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Utilization Off-Grid Solar Powered Cold Storage for Economy Improvement of Fishermen in Mangur Island

Amanda Dwi Wantira[1;] Muhammad Iqbal Sugiharto[2]; Budi Rachman Setiabudi[3]

[1]Logistics Engineering Department, Institut Teknologi Kalimantan, Indonesia

[2]Electrical Engineering Department, Institut Teknologi Kalimantan, Indonesia

[3]Information System Department, STMIK Likmi, Indonesia

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Abstract

The absence of access to electricity from PLN on Mangur Island requires fishermen to preserve fish catches by smoking, which causes the selling price of fish to fall. Some fishermen have diesel engines to power cold storage, but the cost of diesel fuel mixed with kerosene is relatively high, which is IDR 17.000/liter. Mangur Island has a large enough solar potential, with a Global Horizontal Irradiance (GHI) value of 5,6 kWh/m2, where this potential can be implemented by installing a Solar Power Plant (solar PV) system. Installation of cold storage with Off-Grid solar powered (Cortagrid) system is a solution to be able to help fishermen preserve fish catches. Off-Grid solar powered with a solar panel capacity of 1 kWp is installed with an additional 4,8 kWh battery. This solar PV system can supply the cold storage load for the fisherman commodity of Mangur Island of 145 Watt and 2 lighting lamps with each power output of 9 Watt. In the CAPEX for the initial solar PV system of IDR 31.906.000, you will get a payback period of 6 years and 4 months and an NPV of IDR 1.112.269,46. Where the solar PV installed can help the community to enjoy clean electrical energy and maximize the potential of solar energy on Mangur Island.

K*eywords:* *Cold Storage; Fishermen, Mangur; Off-grid; Solar Power*

Introduction

Mangur Island as one of the islands in the Southeast Maluku archipelago has the potential of abundant maritime natural resources. Natural beauty, fish, various animals, to coral reefs are a million charms that can be obtained when visiting this island. The population of 286 people on Mangur Island, precisely in Tiflean Village, the majority of their livelihoods are fishermen. The catch of the fishermen on this island is very promising. Based on the results of interviews conducted with village officials, a fisherman can catch 50 kg of fish per day. If the fishing season, fishermen can get about 200 kg of catch in one go to sea.

This abundant catch is not proportional to the income received by fishermen. Because the distance is far from the city and difficult to reach by buyers, the catch is sold at a low price. Fresh catch

can only be sold if there are collectors who will bring it to the city. However, if there is none, then the fishermen are forced to preserve the catch so that the shelf life can last a long time by drying, so that the selling value is even lower. For fresh fish, fishermen sell it at a price of IDR 10.000 to IDR 15.000 per kilogram, or around IDR 30.000 to IDR 50.000 per fish. Meanwhile, dried fish are sold at a maximum price of IDR 50.000 per kilogram, depending on the type of fish. The types of fish that are mostly obtained are reef fish, such as red snapper, white snapper, and bubara fish.

Data from Ministry of Energy and Mineral Resources of the Republic of Indonesia (2021) shows the electrification ratio in the Maluku and surrounding areas is below the national average of 65,1%. Because of its separate location and far from the regional center, Mangur Island does not have electricity from PLN. As such, people only rely on modest energy sources. Some communities have generator sets/generators to generate electricity. Others, use solar panels as a source of energy with low power capacity. This generator engine and solar panels are only used as a source of lighting at night. Low power generation and high operating costs make it impossible for people to use high-powered electronic devices, including tools that can be used to store and preserve fish in fresh condition.

To pursue remote areas / 3T (Frontier, Outermost, Disadvantaged) one of them can use renewable energy. According to Satryawan (2018) Maluku, including in it, has a large enough potential for solar energy, which is 1905.4 kWh/m^2/year. The manufacture of a cooling machine based on an off-grid solar power plant or named CORTAGRID (Off-Grid Solar Powered Cold Storage) is a solution when the destination does not have a PLN electricity source. Fishermen can collect and store their catch for a longer time with fresh conditions without the need to be burdened by the cost of generator fuel. If fishermen can sell fish in large quantities and in fresh conditions, then the selling value of their catches can increase. In terms of operation and maintenance of refrigeration machines and solar PV, later it can be done by the fishermen groups that will be formed. The involvement of fishermen from the beginning of the design and transfer of knowledge are important to ensure the success of this project in the long term. In the end, this proposal was able to answer the economic problems of the community, especially the fishermen that occurred in Tiflean Village, Mangur Island.

Literature Review

The Solar Power Generation System has several parts such as solar panels, SCC, inverters, batteries, and several other supporting parts. There are several topologies of the solar PV system, such as those that are not connected to the PLN grid, which are called off-grid topologies and those that are connected to PLN are on-grid topologies (Setiawan & Setiawan, 2017). Off-grid solar systems are very suitable to be built in locations that do not have a grid connection with large electricity providers (Akter et al., 2019). One of the off-grid solar power systems that is often built is the stand-alone DC coupling system. In stand-alone systems, the component that has the largest proportion of costs is the battery, because all the daily energy will flow to the inverter through the battery in the traditional system (Ibrahim et al., 2023). The output of the solar panel that has a DC voltage will be controlled directly by the SCC which has 1 input (solar panel) and 2 outputs that go to the battery and to the DC load. In a DC coupling system, the battery is installed in one path to the inverter (Bagus, 2018).

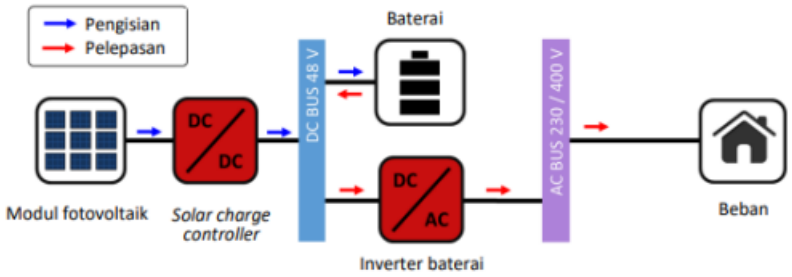

Figure 1. Solar Power Plant Off-Grid System DC Coupling
Source: (Bagus, 2018)

The installed solar PV system needs to take into account the Performance Ratio (PR) value to determine the quality of the designed PV mini-grid system. If the system has a PR value of 70-90%, then the system can be said to be feasible (Hutajulu, RT Siregar, & Pambudi, 2020). In the analysis of solar energy where photovoltaic generally has steady resistance and shunt resistance which has an effect on decreasing efficiency, as shown in Figure 2 below (Hamdani, Subagiada, & Subagiyo, 2011).

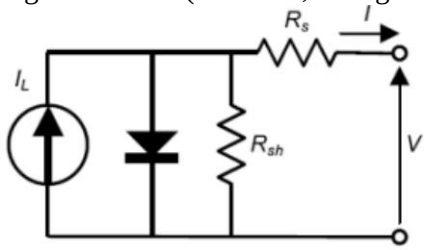

Figure 2. Single diode model for solar panel equivalent circuit
Source: (Hamdani, Subagiada, & Subagiyo, 2011)

The energy production of the solar panel system is determined based on the estimated voltage and current generated by the solar panel, where the output power of the solar panel depends on the technical characteristics and environmental parameters. The solar panel model includes electrical parameters under standard conditions and I, SC short circuit current temperature coefficient, Isc and V, oc temperature coefficient open circuit voltage, Voc (Hamdani, Subagiada, & Subagiyo, 2011). In designing a solar PV system, apart from complying with national and international power quality standards, it is also necessary to calculate the optimal, economical, efficient and safe operation (Hassan, Bass, Al-Abdeli, Masek, & Masoum, 2023).

Research on the design and construction of PV mini-grid using a stand-alone off-grid topology has been conducted for PV mini-grid centered on the outer islands (Kristyadi & Arfianto, 2021) and household needs in Indonesia (Jasuan, Nawawi, & Samaulah, 2019). Jasuan, et. al. (2019) compares between applications using off-grid systems and on-grid systems. The results obtained indicate that the generation cost per kWh using the solar PV off-grid and on-grid systems is IDR 4.644/kWh and IDR 1.244/kWh, respectively, compared to the PLN tariff of IDR 1.467.28/kWh. and can reduce CO2 gas production up to 37,9 tons.

An experimental study on the use of PV panels specifically for the use of chest freezers in areas with hot climates has been carried out on the island of Bali using a power supply system (Suamir, Wirajati, Santosa, Susila, & Tri Putra, 2020). The system consists of a 300 Wp solar PV power supply system with 100 Ah storage battery and a chest freezer system specified for 100 W 220 VAC power input. The solar PV power supply system can generate enough electrical energy to meet the energy consumed by the chest freezer, contributing 1450 Wh per day generation efficiency of 10.1%. The study also found that in order to ensure the continuous operation of the 100 W chest freezer and make it fully

powered by renewable energy sources, the capacity of the solar PV system should be 400 Wp which is about four times the specified power input of the chest freezer.

Another study that is very close to the current research is the use of stand-alone solar PV for marginal farmers to reduce post-harvest losses. The use of cold storage that is integrated with IoT-based sensors helps for remote monitoring. The results obtained, it is known that the use of cold storage can save up to $ 7449 per year. From this value, the payback period is estimated to be 2.1 years (Mishra, Chaulya, Prasad, Mandal, & Banerjee, 2020). In India, a similar study was conducted to assist shallot producers. Onion yields are damaged due to uncontrolled temperature and humidity. The storage area in the form of cold storage is designed to have a capacity of fifty tons with a heat load of 26.11 TR (Joshi, et al., 2022).

Research Method

The research method is the stage used to collect data to answer questions from the implementation of service in Tiflean Village, Mangur Island. This implementation is carried out by several procedures, including identification of problems where there is no access to PLN's electrical energy entering the area. So that the community, especially the fishermen of Tiflean Village, still find it difficult to preserve the fish they catch. This difficulty occurs due to the relatively expensive cost of fuel energy, which is IDR 17.000/liter. To start the diesel engine so that the engine coolant starts in 2 hours.

This implementation method is made so that the implemented solar PV system can work where the benefits will be felt by the Tiflean Village fishing group. A flowchart or flowchart represents a workflow that displays stages in the form of symbols and their sequences connected by arrows. The flow chart used is as shown in Figure 3 as follows.

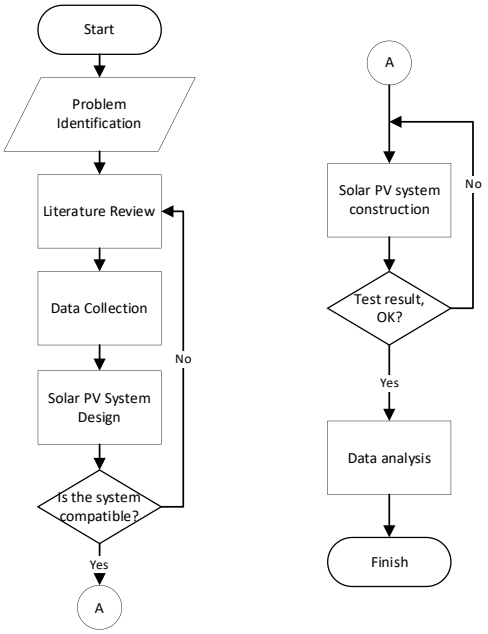

Figure 3. Research Method Diagram

In designing this PV mini-grid system, the data collected on the potential for solar radiation, calculate the daily load used, the selection of solar panels, inverters, batteries and other PV mini-grid components. The explanation of the solar PV system design made is described in the sub-chapter below as follows.

A. Daily Load Data

To design a solar PV system, it is necessary to calculate the amount of daily load that will be used. In this implementation, the installed load is 2 lamps with a total power of 9 Watts and 1 fish cooler of 143 Watts. With a total daily load used for 1 day that is equal to 3648 Wh. This value will be a reference for calculating the off-grid PV mini-grid system.

B. Solar Energy Potential

By taking secondary data using the Global Solar Atlas website, the Global Horizontal Irradiance (GHI) value for the Tiflean Village area is 5,213 kWh/m^2. Furthermore, this value is used to calculate the PV mini-grid components which will be used as follows.

C. Solar Panel

The determination of the solar panels used is the value obtained from the Global Solar Atlas website (Bagus, 2018) with a temperature increase of 26,8 ^{o}C, an increase of 1 ^{o}C can affect the output power that will be generated by the solar PV system to be installed. The equation 1 used to determine the number of panels to be used is as follows (Hutajulu, RT Siregar, & Pambudi, 2020)

$$P_{t\ after^0C} = \%\ per^oC \times P_{MPP} \times Rising\ temperature(^oC) \quad (1)$$

$$P_{MPP\ t\ after^0C} = P_{MPP} - P_{t\ after^0C} \quad (2)$$

$$\mathrm{TCF} = \frac{P_{MPP\ t\ after^0C}}{P_{MPP}} \quad (3)$$

$$PV_{Area} = \frac{P}{G_{av} \times \eta_{pv} \times TCF \times \eta_{out}} \quad (4)$$

$$P_{Wp} = PV_{Area} \times PSI \times \eta_{pv} \quad (5)$$

By using the above equation, the minimum value for the solar panels used is 772 Wp, in this implementation a larger capacity of 1 kWp is used to overcome the shortage of production power in the solar PV system.

D. SCC (Solar Charge Controller)

For the calculation of the SCC component which has a function to control the output of solar panel power to loads such as batteries. Where for this SCC value is obtained by looking at the solar panel datasheet used multiplied by a factor of safety of 1,25. The minimum Iscc value is 22.15 A and the Vdc value is 44,75 V. This value is used to determine the selected SCC (Bagus, 2018).

E. Inverter

The inverter used is required to have a sinusoidal waveform, which follows the waveform of the load used, namely the AC (Alternating Current) load. The inverter that will be used is the PSW (Pure Sine Wave) type. The calculation of the determination of the inverter capacity used is described in equation 6 as follows (Kencana, 2018).

$$Inverter\ (\mathrm{VA}) = \mathrm{Wmax} + (25\% \times \mathrm{Wmax})$$

In the calculation, a value of 201 Watts is obtained, but in the components on the market there is no PSW type inverter so in this implementation using an inverter with a capacity of 1000 W turn on the fish cooler for fishermen in the Tiflean Village, Mangur Island.

Result and Discussion

The result of this research is the installation of an off-grid solar PV system with a capacity of 1000 Wp. Where in this study was also assisted by the people of Tiflean Village, Mangur Island. The cooling machine used is a chest freezer as shown in Figure 4 as follows.

Figure 4. Chest Freezer Cortagrid

The chest freezer used is the GEA type with a capacity of 143 Watts. This chest freezer can be used to preserve the fish caught by the Tiflean Village community. In utilizing the savings in terms of energy consumption to turn on this chest freezer, it takes a large amount of energy if turn it on for 1 day. For this chest freezer, 3,432 Wh/day is needed.

Where in Tiflean Village also still uses a diesel engine to be able to access electrical energy, where for 1 liter of diesel it costs IDR 17.000. Thus, the Cortagrid system utilizes solar energy to save expenses from the use of this Cortagrid system.

Figure 5. Installation of the Cortagrid system with the Tiflean village community

The purpose of this installation involves the Tiflean Village community, so that the community also knows how to install the Cortagrid system. Not only that, the provision of maintenance from the Cortagrid system is also given to the people of Tiflean Village so that the tools provided can be maintained in the future.

In installing the Cortagrid system, it is necessary to check the system that has been designed and installed. The value for the battery output is 25 V, and the output of the AC system to supply the energy needed by the chest freezer is in the 220 VAC range. The entire Cortagrid NRE system used is shown in Figure 6 as follows.

Figure 6. PV mini-grid system

The solar PV system in Figure 6 on the left has a protection system, inverter, SCC in accordance with the results of calculations in chapter 3. Meanwhile, Figure 6 on the right shows 4 batteries that are used as backup energy at night or when the weather is cloudy so the solar panels cannot generate electricity. Figure 7 shows 4 solar panels installed in 2 series and 2 parallel as follows.

Figure 7. Solar panels installed on roofs

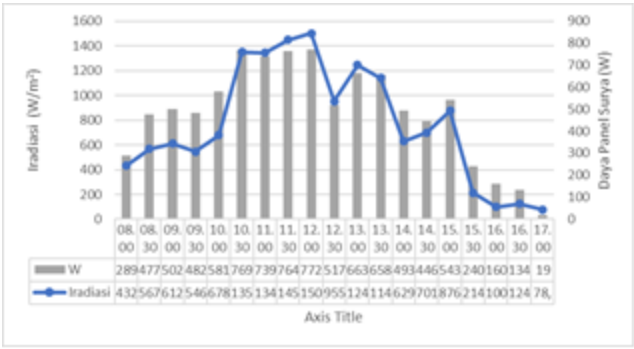

Figure 8. Output power of Cortagrid solar PV system

The output power obtained in this solar PV system is on average large enough to get a value of > 700 Wh for one day. The value is quite maximum because it is supported by the geographical location of this Tiflean Village which has an irradiation time of 5 hours/day, and besides that, irradiation is obtained by real measurements up to 1500 Wh/m^2.

In this Cortagrid system, it requires an initial cost of IDR 30.144.000 for the solar PV system and IDR 4.750.000 for the chest freezer. The percentage of initial capital expenditure for the NRE system used is shown in Figure 8 below.

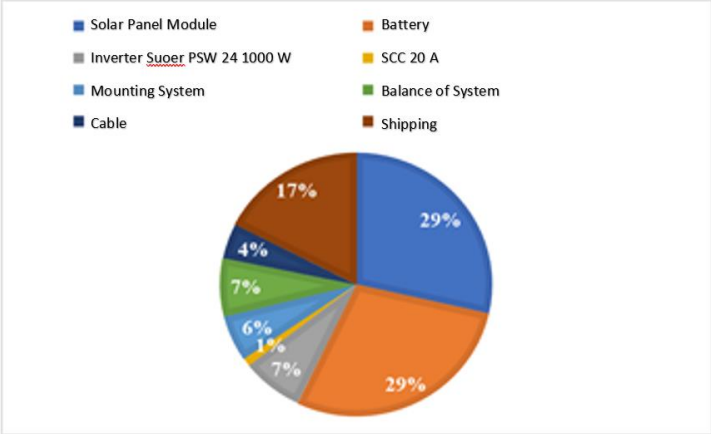

Figure 9. Cortagrid's initial capital percentage

Figure 9 above shows the initial costs that will be used as a calculation of the economic feasibility analysis for this Cortagrid system. Where the largest expenditure is on the main components consisting of 29% solar panels, 29% batteries, 7% inverters, 6% mounting systems, 4% cables, 1% SCC and for the shipping fee of 17%.

In this economic analysis, the value for maintenance or O&M (Operation & Maintenance) is obtained by using the Bank Indonesia interest rate of 3,5%. Obtained a value of IDR 4.966.826. By obtaining O&M costs for 25 years. For the value of energy produced from this solar PV system, it is IDR 1.500/kWh. By using a discount factor of 3,5%, equation 7 is obtained as follows.

$$DF = \frac{1}{(1 + 0{,}035)^1}$$

$$NPV = -S + \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t}$$

$$BCR = \frac{\sum_{t=1}^{n} NCF_t(1+i)^t}{S}$$

The value for the first 2 years is 0.9 so that if you follow the contract period for 25 years, it is 0.4. So, the value of NPV (Net Present Value) is declared feasible because the value is > 0 (Ross et al, 2010).

Direct interviews with the people of Tiflean Village where the price of 1 liter of diesel fuel is IDR 17.000 usually used only for the night. The load used is to turn on 5 lamps with each lamp of 15 Watt, requiring 5 liters to turn on for 12 hours. The cost of the diesel engine used is IDR 11.00.000 and the generator is IDR 8.000.000. For energy costs incurred in one day of IDR 170.000/Wh.

Conclusions

The conclusion is based on the results of the analysis on the service that has been carried out where the installation of the Cortagrid tool is carried out to help the people of Tiflean Village, Mangur Island from the economic point of view of fishermen. Where for this installation process takes 1 month.

The Cortagrid system is able to preserve fish by means of a fish cooling machine that is integrated with a renewable energy system, namely solar energy. The solar PV system built is 1000 Watt with an additional 4800 Watt/hour battery. From the acquisition of an economic analysis that is planned for the next 25 years, you will get a return on investment for 6 years. Where the value of the NPV is IDR 1.112.269 per year. Comparison of the energy produced by a diesel engine (diesel price of IDR 17.000) with solar PV of IDR 31.906.000.

Suggestions in this service are to increase Cortagrid's capacity on a larger scale. So that this system can accommodate all the fish caught by the Tiflean Village Community. The recommended NRE capacity is 20 kWp. Installation can also use the ground-mounting method, due to the lack of potential roof area in Tiflean Village and with a capacity of 20 kWp there is still vacant land that can be applied.

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