The Optimum Configuration of Solar PV system from Conventional Fishing Boat towards e-Boat 12 GT

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Abstract. Fishermen are a type of livelihood that is mostly carried out by Indonesians who live on the coast. In the country with the largest long coast in the world, Fishermen should have good welfare and a healthy lifestyle. But in fact, most of the traditional fishermen in Indonesia have not felt it. They still carry out fishing activities in an inefficient way, due they only follow the work patterns that have been done by their predecessors, far from the touch of technological advances that have an impact on high operational and maintenance costs while searching fish. The boundary of this research is to calculate the average cost of energy from boat lighting to energy sources using the homer simulation method. The purpose of this study is to compare the energy consumption generated by electric boat (e-Boat) and conventional fishing boat. Mercury lighting technology on conventional fishing boat compared to LED electric boat lamps with the same, level of luminance 75% lower energy consumption and Levelized Cost of Energy (LCoE) 11% lower. Thus, the energy is more efficient, clean and there is a new more effective pattern.

Keywords: *Configuration, Solar PV, Fishing, e-Boat, Energy.*

INTRODUCTION

Indonesia is a country with the largest archipelago in the world and has a large sea area [1]. Based on the United Nation Convention on the Law of the Sea (UNCLOS) 1982 which was later ratified by Indonesia through Law No. 17 of 1985, states the total area of Indonesia's sea area of 5.9 million km^2, consisting of 3.2 million km^2 territorial waters and 2.7 million km^2 of waters in the Exclusive Economic Zone (EEZ) [2]. With this wide area, Indonesia is blessed with a lot of marine products, including coral reefs, squid, and various types of fish. Currently, marine fishing technology in Indonesia still uses conventional methods. Where traditional fishermen still use their predecessor's work patterns that are not touched by technological advances. The boat transportation used still uses diesel fuel as a source of lighting energy. Trends in the world today are starting to switch from non-renewable energy sources to renewable energy sources. So that currently, some vehicle technologies have used energy that is more environmentally friendly, for example, electric motors (e-Motorcycle) and electric cars (e-Car).

This is in line with the Paris Conference of the Parties (COP) 21 agreement followed by 195 countries which aim to limit the global temperature rise to 2 degrees Celsius and take steps to limit it to 1.5 degrees Celsius [3]. These countries are slowly turning to renewable energy because it is more environmentally friendly and makes policies that are more pro towards renewable energy, one of which is the application of the Carbon Tax. Squid fishing boats in Indonesia use diesel fuel as propulsion and lighting. Even though, diesel fuel is one of the petroleum derivatives whose combustion produces carbon gas which is harmful to the environment. Therefore in this study, we will try to make a transition to lamp lighting technology by comparing consumption diesel fuel with a renewable energy source, in the form of photovoltaic combined with a battery as a source of lighting. The purpose of this study is to compare the energy consumption generated by electric boat (e-Boat) and conventional fishing boat and to maximize the storage energy from fishing boat batteries due to the limited amount of energy that can be accommodated due to the limited deck of boats owned by 12 GT fishing boat. So there is a need for additional energy that can be obtained by building a Charging Station (CS) location that can be installed onshore or at sea.

METHODOLOGY

This paper uses a simulation in the form of HOMER Pro software which is used to make modeling and simulation of combined systems for integrating solar PV and battery technology as well as modeling boat battery charging systems both from the boat's PV itself and from the charging station. This simulation uses to load data of 500 watts Light Emitting Diode (LED) lamps for integrated PV and battery fishing boats (e-Boat) and 1500 watts mercury lamps for conventional fishing boats using generators.

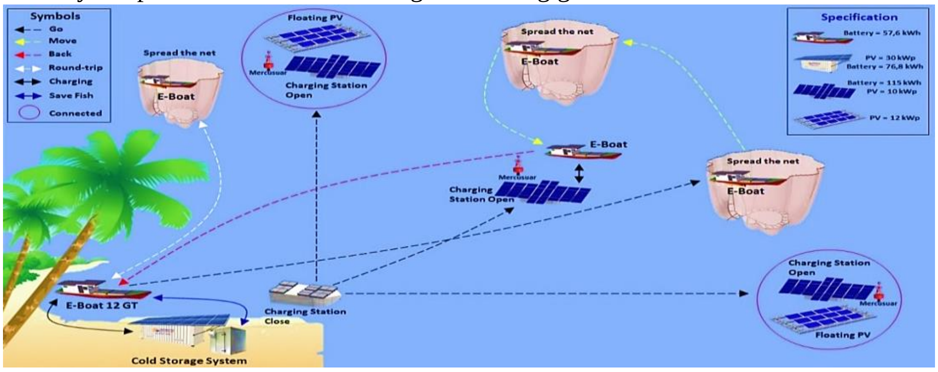
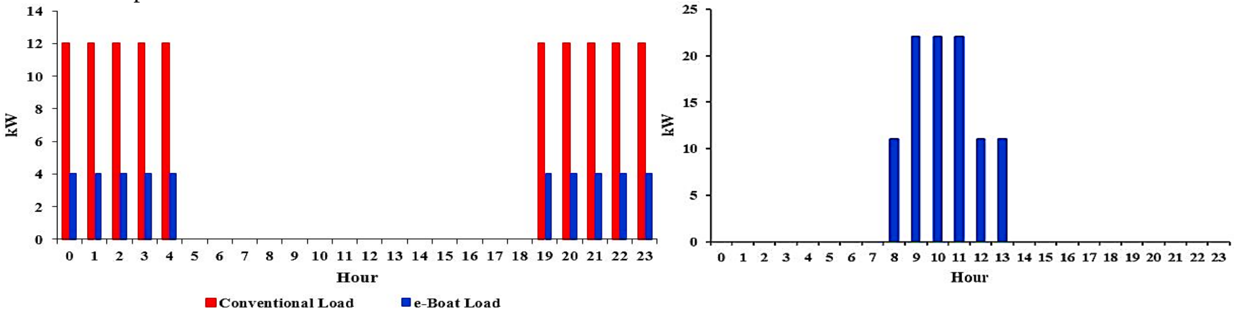


FIGURE 1. e-Boat Activity Pattern

In figure 1. above is a fishing boat activity scheme, it is assumed that the daily fishing activity of 1-3 days using a 12 GT boat that has been designed for lighting systems uses sources from PV and batteries. In this scheme, when the boat is at the initial dock the e-Boat battery is in full condition due to getting energy supply from the PV e-Boat and the charging station onshore. The distance to the fishing location is approximately 10 miles from the coast [4], fishermen depart in the afternoon so that they arrive at the location at around 11 pm using lighting sourced from PV and batteries. When it runs out, the next day, e-Boat fishermen can have two options, that is returning when the battery runs out and can store their catch in cold storage on land or recharge with PV from the e-Boat. However, figure 1. when this is not fulfilled, you can charge it via the nearest e-Boat charging station in the middle of the sea which has been mapped. The location of this research was conducted in Dadap Village, Juntinyuat District, Indramayu, West Java with coordinates 6^0 13 '52.22 "S and 108^0 26' 06.21". The load form used in this simulation uses a blank load profile, consisting of three loads, with the electrical load of conventional fishing boats using 1500 watts mercury lamps, e-Boat with 500 watts LED light loads, and a charging station. The conventional fishing boat system & e-Boat uses a load of 8 lamps for 10 hours starting from 7 pm to 4 am. Meanwhile, the charging station itself uses the load from each incoming boat to charge from 9 am to 2 pm.



(a) (b)

FIGURE. 2 Daily Load Profile (a) Conventional Fishing Boat vs e-Boat & (b) Charging Station [5]

Levelized Cost of Energy Homer (LCOE) defines as the average cost per kWh of useful electrical energy produced by the system.

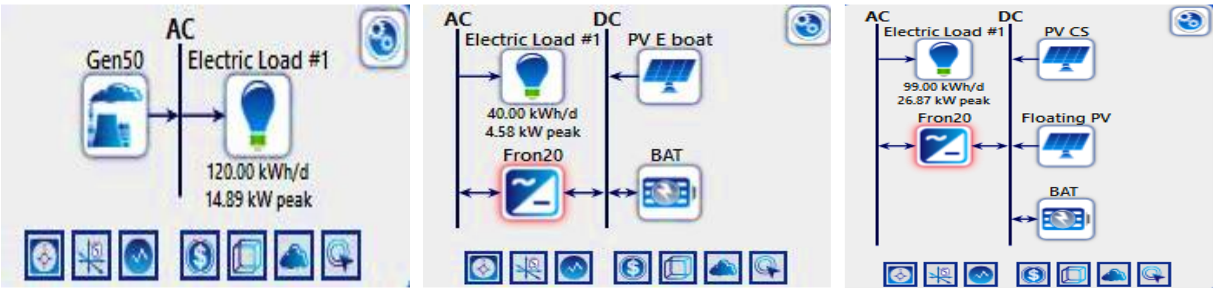
$$LCOE = \frac{\frac{\frac{i'-f}{1+f}\left(1+\frac{i'-f}{1+f}\right)^N}{\left(1+\frac{i'-f}{1+f}\right)^N-1} x\, C_{NPC,tot}}{E_{served,ACprim}} \qquad (1)$$

Where,

	i'	= Discount rate
	f	= Inflation rate (%)
	N	= Lifetime Project (Years)
	$E_{Serverd}$	=Total electrical load served (kWh/yr)

The Net Present Cost (NPC) of a component is the present value of all the costs of installing and operating the component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime. HOMER calculates the net present cost of each Component in the system, and of the system as a whole such as capital cost, operation & maintenance (OM), and replacement cost [5].

The following is a schematic of each system. The conventional fishing boat electrical system uses a generator as a source of electricity and the total electricity consumption of mercury lamps is 120 kWh/d with a peak load of 14.89 kW. Then, the e-Boat system uses a power source in the form of PV & batteries with electricity consumption in the form of LED lights 40 kWh/d, a peak load of 4.19 kW and the charging station system uses the load from the boat which will charge 88 kWh/d with a peak load of 26, 89 kW. The block diagram below is an off-grid model and is all set for 25 years, with a random variability of 5% day to day and a time step of 5%.



(a) (b) (c)

FIGURE. 3 Configuration System (a) Conventional Fishing Boat, (b) e-Boat (b) & (c) Charging Station [5]

Below, is an attached estimate of the initial costs used. There are 3 financing scenarios consisting of total PV module cost ($/kWp), total battery + installation cost ($/kWh), and total inverter and installation cost ($ / kWp). Currently, Indonesia's discount rate is 4%, an inflation rate of 1.42%, which has been applied for 25 years.

TABLE 1. Cost of Configuration Solar PV systems

Component	*e-Boat*	*Charging Station*	*Floating PV*
PV Module			
PV module (J-Leaf, 240Wp)($/kWp) [6]	493,68	493,68	0
PV Floating module 310 Mono ($/kWp)	0	0	372,38
Mounting structure on boat ($/kWp)	125	0	0
Mounting structure on charging station ($/kWp)	0	125	0
Mounting structure on floating PV ($/kWp)	0	0	125
Worker Installation	300	300	300
Miscellaneous expense (licensing, contracts and PV delivery) ($/kWp) [6]	50	50	50
Total solar PV installation costs ($/kWp)	**968,68**	**968,68**	**847,38**
Battery			
Battery BB-48100 15 S ($/kWh)	366,71	366,71	366,71
Additional battery installation and hardware costs ($/kWh)	150	150	150
Total battery + installation cost ($/kWh)	**516,71**	**516,71**	**516,71**
Inverter			
Inverter Growatt, Off Grid Inverter 4.8kW, SPF5000TL HVM ($/kWp)	306,77	306,77	306,77
Inverter installation and additional hardware cost ($ /kWp) [6]	150	150	150
The total cost of the inverter + installation ($/kWp)	**456,77**	**456,77**	**456,77**

RESULT AND DISCUSSION

After the simulation from the homer is carried out, the LCoE of the conventional fishing boat is $ 0,15 per kWh and fuel consumption is 51 L/d with an operation & maintenance cost of 0.02 $/op. hour. It is assumed that the annual capacity shortage is 10% and the price of diesel fuel is $ 0.34 (subsidized diesel), obtained 51 L/day x $ 0.34 = $ 17,34 per day.

Quantity	Value	Units
Total fuel consumed	18,617	L
Avg fuel per day	51.0	L/day
Avg fuel per hour	2.13	L/hour

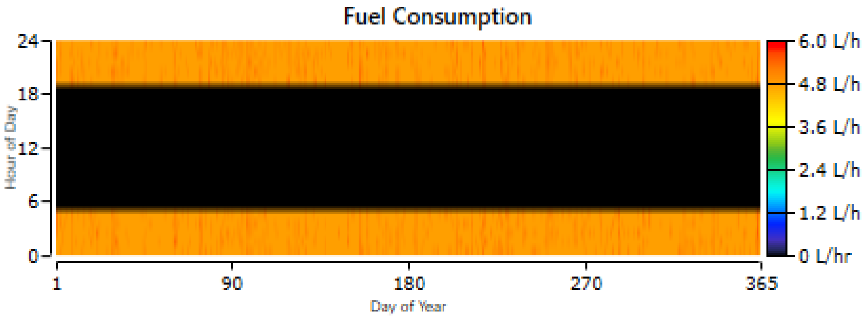


FIGURE. 4 Diesel Fuel Calculation

Then for the e-Boat boat system designed, the maximum capacity of PV that can be installed is 8.64 kW with an annual capacity shortage of 21% resulting in an average output of 31.5 kWh/d so that it produces LCoE e-Boat system is $ 0,14 per kWh. the nominal capacity of the battery that can be used is 57.6 kWh with the ability to perform when using the battery for 3 days when fully charged. Therefore, another energy source is needed to fill the e-Boat by charging the boat to the nearest charging station. The difference percentage between LCoE conventional fishing boat and LCOE e-Boat just 11 %. Meanwhile, the difference in energy consumption of the e-Boat LED lamps is 75% lower. This can be examined further concerning the constituent components of each LCoE system with analysis sensitivity, referring to equation (1) and table 2 below. The e-Boat system has a large enough capital cost value for 3 main components, i.e. Solar PV, battery, and inverters, for operation & maintenance it is almost non-existent, However, make sure the installation position is not shaded so that solar energy can be received entirely. Then the replacement components replace the battery whose lifetime runs out for 5 years, and the inverter for 10 years. Meanwhile, conventional boat systems use the main components, i.e. generators and diesel fuel. The O&M cost is also large due, in addition to operating costs, diesel fuel costs are also subject to increase each year. And the replacement cost for service is done almost every month.

TABLE 2. Economic Comparison of Each Configuration

Schemes	PV (kW)	Gen (kW)	Battery (unit)	Inverter (kW)	LCoE ($)	Net Present Cost ($)	Operating Cost ($/yr)	Initial Capital ($)	Fuel (L/yr)
		50			0,15	127,67	6.595,35	6.770,54	18.615
	8,64		12	5	0,14	30.966,48		30.966,48	
	28		24	30	0,12	76.510,86		76.510,89	

The graph above shows that the highest e-Boat unmet electricity load occurred in the Indramayu region in January with the highest value of 31.36 kW. So that this value is used as a reference for the lack of maximum energy that can be supplied by the charging station. This unmet condition occurs due to low solar radiation which can cause cloudy cloud conditions or in rainy conditions so that there is no penetration of solar radiation into PV. From the simulation, obtained additional energy that can be given to the e-Boat of 31.36 kWh, rounded up to 33 kWh with a safety factor of 4%. The duration of charging energy can be set for 3 hours. So, that is obtained 11 kW for load boat on the charging station. The simulation is carried out charging electricity for 3 boats from 9 am up to 2 pm. LCoE for the charging station is $ 0.12 per kWh for a single charge.

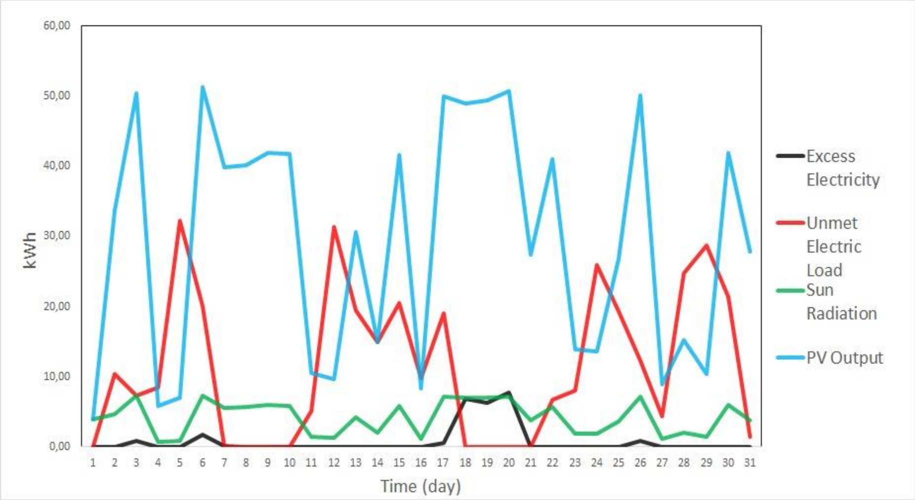


FIGURE. 5 Peak Unmet Electric Load e-Boat

CONCLUSION

The use of the conventional fishing boat at this time must be reduced, conventional fishing boats diesel fuel produces 49,040 kg/year of carbon gas for the 12 GT type. Apart from the air pollution it generates, this conventional method pollutes the environment, affects the quality of marine products, and harms fishermen's health. So it is necessary, to have a more efficient technology transition that can improve the welfare of fishermen. The excess electricity generated by the combination of PV and e-Boat battery is 3.67%. LCoE generated by the e-Boat system cheaper than a conventional fishing boat. the cost for charging electricity e-Boat is $ 3.96 on a single charge if compared it to the cost of charging electricity conventional fishing boat is 0.14 per kWh, so obtained $ 4.62 a single charge, the price is more expensive and keeps in mind, Solar PV no requires the cost of fuel and no maintenance, while the generator still requires. The boundary of this research is to calculate the average cost of energy from boat lighting and the savings that occur are very significant. Moreover, in the future, if the propulsion boat has used sources from PV, it will produce greater savings for fishermen. By obtaining the optimum configuration of this e-Boat design, it will reduce expenses and make fishermen healthier and more prosperous.

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