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Design of a Solar Cell Power Generation System for Utilizing Fuel on Ships

Agus Priyanto[1], Diah Zakiah[2], Damoyanto Purba[3], Retno Sawitri Wulandari[4]
[1] College of Maritime Science, Jakarta, Indonesia, asdia73@gmail.com
[2] College of Maritime Science, Jakarta, Indonesia
[3] College of Maritime Science, Jakarta, Indonesia
[4] College of Maritime Science, Jakarta, Indonesia

[*]Corresponding Author: asdia73@gmail.com

Abstract: The aim of this research is to determine the design of a solar cell power generation system for utilizing fuel on ships at PT. Universal Manunggal Chakra. In this research, the type of research used is Research and Development. Seeing these things, researchers are interested in developing a solar cell power generation system to supply electricity on ships and applying a solar cell power generation system to supply electricity on ships. The results of the research state that the results of the manufacture and development of a prototype solar cell power generator can be concluded that the product is suitable, so it can be applied on ships. This can be proven from the test results by having a percentage of 96.25% in the appropriate category, so that the power generator prototype can supply electricity to the diesel generator on the MT.Hendropriyono III ship.

Keyword: Design, Benefits, Fuel.

INTRODUCTION

UseFossil fuels as an energy source are currently still a top priority. As a result, the availability of fossil fuels in the bowels of the earth is becoming increasingly depleted. Apart from that, the use of fossil fuels is one of the causes of global warming and acid rain due to gas emissions produced and released into the environment. With the increasing prevalence of environmental issues, including in the maritime sector, the Marine Environmental Protection Committee (MEPC) as a unit in the International Maritime Organization (IMO) has revised Annex VI of MARPOL for the gradual reduction of emissions of sulfur oxides (SOx), NOx, and CO2 from ships. The revision of Annex VI MARPOL was carried out in order to make the IMO TIER III regulations a success, where for ships with diesel generator engines built from 1 January 2016 and afterward must meet NOx emission levels of 3.4 g/kWh and for ships built before 2000 it is 3.4 g/kWh. 17 g/kWh (Wang H, 2014).

All ships that will enter the territorial waters of a country that has ratified Annex VI of MARPOL must meet the standards according to these regulations. Currently, various research has been carried out to reduce exhaust emissions from ships, one of which is the

development of a solar cell power generation system on ships, both for the propulsion system and the power generation system. The main benefit of using a solar cell power generation system is reducing fossil fuel consumption by maximizing environmentally sound energy use or increasing the efficiency of combustion engines. The solar power generation system is a generation technology with the principle of converting photon energy from the sun into electrical energy. This is because Indonesia's geographic location is on the equator, so Indonesia's territory will always be illuminated by the sun for 10-12 hours a day. The potential source of solar energy in Indonesia reaches an average of 4.8 kWh per square meter per day, the sun shines for around 2000 hours per year, so Indonesia is classified as rich in solar energy sources (Ministry of Energy and Mineral Resources, 2022).

PT. Cakra Manunggal Semesta is one of the companies in the maritime sector that is developing an ecoship program for its fleet of ships. So the development of a solar cell power generation system is very much in line with the PT program. Cakra Manunggal Semesta in developing environmentally friendly technology. Therefore, this thesis aims to develop a solar cell power generation system that can be applied to ships owned by PT. Chakra of Unity of the Universe.

METHOD

In this research, the type of research used is Research and Development. Research Research and development (R&D) is a research method used to produce certain products and test the effectiveness of these products. To produce certain products, research is used in the nature of needs analysis and to test the effectiveness of the product so that it can function in the wider community, research is needed to test the effectiveness of the product (Sugiyono, 2017). In this research, the R&D method is used because the final results of this research will produce solar power generating equipment. This data analysis technique is carried out at the preliminary stage, during development, data analysis at the validation, evaluation and revision stages, as well as at the implementation stage.

In terms of terms, research and development is a process or steps to develop a new product or improve an existing product, which can be accounted for (Sukmadinata, 2011). Based on what was stated (Borg and Gall, 2003: 10-12) that R&D research is a method for developing and validating a product from findings based on stages which are ultimately tested in the field. This means that research and development aims to develop and produce valid research products through cyclic and repetitive processes or steps such as field testing, product revisions until finally producing a product that meets the stated objectives (Rabiah, 2018).

This research model uses the research and development model according to Sugiyono. According to Sugiyono, the development research model has 10 stages, so it was chosen by researchers because based on theoretical studies the model was developed more simply and explained in detail, so that it could help researchers in developing the product. The steps in research and development according to Sugiyono (2011:298) can be described as follows.

Source: Sugiyono, (2011)

Picture1 R&D Research Flow Diagram

Seeing these things, researchers are interested in developing a solar cell power generation system to supply electricity on ships and applying a solar cell power generation system to supply electricity on ships.

Judging from the potential problems above, the next step is to search for information and analyze data collected through observation when practicing the screen in MT. Hendropriyono III. The process of collecting information is carried out factually and can be used as material for planning certain products which are expected to overcome problems by developing a solar cell power generation system to supply electricity on ships and applying a solar cell power generation system to supply electricity on ships.

The initial stage of searching for information is obtained from the results of studyingtheories related to solar cell power generation. The libraries used are in the form of textbooks in the form of scientific writing, handbooks, e-books, course reference books and also free writings such as writings on virtual forums, free articles from sites, and newspaper writings in the form of hardcopy or softcopy related to the program to be developed.

From product trials carried out, data is obtained which is used as a basis for revising and improving the product being developed. The data was collected using data collection instruments in the form of scales and assessment or response sheets. The data obtained is quantitative and qualitative data. Qualitative data was obtained from the results of validation questionnaires as initial input in developing initial products. Quantitative data is obtained from the power plant product suitability assessment scores given by experts.

Research instruments are tools or facilities used in collecting data to make the work easier or better, in the sense of being more careful, complete and systematic (Suharsimi Arikunto (2010: 203) in (Abidin & Purbawanto, 2015). Data collection instruments are used to Collect data. This research uses an expert judgment or assessment sheet for solar cell power plants. This assessment sheet is a research instrument used to obtain data regarding the suitability of the development of solar cell power plants from experts with a minimum of ATT 1 educational certificate with a screen period of more than 5 years. In research and development, the Likert Scale is used to develop instruments used to measure the attitudes, perceptions or opinions of a person or group of people regarding the potential and problems of an object, a design. products, the process of making products and products that have been developed or created (Sugiyono, 2018). The questionnaire addressed to engineering experts uses a Likert scale using four answers from positive to negative which can be in the form of words including: suitable, quite suitable, not suitable, and not suitable.

On researchand development (R&D), stage I, namely Research or research as the initial stage. In this stage, the techniques used by researchers to collect data are based on facts that are happening in the field. The following are the steps taken by researchers in collecting data, namely the Observation step. According to (Widoyoko 2014:46 in (Ismail & Dedi Sudarmadi, 2019)) observation is "the activity of seeing and regularly recording the visible components of a phenomenon on the research object". This statement is supported by (Sugiyono 2014:145 in (Affany et al., 2022)) emphasizing that observation is a complex process involving various biological and psychological processes. From the explanations of the experts mentioned previously, it can be concluded that observation is a study that involves observing and recording various complex processes, namely biological and psychological processes.

RESULTS AND DISCUSSION

The results of this solar cell power generation energy can beused as a backup energy source on ships, due to its dependence on sunlight. The hotter the sunlight, the higher the energy produced, whereas if the sunlight is dim, the energy produced is lower. The energy

results from this solar cell power plant can be applied to communication and navigation tools which will later be separated from the main energy source on the ship, so that in an emergency if a blackout or damage to the main energy source occurs, the communication system can still operate. Apart from that, if in case the emergency generator cannot work, it can be replaced by a solar cell power generator to supply electricity for emergency lighting or communication and navigation equipment.

The output from a solar cell power plant can be DC (Direct Current) or AC (Alternating Current). The DC current can come directly from the solar panel or from the Solar Charger Controller, while the AC current must pass through the inverter component before being used.

Discussion of Results Product

Solar cell power generation is a generation technology withthe principle of converting photon energy from the sun into electrical energy. In this case, researchers only developed a simple prototype of a solar cell power generator to supply electricity needs. The prototype solar cell power generator can provide more benefits, because it has specifications that can be used efficiently. The advantages include being environmentally friendly, so that the earth's ecosystem can be better maintained. By using electrical energy produced from alternative energy from sunlight, the earth will avoid air pollution. The energy source is sunlight so it never runs out. The development process is carried out through research and development procedures with several stages (Sugiyono, 2014), including potential and problems, information gathering, product design, design validation, product testing. The product was developed with the help of experts in the field, namely Mr. Bambang Wahyudi, M.Mar.E., MM. After the product is produced in prototype form, it needs to be evaluated through design validation and tested on 15 engineering cadets.

The expert validation process produces data that shows that the solar cell power generator prototype is suitable, so that it can continue with the trial process. The trial was carried out by demonstrating to 15 cadets majoring in engineering, then they provided assessments and suggestions. So based on the assessment of 15 cadets majoring in engineering, the prototype was very feasible and suitable. So it can be concluded that the development of a solar cell power generation system can be used as an alternative renewable energy source.

Simple Prototype Budget Plan

RAB (Cost Budget Plan) is the amount of costs requiredboth wages and materials in a tool making job, construction project, etc. By calculating the RAB before carrying out work, it can reduce costs or energy costs, so that we can get maximum results at an efficient cost.

Table 1 Simple prototype cost budget plan

No	Component	Unit	Price
1	Solar panelssolar 60W 12V/5V	1 pc	Rp. 299,303
2	Solar Charger ControllerLCD LED display solar 12V/24V 10 A	1 pc	Rp. 39,900
3	Wattmeters DC 60V 100A 150A	1 pc	Rp. 106,000
4	Mitsuyama 300 mini power inverterWatts convert DC current to AC	1 pc	Rp. 176,474
5	GTZ5S MF DRY PLUS motorbike battery5 A	1 pc	Rp. 90,644
6	MCB 2A	1 pc	Rp. 13,436
7	6 Watt LED light	1 pc	Rp. 7,500
Amount			Rp. 733,257

Application of Solar Cell Power Generation Products on Ships

Application of solar cell power generation system development products on MT ships. Hendropriyono IIInamely by optimizing the area on the MT ship. Hendropriyono III which can be used as a location for placing solar panels. From the observation results, the area that can be used as a location for placing solar panels is the wing deck with an area of 123.24 m2. Laying solar panels on MT ships. Hendropriyono III considers the available area, the dimensions of the solar panels used, and the availability of maintenance space for the solar panels.

By considering the potential availability of solar energy on shipsMT. Hendropriyono III, in this study the load chosen to be supplied by solar panels is lighting as listed in the table:

Table 2 Distribution of Lamp Load ComponentsLighting Using LED

Equipment name	kW
Navigation Light	0.82
GroupSwitch panel & Bridge deck navigation	0.252
Light Panel Board (C Deck Lts)	0.389
Light Panel Board (B Deck Lts)	0.427
Light Panel Board (A & Upper Deck Lts)	0.587
Light Panel Board (On Upper Deck Lts)	0.750
Light Panel Board (Engine Room Lts)	2,906
Total	6,130

To determine the peak load of lighting lamps, factorsWhat you need to pay attention to is the operational time of each lamp, namely how many hours a lamp operates or is turned on in one day. An example of calculating the lighting load on the navigation deck is in table 2. More detailed calculations on other decks are shown in the attachment.

After knowing the energy needed for lighting in navigation*decks*namely 3,953 kWh per day, the potential availability of solar energy on MT ships can be calculated. Hendropriyono III based on the number of panels installed and the power that can be produced by solar panels with the following specifications:

Solar Panel	: SunPower E20-435-COM
OutputsPower	: 435 WP
Max PowerVoltage	: 72.9 V
Max Power Current	: 5.97 A
Open Circuit Voltage	: 85.6 V
Short Circuit Current	: 6.43 A
efficiency	: 20.3%
Size	: 2067 x 1046 x 46 mm
Weight	: 25.4 kg

Source: https://www.solarreviews.com/manufacturers/sunpower/solar- panels/sunpo19768spre20435com
Figure 2 Solar Panel Type SunPower E20-435-COM

After selecting the specifications for the solar panelnumber of solar panels on MT ships. Hendropriyono III with the total power that can be produced can be calculated as listed in table 3

Table 3 Total Power produced by Solar Panels

Location	Amount Panel	Panel Power (watt)	Total (watt)	Total (Wh)	Total (kWh)
Wing decks	2	435	870	4350	4.35

With the average length of sunshine in Indonesiafor 12 hours, the maximum exposure time is assumed to be 5 hours per day, namely between 10.00-15.00, so the total power that can be produced is 4.35 kWh per day.

The inverter specifications selected are as follows:

Type : pwri8k22050
Output ContPower : 10000 watts D.C*input* : 12 Volts
Air conditioningOutputs : 220/380 Volts
Efficiency : 87%

In designing a solar cell power generation system, a storage medium is needed to store electrical energygenerated by the panel

Sun. The storage medium in this case is a battery. Batteries are used to supply electricity needs at night or when solar panels cannot supply energy due to the absence of sunlight.

To ensure the system can operate properly according to the lighting load, a battery is selected according to Figure 2 with the following specifications:

Type : Tree TR 12V 500AH
Capacity : 500 Ah
Voltage : 12 Volts
Ddimensions : 589 x 286 x 464 mm

Source :https://indonesian.alibaba.com/product-detail/Long-Life-12V-500Ah- AGM-Storge-60419283224.html
Figure 3 TR 12V 500AH Tree Type Battery

Every energybattery = 500 Ah x 12 V
= 6000 watts/hour
= 6 kWh
Number of batteries needed = 1 battery

Based on the selected Solar Charger Controller specifications, the number of Solar Charger Controllers can be determined as follows:

Type : Blue Solar Charger Controller 150/100
V*output* : 12/24 V

V*input* : 145 VI rated charge : 100 A
IPV = Isc xn PV = 6.43 x 2 = 12.86 A
N*Chargers* = Ipv/ Irrated charge
= 12.86 / 100 A
= 0.128 ≈ 1 unit of Solar Charger Controller

Excesssolar cell power generation system on board:

1. Clean energy source:Solar cell power generation systems use sunlight as the main energy source. It is a renewable and environmentally friendly energy source, as it does not produce greenhouse gas emissions or air pollution.
2. Low dependencyagainst fossil fuels: By relying on sunlight as an energy source, ships with solar cell power generation systems reduce dependence on increasingly scarce and expensive fossil fuels.
3. Low maintenance: Solar cell power generation systems tend to require little maintenance because they have no mechanical moving parts. Solar panels are generally long-lasting and require little routine maintenance.
4. Efficient use of space:Solar panels can be installed on existing boat surfaces, such as the deck or roof, without requiring significant additional space. This allows for more efficient use of space on the ship.
5. Energy storage: Solar cell power generation systems are usually equipped with systemsenergy storage, such as batteries. This allows ships to store energy generated by solar panels and use it when sunlight is not available, such as at night or in bad weather.

Disadvantages of solar cell power generation systems on ships:

1. Power limitations: Solar cell power generation systems have power limitations depending on the capacity of the installed solar panels and the intensity of available sunlight. This may be insufficient to meet the high power requirements of large vessels or in adverse weather conditions.
2. Dependence on sunlight: Power generation systemsSolar cells depend on sunlight as an energy source. When sunlight is blocked by clouds, rain, or other inclement weather, energy production can be significantly reduced.
3. High initial costs: Initial installation costs of the generating systemSolar cell electricity on ships can be quite high. Although the cost of solar panels has decreased over the past few years, the initial investment can still be prohibitive for some ship operators.
4. Complex maintenance: Although solar panels require little routine maintenance, the solar cell power generation system as a whole may requirecomplex maintenance, especially if energy storage systems such as batteries are involved. Users should monitor and maintain the battery regularly to maintain optimal performance and lifespan.
5. Limitations on night cruises:Despite energy storage systems, ships with solar cell power generation systems may face limitations during long night voyages. The power stored in batteries is limited, and if the vessel relies on solar panels as the primary source of energy, it may be necessary to regulate power usage so as not to exceed the storage capacity.

*Initial costs*solar cell power generation system: Est. solar cell + Solar Charger Controller + battery+ inverter

Table 5 Installation cost budget plansolar cell power generator

Component Name	Price per unit	Amount
PanelSun	Rp. 5,741,000 x 2	Rp. 11,482,000
Solar Charger Controllers	Rp. 11,204,000 x 1	Rp. 11,204,000
Battery	Rp. 2,534,000 x 1	Rp. 2,534,000
Inverters	Rp. 1,364,000 x 1	Rp. 1,364,000
Installation fee	15% of the total component price	Rp. 3,988,000
Total initial cost		Rp. 30,572,000

Diesel generator fuel usage data on ships: LSFO price Rp. 16,600/L reference data from Pertamina per month March 2022. Efficiency of using solar panels and not using solar panels on ships, namely:

1. When anchorageuses 1 diesel generator with a load of 440 kW without supply from solar panels.
2. When anchorageuses 1 diesel generator with a load of 433 kW using a supply from solar panels for lighting.

The advantage of using solar panels is on the diesel generator loadwhich is reduced from 440 kW to 433 kW, namely 7 kW.

FOC dieselgenerator = 189.2 g/kWh = 0.1892 kg/kWh
7 kW x 0.1892kg/kWh = 1,324 kg/d
1.324 kg/h x 24h = 31,776 kg/day
31.776 kg/day x 30day = 953.28 kg/month
953.28 kg/monthx 12month = 11,439.36 kg/year
11,439.36kg/year = 11,439 tons/year 11,439 tons /specificgravity(0.991) = 11,542 kl/year
11,542kl/year = 11,542 L/year
11,542 L/year x Rp.16,600 = Rp. 191,597,200 /year So the efficiency obtained is IDR.
191,597,200,- /year Solar panel lifespan » 25 years reference from sunterra.id
biaya instalasi pembangkit listrik sel surya =**Rp . 30.572.000** = 0.158 years
efficiency yang di dapat Rp. 191.597.200

So the ROI (Return Of Investment) is 0.158 years or 1.9 months. This means that 24.8 years of use are the benefits of the solar panels

CONCLUSION

Based onAfter analyzing the problem that has been carried out, the following conclusions are drawn: The results of the manufacture and development of the solar cell power generator prototype can be concluded that the product is suitable, so it can be applied on ships. This can be proven from the test results by having a percentage of 96.25% in the appropriate category, so that the power generator prototype can supply electricity to the diesel generator on the MT.Hendropriyono III ship; Solar cell power generation development products can be applied on MT ships. Hendropriyono III optimized the area on the wing deck with 2 solar panels with a panel power of 435 watts for a total of 4.35 kWh per day, because the average solar radiation time in Indonesia is 12 hours and the maximum exposure time is assumed to be 5 hours per day.

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