Potential of Solar PV Electrical Energy with a Capacity of 2x550 Wp on Cadet Training Ships

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Abstract *– The development of the utilization of electrical energy sourced from the sun is currently experiencing very rapid development. The use of electrical energy sourced from the sun is not only used for industrial generation, currently the transportation industry also utilizes electrical energy sourced from the sun for propulsion and domestic needs. This study discusses the potential of electrical energy that can be generated by solar PV with a capacity of 2x550 Wp which will be implemented on cadet training ships. Solar irradiance is the most important component for the process of generating electrical energy, where later the irradiance value will become electrical energy using solar PV media. The irradiance value is obtained from a web application called solarglobalatlas which already has big data about the irradiation value in various places. This study took irradiation values in the coordinates area -2.953161°, 104.886022° (-02°57'11", 104°53'10") South Sumatra. The data was taken for 12 months to ensure that the data radiation experienced two seasons according to the characteristics of the area. The best irradiance values occur at 11.00 am – 01.00 pm. The results of the discussion show that the annual electrical energy that can be generated by solar PV with a capacity of 2x550 Wp using the monocrystalline PV type is 1,338.2 kWh with the largest electricity production peak occurring in August of 114.4 kWh. Meanwhile, the smallest production of electrical energy occurred in February at 87.2 kWh.*

Keywords*: Generation Industry, Irradiance, Solar PV, Transportation.*

1. Introduction

The use of fossil energy to fuel ships at this time is one of the contributors to the increasing greenhouse gas effect [1]. The results of the International Convention for the Prevention of Pollution from Ships say that currently, ship operations must find new technologies and ways, especially for the fuel used to reduce gases that can increase the greenhouse effect [2]. One of the fuels that can reduce the effect of greenhouse gases is to use renewable energy. One of the renewable energies that is currently being rapidly developed in its use and development is energy that comes from the sun using photovoltaic (PV) media.

The potential for renewable energy sourced from the sun in Indonesia has a value of 207,898 MW (80 kWh/m2/day) [3]. The potential for new renewable energy for the generation of enormous electrical energy is not wasted by the Government of Indonesia, especially for the needs of public transportation modes. The Indonesian government has issued Presidential Regulation Number 55 of 2019 concerning the Acceleration of the Battery Electric Vehicle Program for Road Transportation [4]. From these regulations, it can be developed more broadly not only for land transportation but can also be developed for the field of water transportation, especially in the field of crossings [1].

The use of electrical energy for crossing transportation using ferry boats can utilize renewable energy in the form of the sun with the help of solar PV as a medium for converting solar energy into electrical energy. In its application, it is necessary to take into account the need

for solar PV to generate electrical energy and a battery to store the electrical energy generated by solar PV for the smooth operation of ferry boats.

In the design of ferry boats using solar PV to generate electricity, of course, it is necessary to pay attention to the technical and economic aspects of the design. The most important technical aspect that must be taken into account is related to the potential of electrical energy that can be generated from a PV system design. For this reason, through this research, the authors make calculations of the potential for electrical energy that can be generated by the PV system that will be installed on a solar-powered crossing boat that will utilize a training ship owned by Politeknik Transportasi Sungai, Danau dan Penyeberangan Palembang.

2. Methodology

2.1. Research Flowchart

The steps taken in this study can be seen in Figure 1. Figure 1 explains that the research methodology was carried out starting from problem identification, literature study, loading data collection, simulation using globalsolaratlas and finally the analysis process was carried out to produce systematic research.

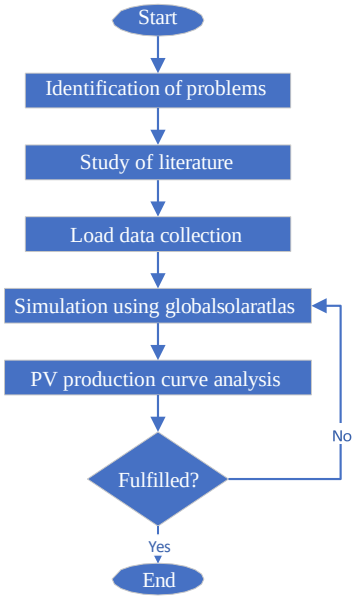

Figure1. Research flowchart.

2.2. Solar Global Atlas

Global Solar Atlas (GSA) is an online map-based application that provides free information on solar resource potential and solar power generation (PLTS) power potential globally. This platform was developed by the World Bank through the Energy Sector Management Assistance Program (ESMAP) and uses data from Solargis, a provider of solar resource data and photovoltaic (PV) energy evaluation services. During the simulation process, location data is entered to search for the potential solar irradiation value which is then used to generate solar electricity. After the location is entered, the potential irradiation value will be generated based on the potential assumed in the GSA digital map.

2.3. Photovoltaic System

Solar energy is energy that comes from the sun which is converted into electrical energy, either directly with photovoltaic media (PV) or indirectly using concentrated solar power (CSP). The method of converting solar energy into electrical energy generally uses the direct method with photovoltaic media.

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Photovoltaic (PV) is one of the newest technologies in the process of generating electrical energy. PV can produce electrical energy sourced from the sun so that this energy becomes clean energy and one of the renewable energy sources. In its use, PV is very sensitive to the weather conditions of the environment in which it operates. This makes it difficult to estimate the potential of electrical energy that can be generated accurately [5].

Photovoltaics (PV) utilizes solar irradiation to become a primary energy source which will be converted into electrical energy through reactions in solar cells which have characteristics like semiconductor materials [6]. This study uses the PV type as in Table 1.

Table 1. Photovoltaic specifications.

Type	**Monocrystaline**
Operational Temperature	-40oC - +85oC
Power Output Tolerance	0 - +5 W
Voc an Isc Tolerance	±3%
Maximum System Voltage	DC1500V (IEC/UL)
Maximum Series Fuse Rating	25A
Nominal Operating Cell Temperature	45±2oC
Protection Class	Class II
Fire Rating	UL type 1 or 2
Maximum Power (Pmax)	550 W
Open Circuit Voltage (VoC)	49.80 V
Short Circuit Current (Isc)	13.98 A
Module Efficiency	21.5 %

2.4. Solar Irradiance

Solar irradiance is an important component in the application of using PV as a medium for generating electrical energy sourced from the sun. Several factors affect solar irradiance, including such as forecasting horizon, weather classification, and performance evaluation metrics, which also need consideration [7].

Accurate estimation of solar irradiance is very important for the design of power generation systems using PV because it greatly influences the design of operating systems and efficient energy management. Irradiance has an intermittent nature, where the sun's irradiance can disappear suddenly due to weather changes that are difficult to predict, so the method for calculating the irradiance value usually uses an application by entering the area where the irradiance value will be taken and entering the type of PV that will be used [8].

The characteristics of the area taken for the irradiance value can be described in Table 2.

Table 2. Regional characteristics.

Project	Sumatera Selatan
Location	Politeknik Transportasi Sungai Danau dan Penyeberangan, Jalan Sungai Kundur, 30963, Sumatera Selatan, Indonesia
Geographical coordinates	-2.953161°, 104.886022° (-02°57'11'', 104°53'10'')
Direct normal irradiation	885 kWh/m²
Global horizontal irradiation	1663.1 kWh/m²
Diffuse horizontal irradiation	969.2 kWh/m²
Global tilted irradiation at optimum angle	1669.6 kWh/m²
Air temperature	26.9 °C
Optimum tilt of PV modules	7°
Air temperature	26.9 °C
Terrain elevation	10 m

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3. Result and Discussion

The installation of a PV system to produce electrical energy sourced from solar irradiance can be seen in the block diagram as shown in Figure 2. The block diagram shows that solar PV will produce electrical energy in the form of direct current which will then enter the charger controller to adjust the voltage and frequency characteristics. to comply with the specifications of the storage area in the form of batteries before being used by each load.

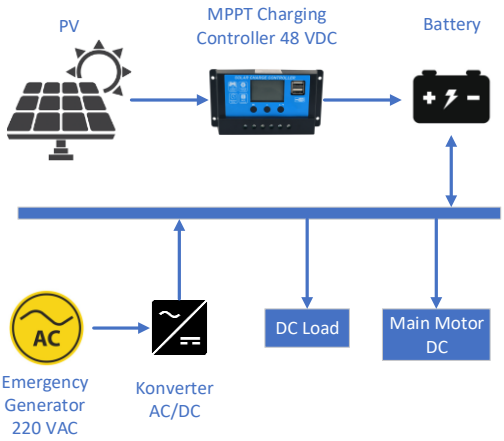

Figure 2. Block diagram research.

3.1. Solar Irradiance Result

Solar irradiance affects current and voltage variations. There is a relationship between variations in radiation and variations in current relationships. The voltage in an open circuit does not change drastically with radiation. However, there is still a slight increase as the radiation increases. The higher the radiation, the greater the current and voltage generated.

This study retrieves solar irradiance data using a web application called globalsolaratlas. The results of this irradiance value will later become the main data in calculating the potential for electrical energy to be generated by PV with a capacity of 2x550 Wp. The irradiance data shown in Table 3 is the solar irradiance value for one year. The measurement of the irradiance value uses a solar irradiance measurement sensor that is connected to the website application's big data so that it allows the irradiance data for each area to be accessed from anywhere. Table 3 data shows that the sun's greatest irradiance in each month within one year occurs between 11.00 am -01.00 pm because at that time the sun's position has the closest distance to the earth among other times.

Table 3. Irradiance value.

Time	Month (Wh/m²)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	1	0
6	18	12	17	39	39	36	29	18	24	31	43	24
7	80	81	98	156	195	189	172	150	142	124	115	87
8	133	159	228	240	291	291	278	251	260	228	182	134
9	183	207	266	329	352	344	332	312	282	270	264	199
10	237	269	326	408	417	404	380	395	345	332	322	254

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11	266	292	355	421	436	408	403	412	358	335	333	280
12	252	283	334	380	404	388	376	370	319	300	299	267
13	216	236	287	328	322	328	311	314	268	238	236	216
14	179	195	229	255	248	261	260	271	229	175	180	167
15	128	139	226	182	169	183	200	201	202	111	109	111
16	82	86	106	99	93	115	138	138	101	49	60	70
17	30	39	34	23	21	28	41	31	15	6	8	17
18	0	1	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

3.2. Potential Solar PV 2x550 Wp

The potential for solar PV electricity with a capacity of 2x550 Wp is obtained from a simulation using irradiance data obtained from globalsolaratlas. Furthermore, the data is processed using the same application to produce the results of calculating the potential of the generated electrical energy.

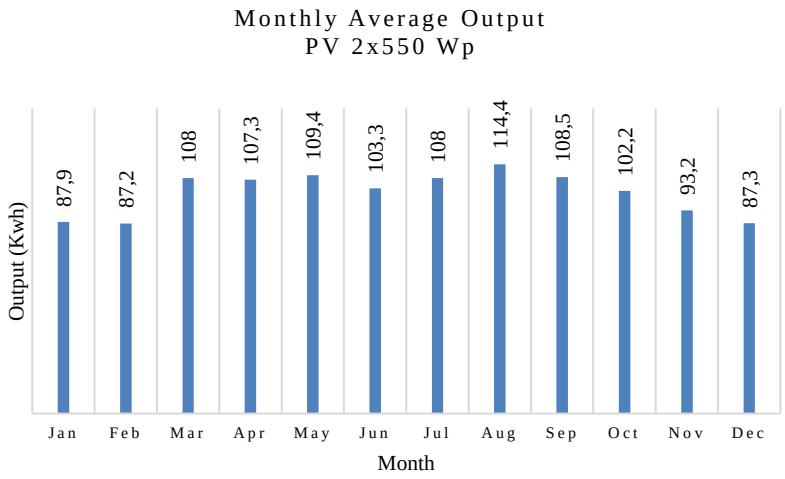

Figure 3. Graph of annual electricity production.

The output of electrical energy in Figure 3 generated by solar PV can occur starting at 06.00 am even though the energy produced is still very small when compared to the installed capacity. The PV output will begin to produce maximum electrical energy starting at 10.00 am to 02.00 pm where the energy produced is almost close to the peak of electrical energy that can be generated at peak times.

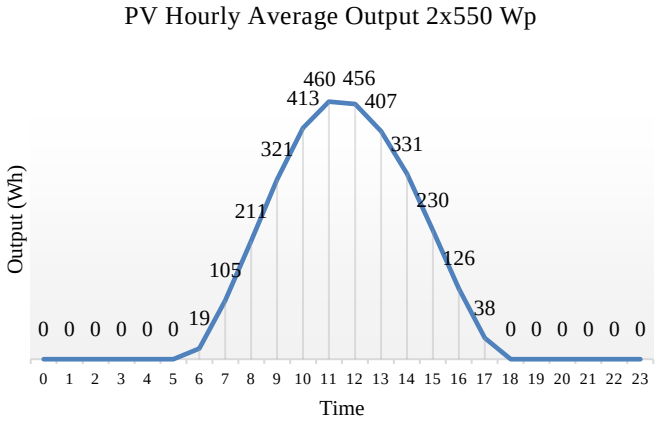

Figure 4. Hourly electricity production curve.

Based on Figure 4, the peak time of electrical energy generated occurs at 11.00 am at 460 Wp because at that time the sun is closer to the earth than at other times. Meanwhile, the electrical energy generated will experience a very drastic decrease starting at 16.00 because the sun begins to set.

The average potential of electrical energy that can be generated in one day by a PV with a capacity of 2x550 Wp is 3117 Wp or 3.117 kWh. Meanwhile, the effective hours of solar PV produce maximum electrical energy for only 3-4 hours. The potential annual electrical energy that can be generated by a PV capacity of 2 x 550 Wp is 1,338.2 kWh with the biggest peak of electricity production occurring in August at 114.4 kWh. Meanwhile, the smallest production of electrical energy occurred in February at 87.2 kWh.

The results of PV electricity production with a capacity of 2x550 Wp for one year are of course very much influenced by the season that is happening at the research location. This is in accordance with the geographical conditions where the research location has two seasons in one year, namely the dry season and the rainy season. In the rainy season, of course, the sun's radiation to the earth will be maximized so that the irradiance received by the PV will be maximized compared to the rainy season. In more detail, the value of the PV production capacity of 2x550 Wp is described in Table 4.

Table 4. PV production capacity of 2x550 Wp

Time	Month(Wh)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	1	0
6	19	14	18	27	27	22	17	18	27	42	49	29
7	105	106	124	156	172	157	146	156	176	174	159	123
8	211	241	302	304	326	307	301	312	346	333	284	226
9	321	354	409	444	451	432	426	446	451	434	410	336
10	413	459	507	559	553	526	524	563	554	529	501	429
11	460	506	564	600	591	563	571	604	589	558	527	469

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12	456	497	549	571	565	549	551	573	550	519	491	460
13	407	442	483	497	477	477	473	502	470	430	413	396
14	331	360	385	380	360	368	380	411	383	318	304	304
15	230	255	307	253	229	241	266	287	284	199	184	199
16	126	144	146	119	109	123	145	155	127	82	83	103
17	38	46	37	23	19	23	31	32	20	10	12	24
18	0	1	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

4. Conclusion

The conclusion in this study after data collection, calculation, and data analysis so that it can be concluded that the potential for producing electrical energy from PV with a capacity of 2x550 Wp can produce an annual electrical energy of 1,338.2 kWh. The production of electrical energy that will be generated is very dependent on solar irradiance reaching solar PV so that one of the determining factors and optimizing the production of electrical energy by PV is the weather because it greatly affects the irradiance value that will reach solar PV.

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