Hybrid energy of Photovoltaic and Palm Oil Diesel for alternative electricity supply of Base Transceiver Station (BTS) on rural Area-South Sumatera

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Abstract. The lack of electricity supply from PLN (The Indonesia State Electricity Enterprise) due to the remote and far geographical location, Some of the BTS rely on diesel generators as the main power plant. So, the cost of electricity generation in the BTS is very high because of the high cost of transportation of these fuels. Therefore, to make efficient use of diesel fuel requires a renewable energy-based power generation model by utilizing the natural potential around the area. This study to analyse the system models hybridization of Photovoltaic System with Palm oil Diesel (POD) to get power plants that have high reliability, low energy costs and low emissions for powering BTS in remote area located at a Sungai Ketupak Village of Ogan Komering Ilir-South Sumatera (Latitude 3°19.9’S and Longitude 105°38.9’E). The Hybrid Optimization Model for Electric Renewable Energy (HOMER) has been carried out to obtain an optimal design based on energy cost/kWh, annual operating costs, the daily loads demand, the NPV cost. The combination PV system and palm oil diesel will provide benefits for telecommunications companies in the savings for fuel generators. This system could also reduce gas emissions from hydrocarbon fuels. Therefore, the join of PV and palm oil diesel systems shows a good prospect of alternative energy for BTS tower energy sources.

1. Introduction

According to information the Ministry of Communication and Information in 2018, around 384,881 BTS has operated in Indonesia and will increase along with the rapid development of information technology and telecommunications in Indonesia [1]. Some BTS towers haven’t received power from the electricity grid yet or poor electrical reliability, so they must install a power backup system so that their services are not interrupted. Genset installation is the choice of the telecommunications operator despite higher operating costs (OPEX) and will produce carbon emissions. For operation of 1 BTS tower unit it is estimated to burn around 4-5 Litters of Diesel per hour at a cost [2,3].

In general, a BTS running on diesel generator with an average running of 12 hours a day, produce 18.75 metric tons of CO2 per year [4]. Thus, extensive use of diesel generators has very adverse impacts on environment causing global warming. The imperative solution towards this problem is to switch over to the renewable energy options for environmental benefits.

The high price of fuel in the Sungai Ketupak makes the operating costs of generators expensive. Besides being caused by fluctuations in world oil prices, weather factors also determine the amount of fuel oil delivery to the region. Therefore, alternative renewable energy-based power plants that utilize local natural potential are needed to minimize the cost of electricity generation in the BTS. In addition,
the availability of fuel that is unlimited and environmentally friendly makes this option attractive to implement. For this reason, it is necessary to conduct a study related to the operation of hybrid power plants in order to obtain the optimum power generation model. South Sumatra is one of the regions with the good solar radiation in this country, as illustrated by NASA's Surface meteorology and Solar Energy database in Figure 1, hence suitable for developing photovoltaic (PV) energy.

![Figure 1. Daily average monthly radiation (kWh/m2) and clearness index in Sungai Ketupak.](image)

This paper analysed the simulation of PV power system combination with Palm oil diesel power generation, completed with battery storage result of hybrid renewable energy system for off grid remote BTS area by using HOMER Pro 3.11.2. HOMER is the micro power optimization model which simplifies and designs both the off-grid and grid-connected power systems for a variety of applications. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. The study aims to analyse the potential of standalone power generation of PV system with palm oil diesel (POD). The purpose of this study to analyse diesel palm oil compared to diesel fuel, and found several advantages, especially those related to utilization of alternative energy yields of PV systems and Palm oil-based biodiesel hybridization for telecom tower. The author is motivated to develop the potential of renewable energy for power sources for BTS tower.

The solar radiation in Sungai Ketupak (south Sumatra area) is high potential, supported by tropical natural resources, is important for developing off-grid hybrid system using Palm Oil Diesel and PV panel. The combination of PV and palm oil diesel yield Net Present Cost (NPC) and Cost of Energy (COE) which are much lower than for diesel generator only. The combination will also be Reducing Carbon (C), Nitrogen (NOx), Sulphur (SOx), and the effect of gas emissions. Also, another plus Palm oil as an energy plantation. In conclusion, the hybrid system proposed in this study is a feasible option to be developed more for power plants in telecommunication towers in order to increase the renewable energy mix and to keep our environment from carbon emissions.

2. Methodology

2.1. Palm oil diesel for substitute diesel fuel

Biodiesel based on palm oil seem to be a promising alternative to renewable fuels the physicochemical properties of diesel palm oil (POD), which are crude palm oil methyl ester (CPO) and crude palm oil (CPS) stearin, are similar to diesel oil. The use of vegetable oil as a fuel for a press ignition engine has been investigated by many studies over the past decade [5]. Vegetable oil does not contain sulphur, aromatic hydrocarbons, metals or crude oil residues. so, it is very feasible to be developed as an
alternative to reducing dependence on fossil energy and reducing carbon emissions to the environment.

2.2. Designing for hybrid power system
In this study the hybrid system renewable energy consist of Photovoltaic panels, batteries and inverter are combined with a biofuel generator set to get a system that the best cost of generating electricity at BTS. Here the block diagram for the system of photovoltaic panel and biofuel generator (Figure 2). This hybrid system analysis was produced by HOMER Pro 3.11. Simulations carried out by enter load data, power sources, power storage, inverters, and some obstacles. HOMER produces the most feasible combination between energy resources and architectures. Finally, a comparison is made between hybrid biodiesel based on Palm oil diesel (POD) generator design and power source just to feed the load, and evaluation of hybrid techno-economics.

![Figure 2. Block diagram PV-Diesel Generator hybrid system.](image)

For the simulation purposes, the HOMER calculated the optimum capacity of PV, battery, and the inverter. As the result, HOMER presented NPC, COE, Operating Cost, and initial capital for each architecture, including the cash flow. It was shown also the electrical profile, fuel summary, performance of each component, and emissions summary. The measure was taken for the period of 25 years.

3. Result and discussion

3.1. The potential of palm oil for biofuel
The characteristics of palm oil compared to diesel [6] are observed in the table 1. This characteristic is the ability of palm oil to be used as a fuel generator and to measure whether palm oil can be used instead of diesel.

| Property                        | Biodiesel | Diesel |
|---------------------------------|-----------|--------|
| Calorific value (MJ/kg)         | 39.72     | 45.95  |
| Density @ 15°C (g/cm³)          | 0.880     | 0.835  |
| Viscosity (mm²/s at 40 °C)      | 4.61      | 2.95   |
| Flash point (°C)                | 314       | 70     |
| Pour point (°C)                 | 4.61      | <5     |
| Cetane number                   | 64        | 54     |

Calorific value is the potential for fuel energy. The main advantage of fossil fuels is has high calorific value. However, although biodiesel fuels have a lower heating value than fossil fuels. They have better oxygen content so it is a value added of biodiesel compared to diesel. Density is defined as the ratio of fuel mass per unit volume, as the Unit of Density is g / cm³ or kg / m. Viscosity is an important property of liquid fuel which is a measure of flow resistance. Fuel viscosity is an important parameter
for atomization of fuel. High viscosity affects atomization negatively and decreases the fuel-air mixture due to its poor volatility.

Pour Point is the ability of a fuel to be used in cold conditions. In cold conditions, a blockage in the fuel pipe and filter is very possible. Biodiesel has a high flash point. So, biodiesel is a safer fuel for storage and transportation. Cetane Number is the quality of the fuel ignition, it is very essential to determine the operating characteristics of a diesel engine. With a high cetane number, the combustion process will be better, resulting in smoother engine operation, easy starter process, better fuel efficiency, reducing noise in the engine, and reducing carbon emissions.

3.2. Hybridization of palm bio diesel and solar panel

The simulation of solar source and palm oil biofuel was analysed, whether it was feasible to be used as a novel alternative of electrical power. Selected design was figured by HOMER as shown in Figure 3. The main goal of the study is to ensure the system can produce 3.06 kW output voltage which is to run the all telecommunication system with a load of rectifier and other electrical parts. The PV / diesel generator system is used not only to reduce the frequency of breakdowns and save maintenance costs, but also to review the cost effective.

![Figure 3. System diagram of hybrid system.](image)

Design of hybrid system is related the technical and economic feasibility for the purpose to reliability, safety and quality of the electrical supply. Selection of appropriate components and sizing should consider the operating strategy [7]. Therefore, in this study, the size of PV, battery, and converter was determined according to the average load consumption and utilizing HOMER Optimizer™. System selection is not only acquired based on the lowest cost but must meet the reliability, fuel efficiency, and environmentally friendly [8].

The parameters and specifications of these hybrid power plant components are provided in Table 2. Subsequently, HOMER would do the calculations and display the most optimal results, both in technical and economic views.
Table 2. Main component data.

| Component         | Details               |
|-------------------|-----------------------|
| Generator         |                       |
| Fuel              | Palm Oil Diesel       |
| Capacity          | 5 kW                  |
| Lifetime          | 15000 hours           |
| Photovoltaic (PV) |                       |
| Panel Type        | Generic Flat Plate    |
| Capacity          | 13.9 kW               |
| Inverter (INV)    |                       |
| Type              | General               |
| Capacity          | 5 kW                  |
| Battery Storage (BAT) |               |
| Type              | Trojan SIND 06 610    |
| Quantity          | 36                    |

Table 3. Comparison of emission.

| Emission Type             | Hybrid (kg/year) | Diesel (kg/year) |
|---------------------------|------------------|------------------|
| Carbon Dioxide            | 0                | 21.217           |
| Carbon Monoxide           | 8.93             | 132              |
| Unburned Hydrocarbons     | 0.39             | 5.84             |
| Particulate Matter        | 0.05             | 0.79             |
| Sulphur Dioxide           | 0                | 52               |
| Nitrogen Oxides           | 8.4              | 124              |

The Results Optimization of hybrid systems provides some architecture and costs overview, as shown in Figure 4. Clearly describe the results of the system that produces the lowest COE, NPC, and Operating Costs required for initial costs. On the other hand, the single source diesel generator and the inverter results in a higher cost compared to a hybrid system completing the lower cost. This shows that using a hybrid system for more than 25 years resulted in an NPC of $44.656 which is far lower than the diesel generator of $105.131. The COE hybrid system is $0.197 which is also cheaper than a single source diesel generator $0.3, the price of diesel fuel ($0.62 / L) compare to the price of Palm oil fuel ($0.52 / L). It is expected that $2,000 is needed to buy generator and inverter as initial capital, while capital is more than $33,721 for investment of hybrid system investments. Thus, large amounts of capital are needed to build this hybrid system but offer lower lifecycle and COE costs in the long time.

HOMER provides some options for hybrid system schemes, subsequently suggesting a minimum investment. they also provide optimal configuration results. The Hybrid systems will be optimal with PV, generator and inverter capacities of 13.9 kW, 5 kW and 5 kW. However, 36 battery units are needed. Among these components, batteries have the highest total cost contribution, followed by PV, generators, and inverters.

Figure 4. Results optimization of hybrid systems architectures and its costs.
The most important in the utilization of hybrid system is reducing negative environmental impact from the use of oil fuel, as shown in Table 3. Palm oil has lower carbon and sulphur content compared to diesel fuel, PV and battery have significant contribution in reducing consumption of the hydrocarbon fuel. The emission of CO2 gas was reduced significantly from 21.217 kg/year to zero of emission CO2 or 100% reduction. Also, the gas emission from SO2 that 100% reduction. CO and NOx were also reduced more than 90% respectively.

4. Conclusion
Palm oil diesel can be potentially used as biofuel for fuelling the generator. Since palm oil have good diesel properties to be used as fuel. The viscosity and density of Palm oil diesel have been slightly higher than those of diesel and fulfilled the required standard to be used for high-speed engine. Cetane number and fire point of POD have been higher than those of diesel fuel in terms of facilitating transport and storage. In addition, Palm oil has had low Sulphur content, which is good for the engine to minimize corrosive effect.

The use of biodiesel based palm oil for fuel generators combined with PV forms a stand-alone hybrid power system to supply electricity in the BTS tower on the Sungai Ketupak. Besides having decent economic factors (NPC and COE), this hybrid also meets reliability through zero unmet electricity loads and measurement of capacity shortage. There has been a significant reduction of oil fuel due to fuel replacement of Photovoltaic. As effect of low utilization of oil fuel, hybrid systems have also considered better the environment by eliminating huge amount of pollutants emitted by power systems. It is also free of carcinogenic benzene, has low carbon (C), Sulphur (SOx), nitrogen (NOx) gas emissions, and is also smoke free when burned. However, this study is an early step to simulate the potential of palm oil and utilize it for hybrid systems. The authors recommend further research taking a real load for daily, weekly and monthly. And also, analysing and controlling renewable energy in the on-grid system.

Acknowledgment
This research was supported by University of Indonesia (UI) through PUTI grant 2020 (International Indexed Publication) launched by DRPM UI.

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