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Application of Homer for Planning a Hybrid Solar Power Plant System at the Makassar Eye Hospital

***Abstract.** The most effective solution for reducing the substantial electricity consumption in office buildings and hospitals is to utilize rooftops for Solar Power Plants (SPP). One such building with this potential is Makassar Eye Hospital. The research process initiates with the identification of issues concerning electricity availability and daily consumption at Makassar Eye Hospital, as well as an evaluation of solar radiation potential. Subsequently, the design of a SPP system takes place. In addition to this, a location assessment is performed using various tools to gather the requisite data for the SPP design. In this research, the planning process utilized Homer software, encompassing both technical analysis based on electrical energy production and system performance calculations. Furthermore, economic analysis involved assessing the capital costs for installing the SPP based on current market component prices. Capital return costs were calculated based on the feasibility of the SPP investment. The feasibility was determined through calculations of the Payback Period (PP), Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), and Return on Investment (ROI). The results of the economic analysis indicate that the initial investment cost for SPP is Rp. 329.878.378. The energy production value per kWh is Rp. 955, with a PP value of 4,44 years, NPV value of Rp. 453.174.500, IRR of 25,0%, and ROI of 27,9%. These findings demonstrate the feasibility of the SPP project at Makassar Eye Hospital, as the IRR exceeds the Discount Rate (8.43%).*

***Abstrakcyjny.** Najskuteczniejszym rozwiązaniem pozwalającym na zmniejszenie znacznego zużycia energii elektrycznej w budynkach biurowych i szpitalach jest wykorzystanie dachów pod elektrownie słoneczne (SPP). Jednym z takich budynków o takim potencjale jest Szpital Okulistyczny Makassar. Proces badawczy rozpoczyna się od identyfikacji zagadnień dotyczących dostępności i dziennego zużycia energii elektrycznej w Makassar Eye Hospital, a także oceny potencjału promieniowania słonecznego. Następnie następuje projektowanie systemu SPP. Oprócz tego przeprowadzana jest ocena lokalizacji przy użyciu różnych narzędzi w celu zebrania danych wymaganych do projektu SPP. W badaniach tych w procesie planowania wykorzystano oprogramowanie Homer, obejmujące zarówno analizę techniczną opartą na produkcji energii elektrycznej, jak i obliczenia wydajności systemu. Ponadto analiza ekonomiczna obejmowała ocenę kosztów kapitałowych instalacji SPP w oparciu o aktualne ceny komponentów rynkowych. Koszty zwrotu kapitału obliczono na podstawie wykonalności inwestycji SPP. Wykonalność określono poprzez obliczenia okresu zwrotu (PP), wartości bieżącej netto (NPV), wewnętrznej stopy zwrotu (IRR), wskaźnika rentowności (PI) i zwrotu z inwestycji (ROI). Wyniki analizy ekonomicznej wskazują, że początkowy koszt inwestycji w SPP wynosi Rp. 329.878.378. Wartość produkcji energii na kWh wynosi Rp. 955, o wartości PP 4,44 lat, wartości NPV Rp. 453.174.500, IRR 25,0% i ROI 27,9%. Ustalenia te wskazują na wykonalność projektu SPP w szpitalu okulistycznym Makassar Eye Hospital, ponieważ IRR przekracza stopę dyskontową (8.43%). (**Zastosowanie Homera do planowania hybrydowego systemu elektrowni słonecznej w szpitalu okulistycznym Makassar**)*

***Keywords:** Planning, Rooftop Solar Power Plant, Homer, Makassar Eye Hospital, Hybrid System*
***Słowa kluczowe:** planowanie, dachowa elektrownia słoneczna, Homer, szpital oczny Makassar, wykonalność*

1. Introduction

Indonesia, the world's largest archipelagic country, comprises approximately 17,500 islands [1]. With a population of around 220 million, 60% of the people reside in rural areas [2]. The majority of Indonesia's power plants still depend on fossil fuels [3]. According to the 2018-2027 State Electricity Company (PLN) Electricity Supply Business Plan (RUPTL), over 82% of electricity in Indonesia is generated from fossil fuels, with the remaining 18% coming from renewable sources. One effective means of electrifying remote rural areas is through the construction of SPP, given the abundant potential for renewable energy sources in Indonesia, particularly solar energy [4]. Data indicates that Indonesia's solar energy potential is a substantial 207,898 MW, yet its current utilization remains minimal at only 0.04% [5]. In addition to its status as an archipelagic nation, Indonesia's tropical climate offers a high solar energy potential, with an average daily radiation (insolation) of 4.5 kWh/m2/day [6]. This potential serves as an affordable, year-round alternative energy source [7]. Therefore, implementing SPP technology is the right solution for harnessing this abundant solar energy [8].

Homer is software developed by the United States-based company, The National Renewable Energy Laboratory (NREL), with the goal of optimizing electricity generation systems. The output from Homer software includes life cycle costs, estimated system capacity, and greenhouse gas emissions [9, 10]. The use of Homer for optimizing Solar Power Plants (SPP) is widespread, with research [11] specifically discussing its implementation in planning solar energy systems in the Duhok location. The results demonstrate that the on-grid hybrid solar-wind energy system is more cost-effective than the off-grid design for the same load. In research [12], the planning of a hybrid micro-hydro and solar photovoltaic system using Homer for rural areas in Central Java, Indonesia is discussed, highlighting significant findings or outcomes. In research [13], the energy, economic, and environmental evaluation of a proposed on-grid solar-wind power system is discussed using the Homer case study in Colombia, with a focus on notable findings or outcomes. In research [14], the planning of a SPP on Cemara Island is discussed, utilizing Homer for essential technical and economic analysis, including design calculations for solar panel, solar charge controllers, batteries, and inverters capacity, along with economic descriptions. In research [15], Homer is proposed for the economical and optimal design of a SPP using a PV/Biomass hybrid energy source for an agricultural and residential community in a small village in Layyah district, Punjab, Pakistan. In another study [9], Homer demonstration programming was employed to illustrate the framework, physical behavior, and life cycle costs of photovoltaic (PV) energy. In the paper [16], Homer is used for analysis in two modes: a PV system connected to the grid and a system connected only to the grid (reference). The model's performance is evaluated for techno-economic feasibility, along with sensitivity analysis using Homer. Numerous studies have demonstrated Homer's utility in the planning of SPP. In this research, we use Homer as the primary tool for planning SPP at Makassar Eye Hospital.

Given the challenge of acquiring large land areas in urban locations for SPP construction, utilizing rooftops is the optimal solution [17]. The optimal solution to reduce electricity consumption in office buildings and hospitals is to utilize rooftops for SPP [18, 19]. The Makassar Eye Hospital is one such building with this potential.

The Makassar Eye Hospital currently receives a 197 KVA low-voltage electricity supply from PLN. However, its infrastructure supports a capacity of up to 500 KVA. Additionally, the hospital has a 500 KVA Generator Set as a backup power source for emergencies. As a healthcare facility, the hospital requires a reliable electricity supply, particularly for medical and non-medical equipment. The use of a SPP not only reduces the cost of electricity but also supports government efforts to promote Renewable Energy [20, 21]. This research proposes electrical system planning and economic analysis calculations for the construction of a SPP at Makassar Eye Hospital using Homer.

2. Research Method

This research employs an experimental approach with a focus on quantitative methods for designing the SPP on the rooftop of Makassar Eye Hospital. It involves calculations, measurements, and the design of SPP circuit and components for use in the hospital. The research process begins with identifying electricity availability and daily consumption at Makassar Eye Hospital, as well as assessing the solar radiation potential. Subsequently, the SPP system is designed, followed by a location assessment using various references and tools to gather necessary data.

2.1. Planning Stage

The planning stage is the initial phase of research, where technical matters are established based on standard guidelines.

2.2. PLTS System Design

In designing the SPP for Makassar Eye Hospital, researchers tailored the design to the building type and existing power infrastructure. This involved calculating the system's capacity, component selection, size calculations, and creating a layout image of the installation.

2.3. Technical Analysis

Following the design of the SPP system, a technical analysis is conducted based on the electrical energy produced and system performance. This analysis relies on simulation results obtained from Homer.

2.4. Economic Analysis

This analysis considers the capital costs for installing a SPP system, based on market component prices. It also calculates the capital return costs based on the feasibility of the SPP investment, determined by factors such as the Payback Periode (PP), Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI) and Return of Investment (ROI) [22].

Payback Periode

The Payback Period (PP) represents the duration required for the project's generated receipts to recover the initial investment, as depicted in equation 1 [22].

(1) $$PP = Year\ Before\ recovery + \frac{Investment\ Cost}{NPV\ Cumulative} - II$$

With: Year before recovery : The number of years before the final purchase year Investment Cost : Initial investment costs.
Cumulative NPV : Net cash amount.
II: Initial Investment

The decision-making criteria for whether an investment proposal is worthy or worthy of being rejected are:

a. An investment is said to be feasible if the payback period is shorter than the life of the project.
b. An investment is said to be unfeasible if the payback period is longer than the life of the project.
c.

Net Present Value

Net Present Value (NPV) is the value of all net cash flows assessed now on the basis of a discount factor. The formula is shown in equation 2 [22].

(2) $$NPV = \sum_{t=1} \frac{NCFt}{(1+i)^t} - II$$

It is said to be eligible or not if:

a. Investment is said to be feasible if the NPV is positive (> 0).
b. An investment is said to be unworthy if the NPV is negative (< 0).

Internal Rate of Return

Internal Rate of Return (IRR) is the interest rate that equates the present value of an investment with the expected net results over the course of the business. For the scenario of two previously known NPV values, IRR can be formulated in the following equation 3 [22].

(3) $$IRR = i1 \frac{NPV1}{NPV2 - NPV1}(i2 - i1)$$

With: NPV1 must be above 0 (NPV1 > 0); NPV2 must be below 0 (NPV2 < 0)

Profitability Index

The formula for calculating the Profitability Index (PI) is as in equation 4 below [22, 23].

(4) $$PI = \frac{Present\ Value\ of\ future\ cashflow}{Initial\ Cost}$$

The decision-making criteria for whether an investment proposal is worthy of being accepted or worthy of being rejected are as follows:

a. An investment is said to be feasible if the Profitability Index (PI) is greater than one (>1).
b. An investment is said to be unfit if the Profitability Index (PI) is less than one (< 1).

Return of Investment

Return on Investment (ROI) is the return on investment or the rate of return on investment which will later be generated in percentage form. A project is said to be feasible if the ROI value is positive. ROI is defined by the following equation 5 [22, 23].

(5) $$ROI = \frac{Net\ Benefita\ at\ the\ end\ of\ life\ time}{Total\ Investment} x100\%$$

3. Results And Discussion

3.1. Economic Calculations

The economic parameters employed in this research include the discount rate (%), expected inflation rate (%), service life (years), capital costs (in Rp), and O&M costs (in Rp per year). Figure 1 below provides an overview of these economic parameters."

Fig 1. Economic Parameters

3.2. Generating System Modeling and Simulation

After obtaining the data, the next step involves modeling and simulating the SPP system. This modeling and simulation process utilizes Homer software, including a Converter component rated at 33 kW, LONGi Solar LR6-72PE PV panels with Homer optimization ranging from 33 kW to 35 kW, and a Trojan SAGM 12v-220 Ah battery. The modeling results are presented in Figure 2 below.

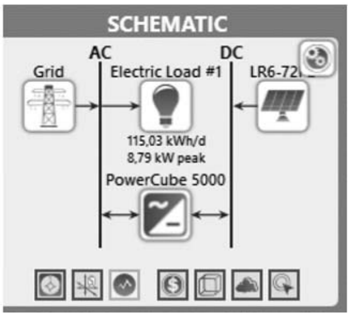

Fig 2. Modeling Results

3.3. Component Ratings

1. Grid

The PLN Grid system used at Makassar Eye Hospital charges an electricity price of Rp. 1.522,88 per kWh. In this design, the author maximizes the use of the SPP by calculating net purchases, as shown in Figure 3, which displays the grid format information.

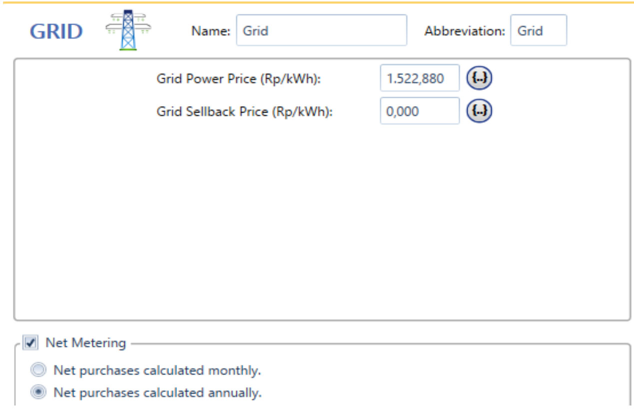

Fig 3. Grid Information Format

2. Solar Panels

Figure 4 shows the solar panel specifications. The solar panel system used by Makassar Eye Hospital has a capacity of 33 kWp. Maintenance costs for solar modules amount to 2% of the total initial investment.

3. Battery

Figure 5 displays the battery design of the SPP installed on the roof of Makassar Mata Hospital. This image provides additional detailed information about the battery in use. Battery operational and maintenance costs are calculated at 2% of the total initial investment costs.

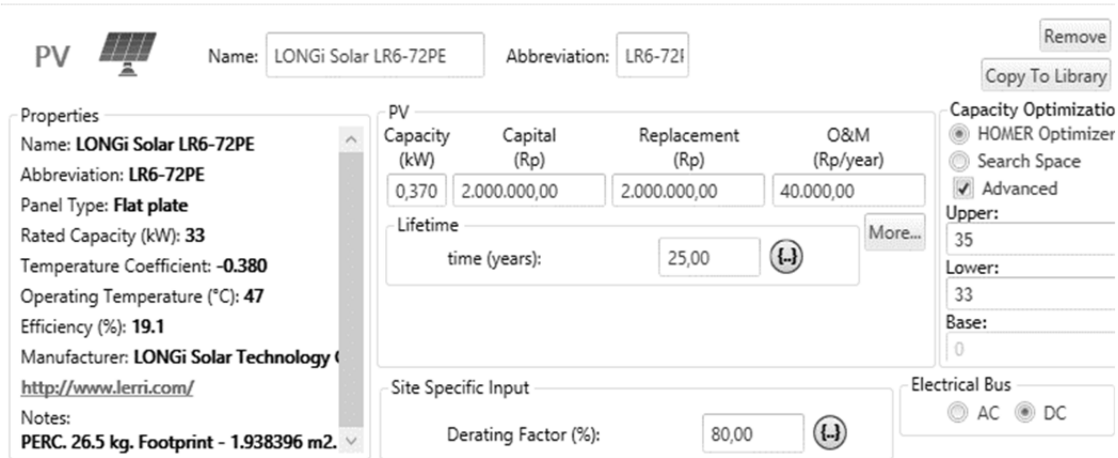

Fig 4. Solar Panel Specifications

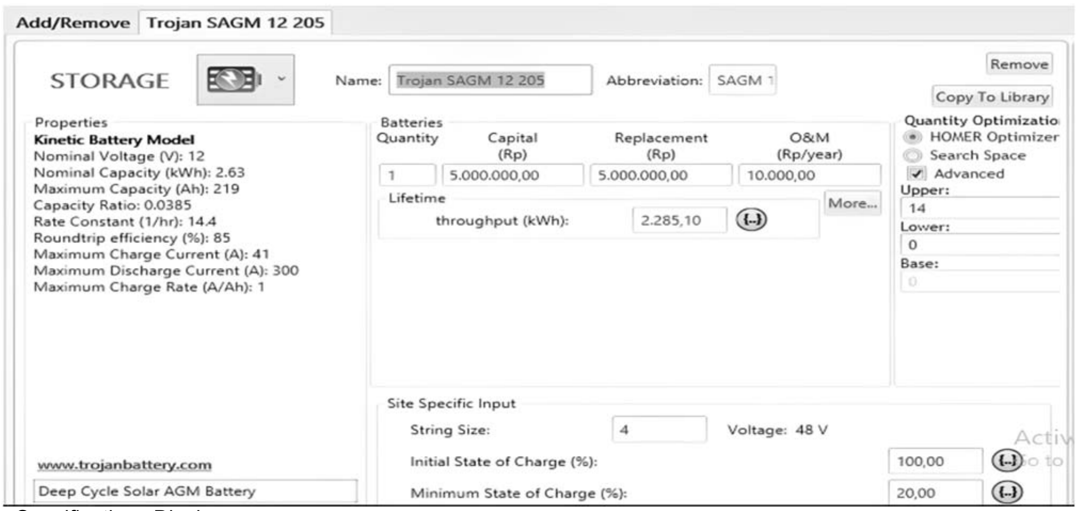

Fig 5. Battery Specifications Display

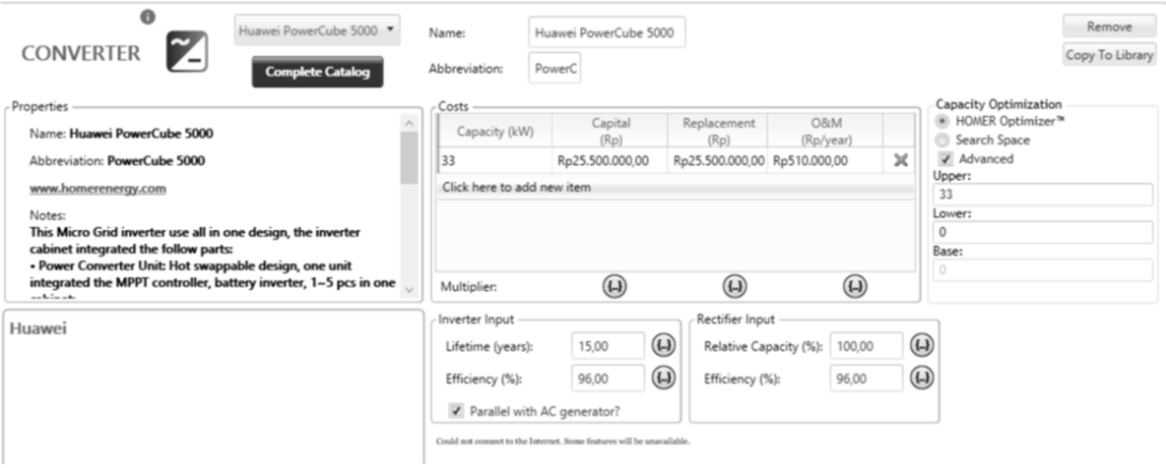

Fig 6. Converter Specifications Display

Fig 7. System Optimization Results

Fig 8. Electrical Simulation Results

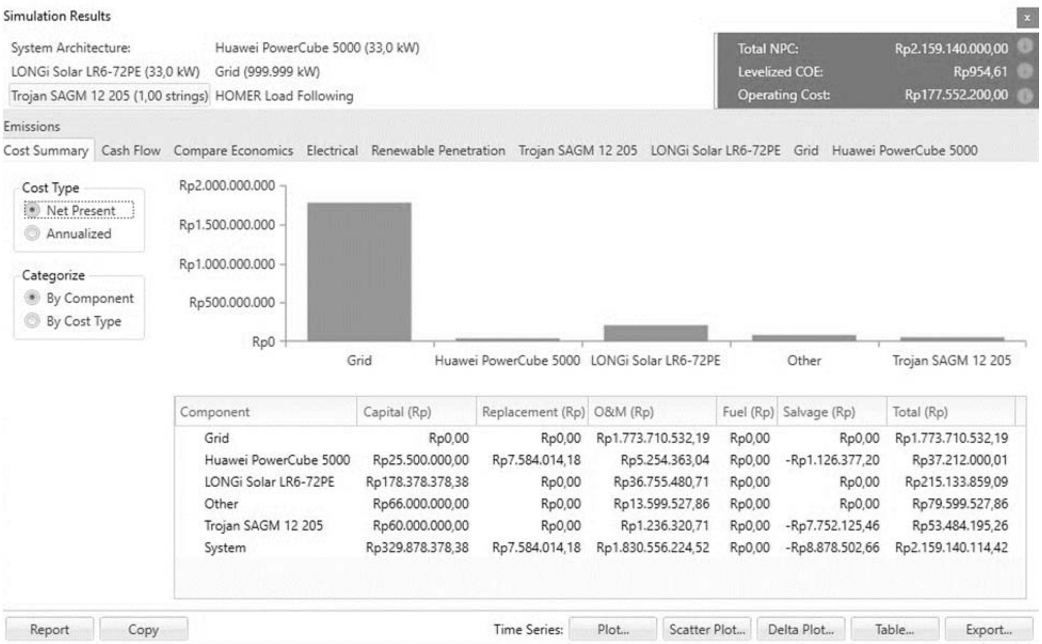

Fig 9. Economic Simulation Results (Cost Summary)

4. **Converter**

Figure 6 provides information regarding the inverter used in the hybrid PV-fuel cell on-grid system, which is as follows:

- Type : Huawei PowerCube 5000 990kVA
- Capacity : 33 kW
- Total : 1
- Price : Rp 25.000.000,00
- Maintenance cost : Rp 510.000,00/year

3.4. Electrical Analysis

Based on the designed system, four configuration simulation results were obtained. The second configuration, which utilizes the SPP system along with the PLN Grid, featuring 33 kW PV, four batteries, and a 33 kW converter, is the most optimal. Figure 7 presents the system optimization results.

Figure 8 reveals that the total system produces 222.177 kWh/yr of electricity. The PV system generates 66.003 kWh/yr, accounting for 29.7% of the total, while 156.174 kWh/yr, or 70.3%, is purchased from PLN. The primary AC load consumes 41.987 kWh/yr.

3.5. Economic Analysis

Figure 9 shows the simulation results in economic terms, namely NPC, TAC, and CoE. The information obtained includes a total NPC of Rp. 2,159,140,000.00. The total annualized cost (TAC) that HOMER simulates is Rp. 177,552,200.00. Another economic value result obtained from the simulation is CoE, which is a parameter that shows the cost of energy production per kWh, which is Rp. 954,61.00/kWh.

Architecture									Cost	
					LR6-72PE (kW)	SAGM 12 205	Grid (kW)	PowerCube 5000 (kW)	NPC (Rp)	Initial capital (Rp)
					0,350		999.999	33,0	Rp2,61B	Rp93,4M
					33,0	4	999.999	33,0	Rp2,16B	Rp330M

Metric	Value
Present worth (Rp)	Rp453.174.500
Annual worth (Rp/yr)	Rp43.986.110
Return on investment (%)	25,0
Internal rate of return (%)	27,9
Simple payback (yr)	3,57
Discounted payback (yr)	4,44

Fig 10. Economic Simulation Results (Compare Economics)

Figure 10 presents the economic comparison between the Hybrid SPP system and the Base system, which relies solely on the PLN Grid for electricity. The SPP system has a present worth of Rp. 453.174.500,00, generates an annual profit of Rp. 43.986.110,00, boasts a 25% ROI, an IRR of 27.9%, and a 4,44-year payback period. These results indicate the profitability and feasibility of implementing the hybrid SPP system.

4. Conclusion

Design of a Hybrid SPP system in the Makassar Eye Hospital Building with Homer software consisting of 89 units of LONGi brand Solar Panels with a nominal power of 370 Wp, 1 unit of Huawei PowerCube 5000 990kVA Inverter, 4 12V 205Ah Trojan SAGM batteries with configuration 4 series. The energy that can be produced is 66.003 kWh/year with 100% system performance. The initial SPP investment cost is Rp. 329.878.378 with an energy production value per kWh of Rp. 955 with a payback period of 4,44 years, an NPV value of Rp. 453.174.500 which has an IRR value of 25,0% and an ROI of 27,9% so it is feasible to do because the IRR value > Discount Rate (8.43%).

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