10.800.000
2	**Operational cost for Energy Output**	
	on 7.119,325 kWh	
	- Fuel Budget	18.646.307
	- Oil, Spareparts and Tecnician	3.729.261
	(Budget for Services)	
	Total	22.375.568
	Cost of Year 1	**33.175.568**

(Spesifik Fuel Oil Comsumption HSD = 0,2331 ltr/kwh [2]

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By taking into account the additional expenses cost such as the maintenance and operational cost, namely :

1. The procurement of solar panels for 25 years is :
   Maintenance Cost :
   M = 1% of initial investment (1)
   M = 1 % x (IDR)135,045,000
   M = (IDR)13,504,500
   For 25 years = (IDR)13,504,500 x 25
                 = (IDR)33,761,250
   Total Investment = Initial Investment Costs + Maintenance Costs
                = (IDR)135,045,000 + (IDR)33,761,250
                = (IDR)168,806,250

2. For the procurement of Diesel Generator set and operational cost for 25 years is
   - Purchase of Generator and Installation = (IDR)10,800,000
   - The operational cost consists of the cost of fuel , oil, spare parts, maintenance is = (IDR)22,375,568 x 25 = (IDR)559,389,200
   - Total Investment = Initial Investment Costs + Maintenance Costs
                  = (IDR)10,800,000 + (IDR)559,389,200
                  = (IDR)570,189,200

The Economic Analysis of Photovoltaic
The total energy generated per year is 131,232.1 kWh, then the revenue generated per year from solar panel is :(IDR)3,380 x 7,119.325 kWh = **(IDR)24,063,319 per Year**

- **The Payback Period Method**
  The total investment required for the installation of solar panel is (IDR)168,806,250 then the duration of ROI by using the Payback method can be calculated by using the formula below: [1]
  Payback Period = Total Investment / Net Cash Flows
  Payback Period = (IDR)168,806,250 / (IDR)24,063,319
  Payback Period = 7.02 Years = 7 years 7 days

Analysis by Net Present Value (NPV) Method, IRR Method and Profitability Index
NPV method with the interest rate of 11% for 25 years, the Solar Panel obtained the value of (IDR)191,247,875,- while the Diesel Genset only obtained the value of (IDR)14,213,808. Similarly to IRR method with the interest rate of 11% for 25 years, for Solar Panel, the value obtained was 16.11 %, which was above the interest rate of 11 % (accepted), while the Diesel Generator set is far below the standard calculation that was #NUM! (rejected). By the PI method, the use of Solar Panels obtained the value of 1.42 (above 1 = feasible) while the use of Diesel Generators only got 0.43 (below 1= not feasible).

4. Conclusion
Based on the analysis result on the utilization of the flat surface on TS 02. Sultan Hasanuddin of PIP Makassar by installing the 10 units of solar panel and then by comparing the use of a Diesel Generator with a capacity equal to the output of the Solar

Panels then the comparison of the energy costs of Solar Panels and the Diesel Generator, it can be concluded that: for the Solar Panels with the capacity of the output power of 2,331 watts and the max capacity 3000 W of Diesel Generator with the output power of 2,331 watts then Solar Panels is more profitable than the use of Diesel Genset.

In the future, it is necessary to consider the use of solar panels on the Training Ship 02 Sultan Hasanuddin with a greater power capacity but still in accordance with the surface of the flat areas on the ship receiving the sun lights with regard to the aesthetic factors as well as the safety for the crews.

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