

# Analysis of Rooftop Solar Power Plant Planning for Lecturers' Houses and Solar Street Lighting at Campus 4 Unkhair Sofifi

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**Abstract** - The use of renewable energy that is trending almost all over the world is the use of Solar Power Plants. In terms of energy utilization, the world is still very dependent on non-renewable energy or fossil energy. The massive use of fossil energy has caused the earth to experience pollution, the environment is damaged due to the waste produced, and greenhouse gas emissions have increased. Therefore, the development of renewable energy is very important to be improved and continues to be echoed lately. To prevent this crisis, many are now starting to switch to using alternative energy sources. One of the most widely used alternative energy sources is the Solar Power Plant or better known as PLTS. This power plant can be the best solution for those of you who want to be more energy efficient and cost effective. Campus 4 of Khairun University in Sofifi currently has lecture buildings, offices, student dormitories and also housing for lecturers. To utilize the potential of solar energy, it is planned to use solar power and also for public street lighting around the campus, as an alternative source of electrical energy. In addition to saving electricity costs, the use of solar panels is considered very effective, because it is environmentally friendly. In this study, an analysis was conducted on the planning of a rooftop PLTS for lecturers' houses and public street lighting around the Unkhair Sofifi campus using PVSyst software as supporting equipment in conducting the analysis. The research results indicate that the rooftop solar power system for the lecturer's house has a total power of 7,920 Watts, using 4 solar modules with a capacity of 450 wp per module. The battery capacity used is 120 Ah 48 volts, with 4 units. For solar street lighting, a total of 17 solar streetlight poles were obtained, each 7 meters high, with a lamp power of 40 watts per pole. The solar module capacity is 100 Wp and the battery capacity is 100 Ah.

**Keywords:** PV, Centralized Solar Power Plant, PV, On Grid, rooftop



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## 1. INTRODUCTION

Solar Power Plants use solar panels that can directly convert solar energy into electricity. Simply put, the working principle of PLTS is to convert sunlight into electrical energy. Sunlight is one form of energy from natural resources. This natural solar resource has been widely used to supply electrical power to communication satellites through solar cells. These solar cells can produce unlimited amounts of electrical energy directly taken from the sun, without any rotating parts and without the need for fuel. So that the solar cell system is often said to be clean and environmentally friendly and reduces the effects of greenhouse gases (green house gas) whose effects can damage the ecosystem of our planet earth.

To support the use of new and renewable energy, the government has started using solar energy to power public facilities. With our country's climate as a tropical nation, solar energy will be maximally utilized in various sectors in the future. This centralized solar power plant is a system for generating solar energy using several solar panels placed in a centralized location, which is then distributed to electricity users such as office spaces, lecture rooms, and places that require electricity. Utility scale projects preclude participation of smaller entities and leads to asset concentration. In contrast, decentralized plants promote community participation, generate higher employment, while enabling energy access for the local community. A balanced policy approach needs to be followed, promoting both types of project configurations. We propose setting up spatially dispersed solar plants along the longitudinal stretch of India, co-located within the substations using standardized templates. This shall enable fulfilment of climate goals, while ushering in a just transition [1]. Consequently, centralized PV power plants may be considered as renewable and clean source of energy. This paper, presents the technical and economic feasibility of a 14MW photovoltaic (PV) power plant near the Houn city which is located in the central-south of Libya in the Jufra Region. In addition, In order to prove the design validity of the proposed system, models and simulations in NEPLAN software is carried out for a practical distribution grid. The result show that PV power plant is economically feasible and sustainable [2]. This paper shows that a centralized planning approach could save 7% to 37% of total system costs over a 15-year time horizon using a Western United States utility as a case study. We show that centralized decision-making deploys substantially more utility-scale solar

and distributed storage compared to a decentralized decision-making paradigm. We demonstrate how a utility could largely overcome the complications of decentralized distributed resource decision-making by incentivizing regulators to develop electricity rates that more closely reflect time- and location-specific, long-run marginal costs. The results from this analysis yield insights that are useful for long-term utility planning and electric utility rate design [3]. This scenario would be about USD\$ 185 billion more expensive than a business as usual scenario, where expansion solely relies on least-cost options. Hence, for the country to incentivize the expansion of centralized solar power, specific auctions for solar energy should be adopted, as well as complementary policies to promote investments in R&D and the use of hybrid systems based on solar and fuels in CSP plants [4]. Distributed energy resources have been almost exclusively deployed and operated under a decentralized decision-making process. In this paper, we assess the evolution of a power system with centrally planned utility-scale generation, transmission, distribution, and distributed resources. We adapt a capacity expansion model to represent both centralized and decentralized decision-making paradigms under various electricity rate structures [5].

This study also used as study material and information from studies on solar power plants used on roofs and public street lighting in the last five years which have been widely carried out. Among them is the Feasibility Study of Solar Rooftop On Grid for the Electricity Needs of Machine Workshops in Polinema [5] In this study, the planning and simulation method uses PVsyst to obtain the output power on the panel. Then the other is the title of Power Analysis on Solar Panels in Rooftop On Grid Solar Power Plants with a Capacity of 30 kVA, PT. Batam Electric Energy Office Building [6]. This study uses a method of collecting data on measuring current, voltage, power, solar irradiance and solar panel temperature to obtain appropriate final results. The next study is the Design and Construction of a Solar Power Generation System (PLTS) with a Capacity of 100 Wp with a 1000 Watt Inverter [7] - [8] where this study uses a research and development method with stages in the form of system analysis, design, implementation and testing to obtain maximum electrical energy output from solar panels. The next study is the Analysis of On Grid PLTS [9] [11]. The method used in this study begins with direct data collection and then analysis is carried out to obtain maximum power utilization. Previous studies that have been carried out related to the analysis of the utilization of Solar Power Plants, namely "Analysis of Optimization and Efficiency of Solar Street Lighting Power in Pulau Ternate District" in 2021. This study was conducted by analyzing the optimization and efficiency of solar street lighting power. In the next study in 2022, a study was conducted with the title "Analysis of Solar Panel Power Utilization for PDAM Water Pumps, Pulau Hiri District, Ternate City". This study analyzes the amount of solar panel power and the power of the water pump engine so that the power generated by the solar panel can be used as much as possible. For ongoing research planned in 2025 with the title Integrated PLTS Planning on Campus 4 Unkhair Sofifi.

## 2. METHOD

The method of conducting this research is to carry out a literature study, field data collection, planning the On Grid PV system model, and calculation analysis.

### 1. Literature Study

This literature study serves to examine and study all matters related to theory to support the planning and analysis of the system.

### 2. Field Data Collection

Primary data includes field data such as the area of building rooftops and the length of the path for streetlight installation. Secondary data includes data sourced from reference books relevant to the research.

### 3. Technical Analysis

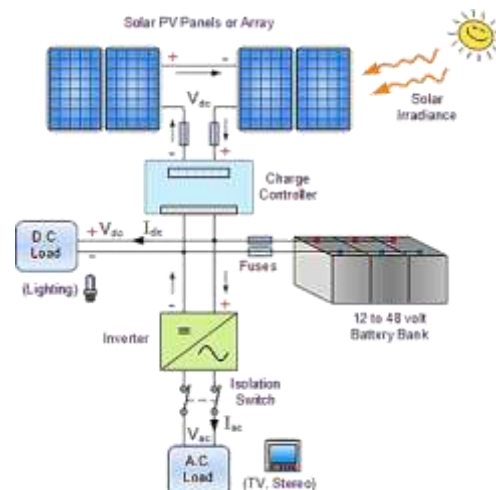


Figure 1. PLTS scheme

- Calculation of load requirements.

The loads to be determined are the lecturer housing load and the load for street lighting.

- Calculation of Solar Panel Temperature (PV Module)

Solar panels will be able to operate optimally if the temperature of the solar cells is at normal temperature (25°C). Every 1°C increase in temperature from normal temperature will result in a power reduction of 0.5%. The calculation of the increase in solar panel temperature is:

$$P_{MPP_{saat\ t^o}} = 0.5\% \times \Delta t \times P_{MPP}$$

Where:

$P_{MPP_{saat\ t^o}}$  is the output power of the solar panel when the temperature increases by °C,  $P_{MPP}$  is the maximum output power of the solar panel and  $\Delta t$  is the temperature increase from 25°C.

- Temperature correction factor (TCF) calculation

The temperature correction calculation uses the equation:

$$TCF = \frac{P_{MPP_{saat\ t^o}}}{P_{MPP}}$$

- PV Array Area Calculation

PV Array Area Calculation using the equation:

$$\text{Area Array} = \frac{EL}{G_{av} \times \eta_{pv} \times TCF \times \eta_{inv}}$$

Where :

EL energy consumption (kWH/day)

$G_{av}$  : average daily solar insolation (kWH/m<sup>2</sup>/day)

TCF : temperature correction factor

$\eta_{pv}$ : solar panel efficiency

$\eta_{inv}$ : inverter efficiency

- Calculation of Power Generated by PLTS (Wattpeak)

From the calculation of the PV array area, the amount of power generated by PLTS can be calculated, namely by persamaan :

$$P_{wp} = \text{Area Array} \times PSI \times \eta_{pv}$$

Where :

PSI : Peak solar insolation = 1000W/m<sup>2</sup>

- Fill Factor (FF) Calculation

$$FF = \frac{V_{mp} \times I_{mp}}{V_{ov} \times I_{sc}}$$

- Solar Panel Calculation

$$\text{Jumlah Panel} = \frac{P(\text{wattpeak})}{P_{max}}$$

- Battery Capacity Calculation

Determining battery capacity must also take into account the autonomy day, which is the day when the battery can still supply the load if the solar module does not produce electricity due to the weather, in this planning the battery autonomy day is used for 3 days.

$$C = \frac{N \times EL}{V_s \times DOD \times \eta} (\text{Ah})$$

Where :

C : Battery capacity (Ah)

N : Number of days of autonomy

EL : Daily energy consumption (kWh)

Vs : Battery voltage (V)

$\eta$  : Battery efficiency x inverter efficiency

- Inverter Capacity Calculation

The inverter capacity is calculated using the equation:

$$\text{Cap, Inv} = \text{Demand watt} \times \text{safety Factor (W)}$$

- Calculation of Lamp Distance

Street lighting is divided into three, namely: single-arm lamps (single ornament), double-arm lamps (double ornament) and lamp posts without arms. Because they have different shapes, it is necessary to calculate the angle of the lamp pole arm so that the lighting point is right in the middle of the road. Calculation of the distance of the lamp pole to the middle of the road uses the equation:

$$t = \sqrt{h^2 + c^2}$$

$$\cos \alpha = \frac{h}{t}$$

Where:

h: pole height

t: distance from pole to the middle of the road

c: horizontal distance from lamp to the middle of the road

W1: pole to end of lamp

W2: horizontal distance from lamp to end of road

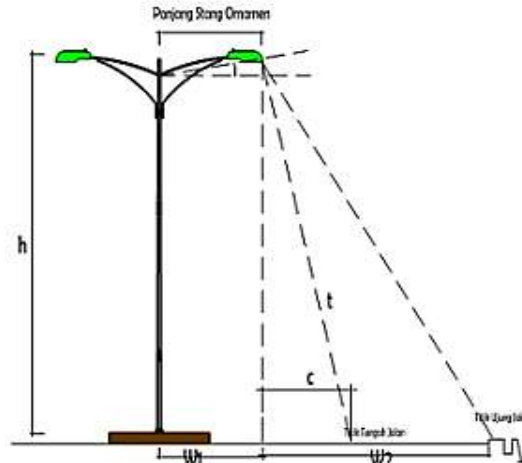


Figure 2. Determining the angle of inclination of the lamp arm towards the road

- Calculation of light intensity

Light intensity is calculated using the equation:

$$I = \frac{\phi}{\omega}$$

Where:

I : light intensity (cd)

$\Phi$  : light flux (lm)

$\omega$  : room angle (sr)

- Illumination Calculation (E)

Illumination is the light flux that falls on 1 m<sup>2</sup> of the surface.

$$E = \frac{\phi}{A}$$

Where:

E: Illumination (lux)

$\Phi$ : luminous flux (lm)

A: area (m<sup>2</sup>)

### 3. RESULTS AND DISCUSSION

#### 3.1 Planning of Rooftop Solar Power Plants for Lecturers' Houses

Estimation of the housing load requirements for lecturers at campus 4 Sofifi as shown in the table below.

Table 1. Electricity usage in the lecturer's house

| No | Tools                     | Quantity     | Installed Power (Watt) | Hours | Power Consumption |
|----|---------------------------|--------------|------------------------|-------|-------------------|
| 1  | <b>Lighting:</b>          |              |                        |       |                   |
|    | Bedroom,                  | 2            | 9                      | 12    | 216               |
|    | Dining room & living room | 2            | 11                     | 8     | 176               |
|    | Bathroom                  | 1            | 7                      | 12    | 84                |
|    | Front and back porch      | 2            | 7                      | 12    | 168               |
|    | Kitchen                   | 1            | 11                     | 10    | 110               |
| 2  | 42-inch LED TV            | 1            | 50                     | 10    | 12                |
| 3  | Washing machine           | 1            | 150                    | 3     | 450               |
| 4  | Refrigerator              | 1            | 150                    | 24    | 3600              |
| 5  | Laptop                    | 1            | 35                     | 12    | 420               |
| 6  | Rice cooker               | 1            | 50                     | 10    | 500               |
| 7  | Others                    | 1            | 50                     | 12    | 600               |
|    |                           | <b>Total</b> |                        |       | <b>6,336</b>      |



Figure 3. Lecturer's House Campus 4 Sofifi



Figure 4. Location of Campus 4 Sofifi

The total power consumption for one lecturer's house is 6,336 Watts. However, this must be increased by a 25% power loss in the solar power system, resulting in a total power requirement of:

$$(25\% \times 6,336) + 6,336 = 7,920 \text{ Watt}$$

Solar panels operate optimally when the temperature of the solar cells is at normal temperature (25°C). Each 1°C increase in temperature from the normal temperature results in a 0.5% reduction in power output. The temperature increase calculation is as follows: :

$$P_{\text{MPPsaat } t^{\circ}} = 0.5\% \times \Delta t \times P_{\text{MPP}}$$

Where:

PMPP at temperature t° is the power output of the solar panel when the temperature increases by 1°C,

PMPP is the maximum power output of the solar panel, and

Δt is the temperature increase from 25°C.

The planned solar panel uses 450 Wp per module.

$$\begin{aligned} P_{\text{MPPsaat } 25.4^{\circ}} &= 0.5\% \times 0.4 \times 450 \\ &= 0.9 \end{aligned}$$

The power output when the temperature increases to 25.4°C is:

$$\begin{aligned} P_{\text{MPPsaat } 25.4^{\circ}} &= 450 - 0.9 \\ &= 449.1 \end{aligned}$$

Calculation of Temperature Correction Factor (TCF)

The temperature correction factor is calculated using the formula:

$$\begin{aligned} \text{TCF} &= \frac{P_{\text{MPPsaat } t^{\circ}}}{P_{\text{MPP}}} & \text{TCF} &= \frac{449.1}{450} \\ & & &= 0.998 \end{aligned}$$

The area of the PV array is calculated using the formula:

$$\begin{aligned} \text{Area Array} &= \frac{EL}{G_{\text{av}} \times \eta_{\text{PV}} \times \text{TCF} \times \eta_{\text{invt}}} & \text{Area Array} &= \frac{7,920}{5,139 \times 0.204 \times 0.998 \times 0.95} \\ & & &= 7,980 \text{ m}^2 \end{aligned}$$

From the PV array area calculation, the total power generated by the solar power system is::

$$\begin{aligned} P_{\text{wp}} &= \text{Area Array} \times \text{PSI} \times \eta_{\text{PV}} & P_{\text{wp}} &= 7,980 \times 1,000 \times 0.204 \\ & & &= 1,625.520 \text{ Watt} \end{aligned}$$

- Calculation of Number of Solar Panels

$$\begin{aligned} &= \frac{P_{\text{wp}}}{P_{\text{panel}}} \\ &= \frac{1,625.520}{450} \\ &= 3,612 \approx 4 \text{ Panel} \end{aligned}$$

To determine battery capacity, we must also consider autonomy days, which refer to the number of days a battery can supply power when the solar panel does not generate electricity due to weather conditions. In this design, the battery autonomy is planned for 2 days.

$$C = \frac{N \times EL}{V_s \times DOD \times \eta} (\text{Ah}) \quad C = \frac{2 \times 7,920}{48 \times 0.8 \times 0.95} (\text{Ah})$$

$$= 434.211 \text{ Ah}$$

If the battery capacity is 120 Ah, the total number of batteries required is:

$$= \frac{434,211}{120}$$

$$= 3.61 \approx 4 \text{ buah}$$

### 3.2 Solar Street Lighting Planning for Public Roads

This planning of solar-powered street lighting (PJU PLTS) is for Campus 4 of Khairun University in Sofifi. The planning criteria follow local primary road standards..



Figure 5. Location of the road where the PJU PLTS will be installed at Campus 4, Khairun University, Sofifi.

The total length of the road to be illuminated is approximately 645 meters. The number of poles to be used can be calculated using the following formula:

$$T = \frac{L}{S} + 1$$

$$T = \frac{645}{40} + 1$$

$$= 17 \text{ tiang}$$

The distance between poles for solar street lighting is between 30 to 50 meters. For this calculation, a distance of 40 meters is used, so the total number of poles is: To ensure the light from the lamp focuses on the center of the road, the pole angle is calculated using the formula:

$$t = \sqrt{h^2 + c^2}$$

Where:

h = height of the pole

c = horizontal distance of the lamp from the center of the road

t = distance of the lamp to the center of the road

$$\cos \varphi = \frac{h}{t}$$

$$= \frac{7}{7.07} = 0.99$$

$$\varphi = \cos^{-1} \times 0.99$$

$$\varphi = 8.11^\circ$$

The pole angle to be used is 8.11°.

The light intensity is determined using the BSN SNI 7391-2008 standard table for normal lighting quality, where for local primary roads, the light intensity should be 2 - 5 lux. The formula used is:

$$E = \frac{I}{h^2}$$

Where:

E = lux value

I = light intensity

h = pole height

$$5 = \frac{I}{7^2}$$

$$I = 5 \times 49$$

$$I = 245 \text{ Cd}$$

From the calculation above, with a pole height of 7 meters, the light intensity is 245 Candela (Cd).

The light flux is determined using the following formula:

$$I = \frac{\Phi}{4\pi}$$

$$I = 245 \text{ Cd}$$

$$\pi = 3,14$$

$$\Phi = 245 \times 4 \times 3,14$$

$$\Phi = 3,077.2 \text{ lumen}$$

The type of lamp used will be a LED lamp with an efficacy of 115 - 180 lumens per watt. The power of the lamp is calculated using the formula:

$$K = \frac{\Phi}{P}$$

Where:

K = lamp LED efficacy (lm/W)

$\Phi$  = light flux

P = lamp power

$$P = \frac{3,077.2}{140}$$

$$P = 26.7 \text{ watt}$$

The power of the lamp used is 40 watts.

To determine the power of the solar module, the total energy required by the lamp over 12 hours for road lighting must be calculated. The total power used is:

$$P = 40 \times 12$$

$$P = 480 \text{ watt}$$

Solar panel power:

$$P_{\text{panel surya}} = \frac{E_{\text{tot}}}{\text{Insolasi matahari}}$$

Where:

Etot = total energy

The average solar insolation in Indonesia is 5 hours.

$$P_{\text{panel surya}} = \frac{480}{5}$$

$$= 96 \text{ watt} \approx 100 \text{ Watt}$$

The solar panel power used is 100 watts

The battery capacity is calculated using the formula, with a Depth of Discharge (DoD) of 2 days:

$$C = \frac{N \times EL}{V_s \times DOD \times \eta} (Ah) \quad C = \frac{2 \times 480}{12 \times 0.8 \times 0.98} (Ah)$$

$$C = 102 Ah$$

#### 4. CONCLUSION

Based on the results of the planning, the conclusions are as follows: For the rooftop solar power system at the lecturer's house with a total power of 7,920 Watts, four solar panels of 450 Wp each will be used. The battery capacity is 120 Ah, 48 volts, and a total of 4 batteries will be used. For the solar-powered street lighting system, a total of 17 solar street lighting poles will be used, each with a 7-meter pole height and a 40-watt lamp. The solar module capacity is 100 Wp, and the battery capacity is 100 Ah..

#### REFERENCES

- [1] Kadem, A., Rajab, Z., Khalil, A., Tahir, A., Alfergani, A., & Mohamed, F. A. (2018, March). Economic feasibility, design, and simulation of centralized PV power plant. In 2018 9th International Renewable Energy Congress (IREC) (pp. 1-6). IEEE.
- [2] Thapar, S. (2022). Centralized vs decentralized solar: a comparison study (India). *Renewable Energy*, 194, 687-704.
- [3] Malagueta, D., Szklo, A., Borba, B. S. M. C., Soria, R., Aragão, R., Schaeffer, R., & Dutra, R. (2013). Assessing incentive policies for integrating centralized solar power generation in the Brazilian electric power system. *Energy Policy*, 59, 198-212.
- [4] Malagueta, D., Szklo, A., Borba, B. S. M. C., Soria, R., Aragão, R., Schaeffer, R., & Dutra, R. (2013). Assessing incentive policies for integrating centralized solar power generation in the Brazilian electric power system. *Energy Policy*, 59, 198-212.
- [5] Carvalho, J. P., Zhang, N., Murphy, S. P., Leibowicz, B. D., & Larsen, P. H. (2020). The economic value of a centralized approach to distributed resource investment and operation. *Applied Energy*, 269, 115071.
- [6] P. Gunoto and H. D. Hutapea, "ANALISA DAYA PADA PANEL SURYA DI PEMBANGKIT LISTRIK TENAGA SURYA ROOFTOP ON GRID KAPASITAS 30 KVA GEDUNG KANTOR PT. ENERGI LISTRIK BATAM," *SIGMA Tek.*, vol. 5, no. 1, pp. 057–069, Jun. 2022, doi: 10.33373/sigmateknika.v5i1.4180.
- [7] E. A. Karuniawan, "Analisis Perangkat Lunak PVSYS, PVSOL dan HelioScope dalam Simulasi Fixed Tilt Photovoltaic," *J. Teknol. Elektro*, vol. 12, no. 3, p. 100, Oct. 2021, doi: 10.22441/jte.2021.v12i3.001.
- [8] A. Asrori, A. F. Ramdhani, P. W. Nugroho, and I. H. Eryk, "Kajian Kelayakan Solar Rooftop On-Grid untuk Kebutuhan Listrik Bengkel Mesin di Polinema," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 10, no. 4, p. 830, Oct. 2022, doi: 10.26760/elkomika.v10i4.830.
- [9] Y. S. Wijoyo and A. F. Halim, "Analisis Pemasangan Rooftop Photovoltaic System pada Sistem Elektrikal Bangunan," 2018.
- [10] H. B. Nurjaman and T. Purnama, "Pembangkit Listrik Tenaga Surya (PLTS) Sebagai Solusi Energi Terbarukan Rumah Tangga," *J. Edukasi Elektro*, vol. 6, no. 2, pp. 136–142, Nov. 2022, doi: 10.21831/jee.v6i2.51617.
- [11] Delle, M., Civcisa, I., Vitolins, V., Lauka, D., & Blumberga, D. (2019). Integration of sun PV electricity in centralized heating systems. *Rigas Tehniskas Universitates Zinatniskie Raksti*, 23(3), 245-259.

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