Solar Cell System Design for Mechanical Cooling System on the Ferry 500 GT

Danny Faturachman, Shariman Mustafa, Yoseph Arya Dewanto, and Muswar Muslim

Abstract**—**Nowadays energy electricity is a primary need for almost the entire human race. Electrical Energy is very instrumental in carrying out the activities of the economy. Source of electric energy can be produced from a variety of sources of energy. Outline his energy can be in for two kinds of energy that can be *updated* and energy that cannot be updated. Source of energy that cannot be updated, among others derived from fossil and nuclear and energy can still be updated, among others derived from geothermal (solar energy), ocean waves, waterfalls, wind, etc. Source of energy that cannot be updated, notably energy derived from fossil gradually going on leave because the price become more expensive and the amount of energy sources already reduced. The Energy of the Sun can be used in the energy to heat (solar thermal) or as energy electricity (photovoltaic). Utilization of solar energy as solar photovoltaic plant in the engineering as a source of electrical energy to produce no pollution, air pollution and pollution on the surrounding environment. The basic ingredients of photovoltaic is solar cell. The use of solar cell on a vessel can be used as energy in a variety of electrical equipment on the ship, due to the relative abundance of Sun energy and never run out because the Sun bathes the territory Indonesia 10-12 hours a day. In this case the solar cell used to meet the needs of the mechanical cooling equipment on board the ferry that sails around the region of Indonesia. Expected usage of this solar energy can reduce the use of fossil fuels oil and can save on operational costs.

Keywords**—**Energy saving, Ferry, Mechanical cooling system, Solar Cell

I. Introduction

THE need for electricity in a ship must provide by the generator and its immense power available is very dependent on operational the ship. The generator choices is specialized of idealizing systems in this role for planning because it involves techno-economy problem. Supply electricity to vessels needs. System neutral body of ship grounded on may not except:

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- Zinc anode protection system must be a cathode or the outer part body of ship;
- System limited or local ground as system starting and starting motor in motor fuel combustion;
- A measuring monitor insulator instrument to the current that circulated no more than 30 mA in the worst of conditions;
- High voltage neutral ground to avoid dangerous areas were defined in requirements.

Power supply and distribution.

- Generator, switch board and battery must be in a separate location from the fuel tank and oil pump, with a cofferdam or with sufficient distance.
- Cable that may be open to steam and gas needs to be protect with insulation in accordance, with the possibility of reducing corrosion.

Some requirements in the form of cable for installation on board based on the position where the cables will be placed, adapted to the structure of the ship so that the installation and buffer plate avoid of strains/stresses possibility. Stages of electricity ship system from the genset generator with his drive that serves as power plants that supply all the needs of electric power on board. Then the flows in the channel generate main switch board (the main liaison panel) which is a main panel that combines the power of some existing genset for distributed the junction was then in the forward to all components of each junction. Junction power is a terminal of some existing equipment on board that require a three-phase electric power:

a. Junction lighting is a terminal for the power supply to be used as a means of lighting (lights) on the ship.
b. the Junction is a communication terminal for the power supply being used as communication tools on board.
c. Monitoring the terminal Junction is to supply electric power to be used as a monitoring tool.

After using the genset, ships can use the power of the land through shore connection which is usually in use at the time of the ship's docking. If the genset is not active then the emergency source of electrical power (power source) is usually in the form of battery. Due to the nature of the emergency then only certain equipment and very important in the supply by the emergency source of electric power for example his lights, lamps, navigation, gangway lighting appliances, and others. Emergency power source will be stored automatically through the emergency switch board if all the genset is not active.

II. Solar Energy

The need for increasing energy and depleting reserves of oil, forcing people to look for alternative energy sources.

Developed countries have also competed and raced the latest breakthroughs to search a creating new technologies that can replace petroleum as an energy source. Depleting his supplies of energy and also the dependence on one type of energy in which the fuel oil is very huge and almost all sectors of life using this fuel, while fuel oil Is a commodity exports dominant to state revenues. In the utilization solar energy in Indonesia as an equatorial and tropical areas with the land area of almost 2 million square km, endowed with irradiating the sun more than six hours a day or about 2,400 hours in a year. Solar energy on Indonesia have intensity between 0.6 - 0.7 kW / m^2 how its abundance of energy most wasted this. For solar energy utilization attempts Indonesia has various advantages such as:

- The energy is available with large numbers in Indonesia.
- Strongly support the national energy policy of austerity.
- Verified and equitable energy.
- Allow built in remote areas because it does not require the transmission of energy or transportation of energy resources.
- Solar energy is an environmentally friendly energy source.

While in Indonesia should actually solar cells get special attention, this because Indonesia which is the tropics and is in the equatorial region and Indonesia has the characteristics of the wind to a less well (very fluctuates) in an appeal with the characteristics of the wind in the western countries but it was very profitable to solar energy average get a sunburn six hours a day. An effort to search for new energy sources should meet requirement that produce the amount of energy quite strong the cost of economical and not have a negative impact on the environment. Hence search- are in direct in the use of solar energy either directly or indirectly by the use of a panel that solar cell that can change solar energy into electrical energy in call of solar cell are very supportive.

Solar cells or in the international world is more known as a photovoltaic cell, is a semiconductor that has a surface and consists of a series of p and n type diodes, which able to convert the energy of sunlight into electrical energy.

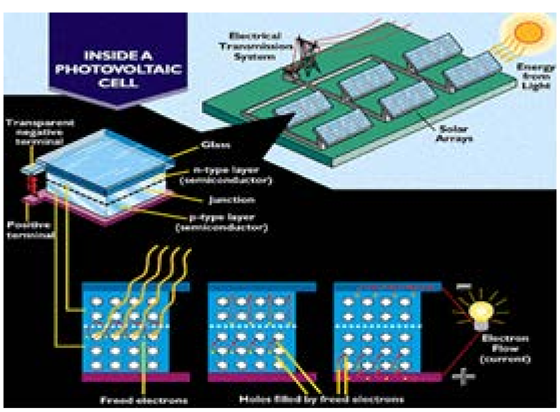

Fig. 1 Solar Cell

Solar Cell application in Marine Engineering:

1. The use of solar cells on a supertanker [5]
2. Solar boat [8].
3. Japan first cargo ship sets [6].


Fig. 2 Solar Cell in Tanker

III. Design of Solar Cell System

A. Principal Dimension Of Ship Data

Length Over All	(Loa)	:	45.05 m
Length Between Perpendicular	(Lpp)	:	40.15 m
Length of Water Line	(L_{WL})	:	42.00 m
Breadth	(B_{mld})	:	12.00 m
Height	(H_{mld})	:	3.20 m
Draft	(d)	:	2.15 m
Speed	(Vs)	:	11 knot
Distance of voyage (s)		:	15 sea mil
Main Engine		:	2 × 800 HP
Auxiliary Engine		:	2 × 80 kVA
Genset emergency		:	25 kVA

B. Power Need Analysis For Cooling System

Power need for the ship's cooling system Ro-Ro ferry is used for Steering Room, Passenger Rooms, Cabin Crew Rooms and the Control Room, installed air conditioning (AC) machine in the form of AC Split in each room. AC Blower must be arranged so that every part of the room to get the same temperature influence. Engine/generator AC should be placed outdoors and protected from direct weather influences and the sea air or given a construction for protection against the weather. For AC generators placed on vehicle load space must be given a protective fender, or construction to protect the generator from the possibility of a collision with a vehicle.

Specifications for AC and its placement are:

- The engine control room : 1 x ½ PK
- Medical Room : 1 x ½ PK
- Mess Room : 1 x ½ PK
- Captain and Engine Room Operators : 1 x ½ PK
- Mosque Room : 1 x ½ PK
- Passenger Executive Room : 4 x 1½ PK

There are 3 factors to consider when determining the need for PK of AC power conditioners, namely AC power (BTU/hour), electrical power (Watts), and PK of the AC compressor. Actually number PK on AC power is a unit on the AC compressor, not AC cooling power, so to decide on the power need, we must look from the specification of AC.

TABLE I
POWER NEED

Room's Name	Unit	AC Power (PK)	AC Power (BTU/h)	AC Power (Watt)
Engine Room	1	1/2	± 5000	220
Captain & Engine Room Operator	1	1/2	± 5000	220
Passenger Executive Room	4	11/2	± 12000	1560
Medical Room	1	1/2	± 5000	220
Mosque Room	1	1/2	± 5000	220
Mess Room	1	1/2	± 5000	220
			Total	2660

According to table1, it needs power for air conditioner on board during the cruise of 10 hours is 2660 x 10 = 26,600 W ≈ 26.6 Kwh.

C. design & Selecton Of Solar Cell System

In determination of solar panels which will be used, there are parameters that serve as a reference. The parameters in selection solar panels are:

- General rule in passenger vessels. It is used as a reference by which solar panels this can be mounted on board, because not all parts of a passenger ship can be mounted by solar panels.
- Room available on a passenger ship. Solar panels selected for planning power plant will be adjusted with a common plan (general arrangement) a vessel ferry Ro-Ro, so they will be known how many panel that can be attached on board.

Based on data of the irradiating sun from several locations in Indonesia, solar radiation in Indonesia can be classified as follows [9]:

- to western region Indonesia around 4.5 kwh/m^2 day with variations monthly about 10%.
- to eastern Indonesia around 5.1 kwh/m^2 day with variations monthly about 9 %.
- wind speed average in Indonesia about 4.8 kwh/m^2 day with variations monthly 9 %.

From calculation of the total solar module above then we chosen brands of solar cell to be used is type FVG 240P – MC with the specifications:

- Power peak : 240 watt peak
- Efficiency : 14.6 %
- Voltage of module (max) : 30.50 V
- Current of module (max) : 7.88 A
- Current of short circuit : 8.28 A
- Voltage open circuit : 37.60 V
- Dimension : l × b × h

(1650 × 990 × 35) mm

From selection of the solar panels, it can be calculated how many pieces of solar panels needed to meet the power for cooling load. For conditions in Indonesia, even though the duration of the sun shines is 8 hours/day, but the effectiveness of the photon beam obtained solar panels during the day is only 5 hours.

With so many panel to meet the needs of power equal to 26600 watt as many as the efficiency of solar panel hence: 240 x 14.6 % = 204.96 W.

The number of panel = (26.600 Wh) / (204.96 W x 5 hour) = 25,956 ≈ 26 solar panels. This solar panel will be installed as many as 26 solar panels with consideration of the bridge deck is still able to accommodate the number of solar panels, Besides all the power produced will be higher than or in other words the number of solar panels directly also increased the amount of resources resulting.

The amount of power generated by the solar panel in 1 hour is: 26 x 204.96 Watts = 5328.96 Wh. The magnitude of the power generated by the solar panels all over in 5 hours is: 5328.96 x 5 = 26644.8 Wh.

Then solar panels chosen is FVG 240P-MC model with consideration to address the needs of load power lighting. It has solar panels, power and sufficient for the largest area on the deck of the bridge 20 x 8 = 160 m^2.

For the placement of solar cell will be placed on deck wheel house and the installation is done in parallel in order to optimize the absorption of solar energy.

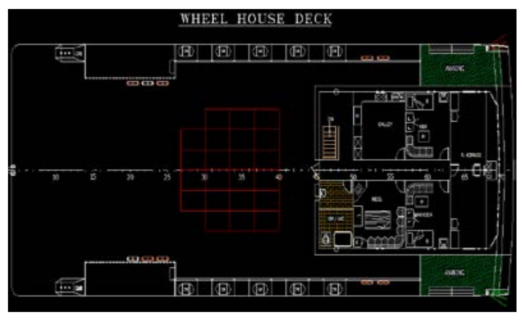

Fig. 3 The Placement of Solar Panel in Deck House

D. Charger Controller Need

The function of this control is to control the flow of current from photovoltaic modules to arrangement the battery charging and to protect the battery from the charging level is allowed, prevent the occurrence of excessive charging or lack of because this will result to the battery damaged, further characteristics can decline, this means shortening battery life. Now many of the powerful control system capable of controlling the control system as a whole.

From the existing controller charger specifications, the maximum current that can be issued charger controller is of 60 A. Whereas current generated by a solar module with voltage of 30.5 V is 7.88 A. So that one charger controller was only able to be used for 7 pieces of solar modules.

The number modules of 1 charger = (charger power) / (power module) = 60/7.88 = 7.61 ≈ 7 pieces, so for 1 charger controller accommodates up to 7 panels.

To determine the amount of controller charger:

charger = (number of modules) / 7 = 1/7 = 3.28 ≈ 4 controller charger.

Current output for 1 charger controller:

l = 7.88 x 7 = 55.16 A (the current maximum of 60 A controller charger issued)

Current output 4 controller charger for 10 hours :
o_{utput} = l x (n) charger = 60 x 4 x 10 = 2400 A
The Total power generated by charger controller: 60 × 4 × 24 V = 5760 Watt

E. Battery System Design

A battery must be in a circuit in order to work. Battery is a device that converts chemical energy directly to electrical energy. A battery consists of one or more voltaic cells. Each voltaic cell consists of two half cells connected in series conductive electrolyte containing with anion and cation. Half cell electrolyte and electrodes including anions (negative ions) migrate, i.e. the anode or negative electrode, half other cells including electrolytes and electrodes cation (positive ion) migration, i.e. the cathode or positive electrode.

To measure the amount of electrical energy that have a battery can be done at the same time ongoing while charging power to the battery. To measure the amount of electric power can be in use for the tool cells tester, this tool consists of two legs that are isolated from each other, between the legs of a DC voltmeter has the limit of measurement to a 3 volt, the electric power situation in the cell of the battery are as follows:

1. battery in good condition = 1.5% - 2 volts
2. battery condition is not good = 1.5 - 1.85 volts
3. battery condition is broken = 1 - 1.5 volt

Battery serves as a repository of energy for use at night or in cloudy time. There are several battery suitable for photovoltaic systems:

- Nickel cadmium.
- Lead acid.
- Nickel-iron.
- Sodium sulphate.

To ensure the system can be operate properly and in accordance with the needs of the planned system, needs to load the battery. As for the process, such as: Unknown total load power in need is 26600 Watt. Planned use of marine rolls type.
Battery capacity = 1104 Watt, battery voltage = 4 Volt.
Battery current: 1104 x 4 = 4416 Wh ≈ 4,416 Kwh then the number of batteries needed to load total:
Number of the battery = (total load needs) / (battery power) = 26600/4416 = 6.023 ≈ 6 battery
Battery capacity for 6 units is: Q_{batt} = 1104 x 6 = 6624 Ah
Total battery capacity is: Q_{tot} = 6624 bat x 4 = 26496 Wh = 26.496 KWh
Battery charging time = (battery power) / (power solar cell) = (1104 x 4 x 6)/(26 x 204,96) = 4.97 hour.
Battery operating Time = (operational length of battery power)/(total load power that needs) = (26496 x 10)/26600 = 9.96 h.

F. Inverter

An Inverter is used to convert the input voltage DC output voltage air conditioning became an inverter can be either adjustable-voltage and voltage. The input voltage source inverter can use battery, fuel cell, solar power, or another DC voltage source. The regular output voltage of 120 V 60 Hz is generated, 220V 50 Hz, 115 V 400 Hz. in principle, generate photovoltaic current DC. When Ac current is needed, then it can be met by installing a relay modifier, electronic equipment that work efficiently, called inverter.

In designing this solar cell system, the current resulting from the solar module is the current DC. While the current that is used to drive the compressor using the flow of AC current to change DC, needs inverter current. Planned use type XANTREX model SW3024E with the specification:

- Power : 3300 watt
- Voltage : 24 V
- Efficiency: 94%, so 94% x 3300 watt = 3102 watt

The amount of inverter need:
Total inverter = Inverter produced / Inverter power
= 26644.8 / 3102
= 8.59 ≈ 9 inverter

IV. Solar Cell System Design

Needs analysis of the existing load, the need for early and after modified is:

- Known power generator is: 80 kVA = 80,000 watts,
- the burden of resources available: 26,600 watts
- resources panel that is produced: 26,496 watts, so:

The amount of resources which are borne generator is:
VA = 80,000 – 26,496 = 53,504 the amount of power and the savings could be done is:
Saving energy = (the load early - the load after) / (the load early) x 100 % = 80,000 / 53,504 x 100 % = 1.49 %
Analysis of driving force system between diesel engine and solar cell:
Ship propulsion system component:

- with motor diesel:
  - 1 unit auxiliary 80 kVA
  - Tool kit engine
- with solar cell:
  - Use solar cell 26
  - 4 controller charger
  - 6 battery
  - 9 inverter

The calculation of fuel consumption using generator power planned 80 kVA, for 10 hours cruise:
W_{fo}: 80 x 210 x 10 x 10^{-6} x 0.6 = 0.1008 tons
The volume of fuel:
$W_{fo} / \gamma_{fo} =$ 0.10 / 0,85 = 0.11 m^3 = 110 liter
The price of diesel fuel for the total fuel shipping is 110 liter and the price of 1 liter of marine diesel is Rp 8,500,-
The calculation for motor diesel:
Investment for the purchase of diesel

- Generator 1 unit: Rp. 43.000.000,
- Tool kit-engine 1 set: Rp. 2,000,000,-

Operations:
The fuel for the 5 trip for 1 day needs 110 liters.

- 1 day cruise 110 liters x Rp 8,500 = Rp 935,000
- For a year Rp 935,000 x 365 days = Rp. 341,275,000
- For 5 years Rp. 341,275,000 x 5 =: Rp. 1,706,375,000,-
- For 10 years = Rp. 1.706.375.000,-

For 10 years usage performed 4 times engine maintenance and costs Rp 6,000,000 x 10 : Rp 60,000,000.-

Investment for the purchase of solar cell:

- Using 26 units solar cell @ Rp. 3,139,500- = Rp. 81,627,000,-
- 4 pieces charger controller @ Rp. 6,490,000,- = Rp. 25,960,000,-
- 6 batteries @ Rp. 9,093,500,- = Rp. 54,561,000,-
- 9 inverter @ Rp. 34,950,000 = Rp. 314,550,000,-
- 1 tool kit set engine: Rp. 2,000,000,

Operational battery backup 6 pieces @ Rp. 9,093,500,- = Rp. 54,561,000,-

Maintenance costs for 10 years @ Rp. 2,000,000/yrs = Rp. 20,000,000,-

TABLE II
TOTAL INVESTMENT

Year	Generator	Solar cell
1	Rp. 341,275,000,-	Rp. 434,329,500,-
5	Rp.1,706,375,000,-	Rp. 10,000,000,-
10	Rp.1.706.375,000,-	Rp. 20,000,000,-
After 10 years	Rp. 60.000.000,-	Rp. 54,561,000,-
Total	Rp. 3,814,025,000,-	Rp. 553,259,000,-

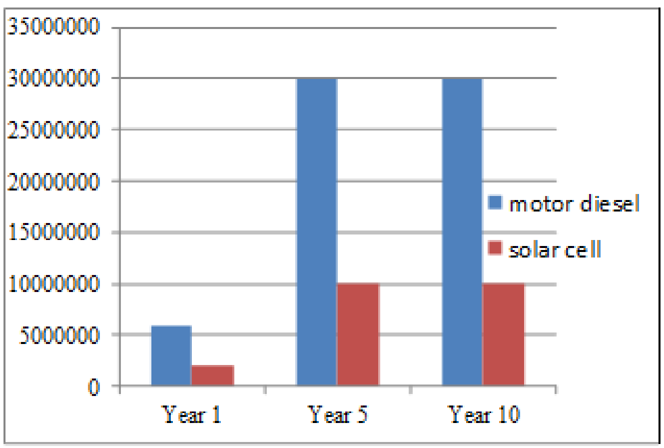

Fig. 4 Data comparison maintenance costs

V. CONCLUSION

Total overall resources for 5 trips Merak-Bakaheuni cruise trip is 26.6 kWh. This value is calculated based on 1 trip cruise for 2 hours. Based on the data above, the planning of solar cell for the cooling system are as follows: The module used is type FVG 240 P-MC with:

- Power peak specifications: 250 Watts
- Efficiency: 14.6%
- Voltage module (max): 30.50 V
- Flow module (max): 7,88 A
- Short circuit Currents: 8,28 A
- Open circuit Voltage: 37,60 V
- Dimensions: p l t (1650 x 990 x 35) mm
- Output power panel : 204,96 Watts

The amount of the planned solar cell is 26 units with the effectiveness of the Sun for about 5 hours, so that the total power output is obtained by 26,496 kWh. The overall surface area of panels for installation planning 37,57 m^2 solar cell placed on the wheel house decks with a total area of 160 m2.

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