Techno Economic Study of Potential Using Solar Energy as a Supporting Power Supply for Diesel Engine for Landing Craft

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Abstract

Increasing price of oil and the concern of maintaining clean environment have become the main reasons for a shipping company to focus on the vessel fuel consumption. Fuel economy has become a major concern due to the increasing of oil price. The availability of fossil fuels is limited and depleting day by day as the consumption is increasing very rapidly. Environmental impact by diesel exhaust is also taken into consideration as diesel exhaust is a complex mixture of thousands of gases and fine particles (commonly known as soot) that contains more than 40 toxic air contaminants. These include many known or suspected cancer-causing substances, such as benzene, arsenic and formaldehyde. As for these matters, renewable energy is said to have potential in replacing fossil fuels in providing energy and is more environmental friendly. Solar energy represents one of the best practice available alternative energy to mitigate this challenge. Solar energy can assist in supporting auxiliary power for the instrument on board vessel such as landing craft. This study will determine the potential of using solar PV system onboard a landing craft by analyzing the reduction usage of fuel and diesel exhaust as well as carrying out economical analysis. The power requirement for the vessel was calculated. Fuel and money saved by using solar panels were obtained and comparison between data of using diesel alone and using solar panels as supporting power supply were analyzed. Economical analysis were obtained by determining data of cost estimation, cash flow diagram, Annual Average Cost (ACC), and return investment of both vessel with the support of solar PV system and without solar PV system.

Key words: Solar PV system, landing craft, auxiliary power supply, fuel reduction, Annual Average Cost (ACC)

1. Introduction

A lot of studies had been carried out in order to find an alternative energy for fossil fuel with other renewable energy resources. One of the most promising renewable energy is the use of solar energy. Solar energy can save sailing vessel and powerboat owner's money by reducing their dependence on shore power and or gas/diesel generated electricity. Solar power has become an important part of ocean-cruising by providing recreational and commercial boaters a secure, safe, sustainable and renewable energy source. Solar energy is holding out promise for reduced usage of fossil fuels, with consequent economic and environmental benefits [1,2].

This paper present result of techno-economic analysis of the study that deal with reduction in usage of fossil fuel and economic aspects analysis. These points will be the evidence of whether there are any potential of using solar energy as a supporting power supply for diesel engine of a landing craft owned by Dickson Marine Co. Sdn. Bhd. There is currently the need of an alternative energy to support the power supply of a marine vessel and also find ways to minimize the impacts of diesel fuel to the environment.This paper describe the potential of using solar energy with diesel engine on a landing craft by using other means of supplying energy and reducing diesel exhaust pollution.

The paper discussed assessment of effectiveness of using solar energy as a supporting power supply in reducing fuel consumption and diesel emission. The paper also discussed the economic analysis that the effectiveness of installation of solar panels for auxiliary purposes [3,4].

2. Methodology

Data from the landing craft, Dickson 33, which have report, logbook and plan, is taken to obtain data on the fuel and power consumption, voyaging route and its principle particular. The auxiliary power of the vessel consumed is taken into consideration to determine the solar panels which are suitable for this vessel and can supply enough power as supplied by diesel. Data on solar radiation at certain route is also taken into consideration. The route of the ship is limited in Malaysia only. Other data and facts required include the cost of purchasing diesel fuel and exhaust of diesel from the vessel. The cost of purchasing diesel is obtained from the company. The cost of diesel is determined to compare the cost of using diesel and the cost of using solar panels. Other data collected for the solar power which will be used on the vessel would be the market price of the panels [5, 7, 10]. Then the total power requirement for 24V DC is calculated to find the power needed for the solar panels to supply that will be used in the system. For this project, solar panels will be used to supply power of 24 volts DC from 2 banks of 24 volts 200 ampere hour batteries which runs electronic equipments such as alarms, emergency lights, radio navigational aids, navigational lights and other emergency loads on board the vessel.

Assume the system requires 2 kilowatts for 24 hours per day. As natural losses are also taken into consideration, the result must be multiplied by 1.2, assuming 80% of efficiency. The corrected load will be determined by multiplying power required by system with 24 hours. Then this load will be multiplied by 1.2. It is assumed that the solar panels received 8 hours of solar radiation. So the power is divided by 8 hours [6, 11].

2.1 Cost Estimation

When alternative power source such as solar panels is to be installed to a vessel, some costs need to be taken into consideration. The costs are investment/initial cost, maintenance cost, operation cost and salvage value. Comparison between the cost for vessel with solar PV system and vessel without solar PV system are discussed.

2.2 Economical Analysis

Economical aspect is one of the main points that would be the evidence of whether solar power has the potential to be used on board the vessel as an assisting power supply for the electrical instruments to reduce fuel consumption thus saving cost of purchasing diesel fuel. For this project, Annual Average Cost (AAC) between actual vessel which is operated by main engine and solar assisted vessel are studied. There are several valid economic criteria that relate to the profitability of competing ship design [8, 9].

3. Results and Discussion

It is known that the north-east monsoon season is between the months of November to March. So for 5 months, the generator must produce 4/8 to 7/8 of the system needs. For the dry season, it is assumed that the solar panels will receive more solar radiation where the solar PV system can be used to the max. During the dry season, the generator is estimated to only produce 1/8 to 4/8 of the system needs. Tables 1-3show that, more power is supported by the generator during wet season, if the solar panels are used to the max during the dry season, it would reduce the total annual generator output thus reducing the fuel consumption of the generator [12, 1, and 17].

Table 1: 5 Months of wet season (November – March)

Hours	Power produced by generator	Power requirement for 5 months
4/8	4/8 x 58.1 = 29.1 kWh	29.1 kWh x 151 days = 4394.1 kWh
5/8	5/8 x 58.1 = 36.3 kWh	36.3 kWh x 151 days = 5481.3 kWh
6/8	6/8 x 58.1 = 43.6 kWh	43.6 kWh x 151 days = 6583.6 kWh
7/8	7/8 x 58.1 = 50.8 kWh	50.8 kWh x 151 days = 7670.8 kWh

Table 2: 7 Months of dry season (April – October

Hours	Power produced by generator	Power requirement for 7 months
1/8	1/8 x 58.1 = 7.3 kWh	7.3 kWh x 214days = 1562.2 kWh
2/8	2/8 x 58.1 = 14.5 kWh	14.5 kWh x 214days = 3101.0 kWh
3/8	3/8 x 58.1 = 21.8 kWh	21.8 kWh x 214days = 4665.2 kWh
4/8	4/8 x 58.1 = 29.05 kWh	29.5 kWh x 214days = 6216.7 kWh

Table 3: 7 months of wet season (April – October)

Wet season	Dry season	Total Annual Generator Output
4/8 = 4394.1 kWh	4/8 = 6216.7 kWh	10610.8 kWh
5/8 = 5481.3 kWh	3/8 = 4665.2 kWh	10146.5 kWh
6/8 = 6583.6 kWh	2/8 = 3101.0 kWh	9684.6 kWh
7/8 = 7670.8 kWh	1/8 = 1562.2 kWh	9233.0 kWh

Without the PV system, the generator would have to provide 58.1 kWh per day for the whole 365 days in a year. So if 58.1 multiplied by 365 days would results in 21206.5 kWh of annual generator output. For the maximum use of PV system during dry season, the PV system saves 21206.5 kWh – 9233.0 kWh = 11973.5 of generation by generator. It is estimated that 1 kWh uses 0.3 liters of fuel. For 9233.0 kWh generator output, the generator is using 2769.9 liters of fuel per year. If the vessel is using the generator for the whole power supply, the total generator output multiplied by total days in a year, results in 21206.5 kWh. As 1 kWh uses 0.3 liters fuel, 21206.5 kWh x 0.3 = 6361.95 liters of fuel. To determine the liters of fuel saved by using solar panels for 1//8 and 7/8 fraction, the total fuel used by generator without solar panels is deducted by the total fuel used by generator with support of solar panels. By using solar panels to the max, the generator can save 3592.1 liters of fuel per year (See Table 4 and 5).

Table 4: Assume that 1 liter of diesel today cost RM2 (4 RM = 1USD)

Generation by generator		Total Annual Generator Output	Energy saved by using solar panels	Fuel saved (liters)	Money saved (RM)
Wet season (5 months)	Dry season (7 months)				
4/8= 4394.1 kWh	4/8 = 6216.7 kWh	10610.8 kWh	10595.7 kWh	3178.7	3178.7 x 2.0 = 6356.2
5/8 = 5481.3 kWh	3/8 = 4665.2 kWh	10146.5 kWh	11060.0 kWh	3318.0	3318.0 x 2.0 = 6636.0
6/8 = 6583.6 kWh	2/8 = 3101.0 kWh	9684.6 kWh	11521.9 kWh	3456.6	3456.6 x 2.0 = 6913.2
7/8 = 7670.8 kWh	1/8 = 1562.2 kWh	9233.0 kWh	11973.5 kWh	3592.1	3592.1 x 2.0 = 7184.2

For overall fuel consumption by both main engine and generator, the percentage of the fuel reduced is determined by obtaining the difference between the amount of fuel used by the vessel without PV system and the amount of fuel used with the support of PV system. The difference is divided with the normal amount of fuel used without the support of PV system and the value is then multiplied with 100 to get the percentage. The percentage of fuelreduced is 0.66%. Even though the percentage of saved fuel is small, for a long term consideration, it would really help in saving the environment due to the saved fuel as lesser fuel used would reduce the exhaust.

The solar panels are used to supply power to be stored in the batteries to support power for alarms, emergency lights, radio navigational aids, navigational lights and emergency loads. These equipments are very important even though they do not use a high amount of power. With the support of solar panels, the power will be stored in the batteries where the vessel will continuously receive power supply even though both of the generator sets broke down. These equipments are crucial during emergencies at sea [14, 15, 16].

Table 5: Percentages of fuel savings

Generation by generator		Total Annual Generator Output	Energy saved by using solar panels	Fuel saved (liters)	Savings percentage
Wet season (5 months)	Dry season (7 months)				
4/8= 4394.1 kWh	4/8 = 6216.7 kWh	10610.8 kWh	10595.7 kWh	3178.7	50%
5/8 = 5481.3 kWh	3/8 = 4665.2 kWh	10146.5 kWh	11060.0 kWh	3318.0	52%
6/8 = 6583.6 kWh	2/8 = 3101.0 kWh	9684.6 kWh	11521.9 kWh	3456.6	54.3%
7/8 = 7670.8 kWh	1/8 = 1562.2 kWh	9233.0 kWh	11973.5 kWh	3592.1	56.5%

3.1 Economic Results

Economical analysis is done to make comparison between the original vessel and the vessel with a solar PV system attached to it to support the generator in supplying power for auxiliary purposes. The analysis is carried out to determine Annual Average Cost (AAC) and the capital investment recovery. The analysis also discussed on the sensitivity due to oil price.

3.2 Cash Flow Diagram

Cash flow diagram is determined to show the flow of the costs for a project. The positive direction shows that the profit (debit) and negative direction shows that expenditure (credit).

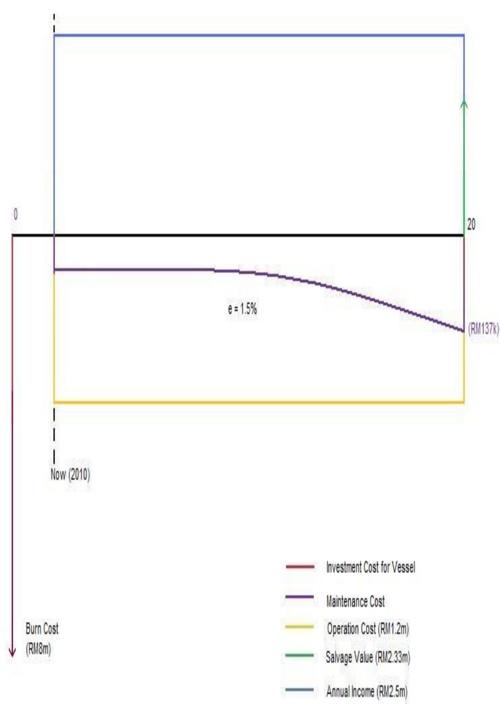

Figure 1: The costs for the vessel without solar (including burn cost)

From Figure 2 the cash flow diagram shows the cash flow for the vessel without PV solar system including the burn cost which is the cost to build the vessel. The maintenance cost will go through 1.5 percent reduction each year. The operation cost and annual income are estimated to be the same each year.

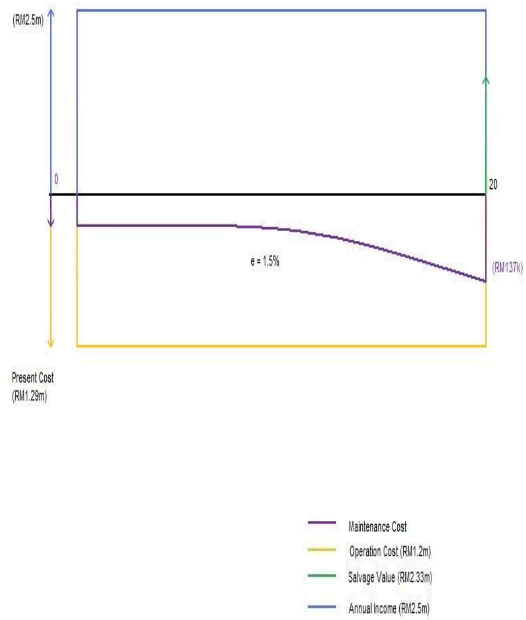

Figure 2: Cash Flow Diagram for vessel without solar

Figure 3 hows the cash flow diagram for vessel without solar. In this figure, all the costs are sum up to get the present cost except for the salvage value as it is profitable only after 20 years of usage.

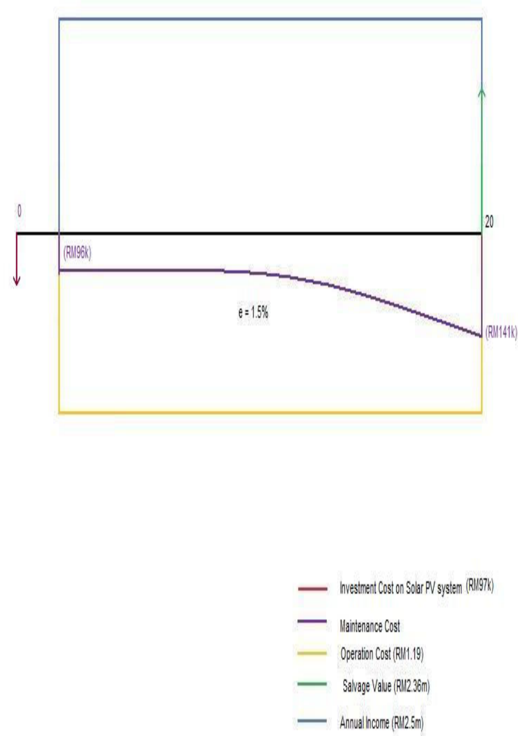

Figure 3: Cash flow for vessel with solar PV system

In Figure 4.5, the graph shows the cash flow diagram for vessel with solar PV system. The graph is similar to the 2 graphs above but this graph includes the investment cost on solar PV system.

3.3 Annual Cost

Annual Average Cost (AAC) between the original vessel and the solar assisted vessel will be analyzed in this section.The calculation of AAC can be obtained by using the following formula.

$$AAC\ (NPV) = NPV\left[\frac{i(1+i)^n}{(1+i)^n-1}\right] \text{ (equation 1)}$$

$i = 10\%$, $n = 20$ year

NPV = total net present value

The result from the Figure, both cases under consideration for the vessels are found to be profitable due to the positive direction according to the cash flow flow charts. The ACC for vessel with solar PV system is found to be lower than the ACC for the original vessel. The result shows that using solar PV system on the vessel is more economical rather than to use diesel generator alone. The analysis may get a better result if the cost of the installation of the PV system is much cheaper and more efficient in supporting the power supply. With a lower cost and the ability to save more fuel, the result may come out much better where using solar panels would give more benefit and profit rather than disadvantages.

3.4 Return on Investment

Return on investment is carried out to determine the numbers of years that the investment will be recovered. The capital investment recovery can be determined as shown;

Investment cost for boat with solar PV system = RM97280.30

Cost saved = RM7184.20

Investment recovered = RM97280.30/RM7194.20 =13.5year= 14 year

4. Conclusion

The use of solar panels to supply some of the power required by instruments and lightings onboard the vessel reduced fuel consumption and thus reducing the diesel exhaust. With the instability of fuel price nowadays, reduction in fuel consumption would help in saving the company's money and would somehow increase the income. The reduction in diesel exhaust might be small but for a long term period, the reduction of those exhausts would really help in saving our environment from pollution. The solar panels would also helps in keeping the power supply continuously if both generators face breakdown or difficulties. As the solar energy provide power for 24V DC, it will ensure there will be power to operate the alarms, emergency lights, radio navigational aids, navigational lights and other emergency loads. Even though these instruments use a small amount of power, their functions are very important in case of emergencies and also for navigational purposes.In conclusion the use of solar panels will give benefits to the vessel and also to the environment. Reduction of fuel consumption and diesel exhaust are proven to show that there are potential in using solar energy to support the power requirement for the landing craft as the installation of the solar hybrid system give benefits to the company and also the environment.

4.1. Recommendations

There are a lot of aspects that could be investigated and improve in the future for a much better results**.** Some of the suggestion and recommendation are as follows [17, 18].

- Design of a prototype of the system is encouraged as it would give more accurate results.

-Different types of solar panels can be taken into consideration to improve the performance of the system. There are more improved and hi-tech solar panels nowadays that can be used for the system and may give better results.

-It is also advisable to reduce the installation cost by looking for cheaper yet efficient equipments for solar PV system especially the solar panels. By reducing the installation price it would give a much better results in the economic analysis for the vessel with solar PV system.

-Comparisons with other hybrid system are also recommended to find the best system that can be applied on a vessel.

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