Clean Energy and Smart Technology
Volume 02, Number 01, October 2023
DOI : https://doi.org/10.58641/
e-ISSN : 2964-2647

ON GRID SOLAR POWER PLANT (SOLAR HOME SYSTEM) HOUSEHOLD SCALE

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Submitted : 2023-09-07 | **Accepted** : 2023-09-29| **Published** : 2023-10-31

Abstract: The need for electricity in Indonesia continues to increase every year and its supply is increasingly limited because most power plants in Indonesia still depend on conventional energy (fossil fuels). Solar power plants (PLTS) are very suitable to be developed in Indonesia because they have abundant sources of solar energy. with an average solar radiation intensity of about 4.8 kWh/m² per day. Therefore, in this study a design of a household-scale solar power plant (Solar Home System) will be made, with the aim of saving electricity and electricity bills from PLN. The power designed in this study is 0.9 kW. Using 3 units of ST Solar 300 Wp solar panels and the Solis On-Grid Mini-1000-4G Inverter. Based on the economic analysis, this design requires an initial capital of Rp. 17,500,000. savings in electricity bills obtained each month is IDR 154,464. and from the results of the BEP calculations that have been carried out, it is known that the capital will return in the 9th month-6th year

Keywords: Energy, PLTS, On-Grid, BEP

1. INTRODUCTION

Currently, electrical energy is a very vital human need. Electrical energy is needed in various fields, both from an economic, technological, social and cultural perspective. Every year the need for electricity in Indonesia continues to increase, Minister of Finance Sri Mulyani Indrawati revealed that electricity consumption grew 16.6 percent as of May 2021 on an annual basis (CNN Indonesia, 2021). The increasing need for electrical energy in Indonesia can be an indicator of increasing prosperity, but on the other hand it also raises problems in its supply. To meet electricity needs, currently most people still use fossil fuels, the supply of which will become increasingly depleted and the price will become more expensive. So alternative energy is needed to meet future energy needs.

There are various types of alternative energy, namely solar energy, geothermal energy, water energy, wind energy and biomass energy. In Indonesia, the potential for solar energy is the largest compared to other alternative energies. The potential for solar energy in Indonesia is 10x that of geothermal energy, however its utilization is still very low compared to the potential it has. Director of New, Renewable Energy and Energy Conservation (EBTKE) Dadan Khusdiana said, until 2020, the use of solar energy in Indonesia had only been absorbed at 153.4 MW out of a total potential of 207.8 GW. The advantages obtained when using solar cells include that they do not produce gases like the results of burning fossil fuels, they do not cause noise like power plants that use turbines, and solar cells are quite practical because they can be used anywhere provided there is lots of sunlight (ESDM/media -center,2021).

Solar power plants (PLTS) are very suitable to be developed in Indonesia because they have abundant solar energy sources with an average solar radiation intensity of around 4.8 kWh/m² per day, covering almost all of Indonesia. Several buildings in Jakarta already use PLTS, such as the one on the roof of the ESDM ministry building. When using PLTS, care is needed for the surface of the solar panels to avoid dust, because dust that

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sticks to the surface of the solar panels results in the absorption of solar energy not being optimal, so that the PLTS cannot supply electrical energy properly. And also financial calculations must be done correctly so that the investment made is not in vain because the costs incurred in building a PLTS are not cheap. Therefore the research carried out in this thesis takes the title "Design of a Household Scale On Grid Solar Power Plant (Solar Home System) in Mega Regency Housing, Bekasi". With the hope that it can become a pilot project for the implementation of household scale PLTS technology (Solar Home System).

2. METHOD

The method used in this research is a quantitative method, namely a research approach that uses a lot of numbers. Design and analysis of electrical power needs in Mega Regency Housing, using a calculation and measurement approach then applying it to the design of PLTS that will be used in housing in the Bekasi district area. In order to make this research easier and more focused, a flow chart is needed which contains steps to solve the problems that will be discussed. The following is a flow chart for this research:

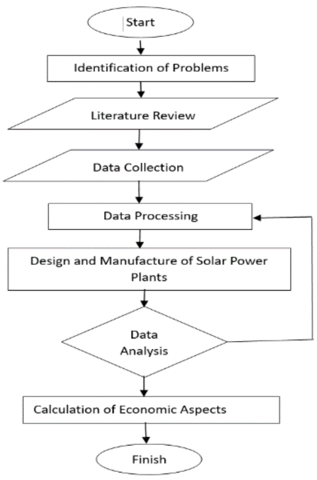

Fig 1. Research Design Flow Chart

The Irradiance value or radiation power per unit area is very necessary in designing a PLTS, where knowing the availability of solar energy at the location will determine the calculation of predictions for electrical energy production in a certain period. NASA POWER provides satellite-derived maps and data products and Analysis Ready Data (ARD) of solar energy at four temporal levels: hourly, daily, monthly, climatological. Data is updated nightly to maintain Near Real Time (NRT) availability (2-3 days for meteorological parameters and 5-7 days for solar). Radiation values are obtained through the NASA POWER (Prediction Of Worldwide Energy Resources) online application. NASA POWER (Worldwide Energy Resources Prediction) is an online application that contains mapping or information on maps of solar energy potential, including radiation values, temperature, and others.

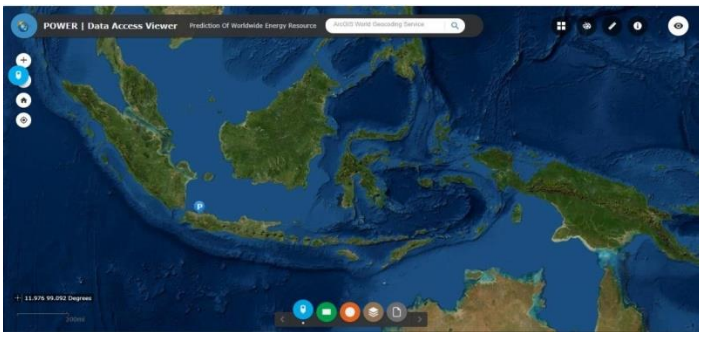

Fig 2. *NASA POWER / Data Access* Viewer
Source: https://power.larc.nasa.gov/data-access-viewer/ Accessed 8 June 2022

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PLN on Grid In simple terms, the electrical energy produced by solar cells will be channeled to the combiner box, inside the combiner box there is surge protection to protect against electrical surges caused by lightning strikes and a mini circuit breaker (MCB) to isolate the circuit from overcurrent. dc from the combiner box will be converted to ac using an inverter and will be channeled to the PHB and then forwarded to the load. If the electrical energy produced is not sufficient for daily load requirements, it will be supplied from the PLN network, and if the electrical energy produced is greater than the load, it will be forwarded to the PLN network as a temporary storage area and the amount will be calculated via kWh meter exim.

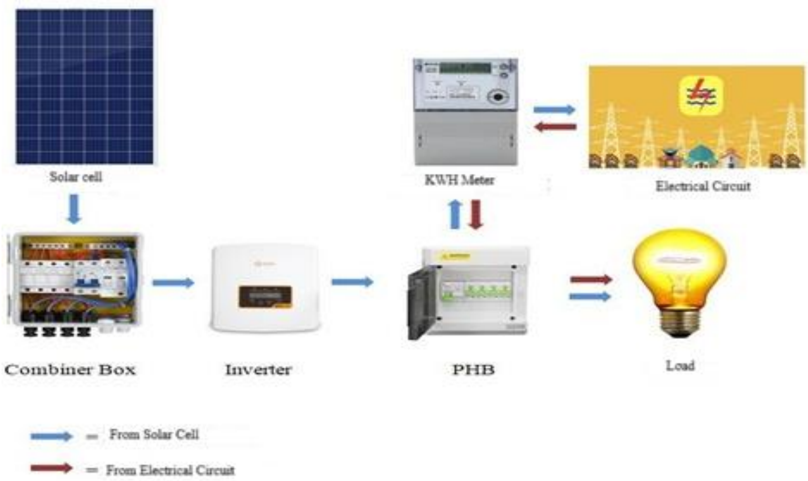

Fig 3. Block Diagram of On-Grid PLTS

3. RESULT AND DISCUSSIONS

Daily Load Data

After obtaining a list of equipment specifications and electricity usage loads, the daily load requirements can be calculated as follows:

Table 1. Electrical Load Usage Data

Data on Household Expense Usage				
Equipment	Units	Power	Time (Hour/day)	Power Consumption (Wh)
Porch Lights	2	12	12	228
Living room lamp	1	15	4	60
Central Room Lamp	1	15	8	120
Room lamp	2	12	6	144
Kitchen lights	1	18	6	108
Bathroom Lights	1	10	5	50
Television	1	40	10	400
Rice Cooker	1	350	0,4	140
		60	14	840
Refrigerator	1	90	10	900
Iron	1	300	2	600
Fan	3	50	6	900
Totals				4550

Average data on electricity usage and bills at Mega Regency Housing can be seen in table 2 below.

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Table 2. Average Usage and Billing Data

Average monthly electricity bill data using PLN Mobile		
Used / Period	Bill (Rp)	Usage (kWh)
Monthly	Rp. 212.366	152,5 kWh
Daily	Rp. 7.079	5,08 kWh

Solar Radiation Data

Solar Radiation Values are obtained using the NASA POWER online application with points

Table 3. Solar Radiation Data
Average monthly solar radiation data from 2019-2022

Month	Solar Radiation (kWh)	Temperature (^{0}C)
January	4.22	24.65
February	4.30	24.74
March	4.76	24.86
April	4.92	25.23
May	4.77	25.37
June	4.67	24.75
July	5.06	24.23
August	5.33	24.55
September	5.74	25.19
October	5.48	25.83
November	5.07	25.91
December	4.48	24.96
Average	4.91	44.99

To find out the output power of a solar panel when the temperature rises to 25.83°C, use the following formula:
$PMPP$ when it rises to $t\ °C$ = $PMPP$ – $P$when it raises $°C$
$PMPP$ when t−25.83$°C$ = 300 Wp – 1,245 Wp = 298.755 Wp

Amount of Power that PLTS Can Generate (Watt Peak)

To calculate the amount of power generated by a PLTS, you can use the following equation:
$Pwattpeak = PVarea$ × PSI × ɥPv

The $PVarea$ value is 5.68 m² with Peak Sun Insolation (PSI) is 1000W/m², and the efficiency of the solar panels is 17%. Then the calculation is as follows:

$Pwattpeak$ = 5.68 m² × 1,000W/m² × 0.17 = 965 Watt Peak ≈ 0.965 kWp

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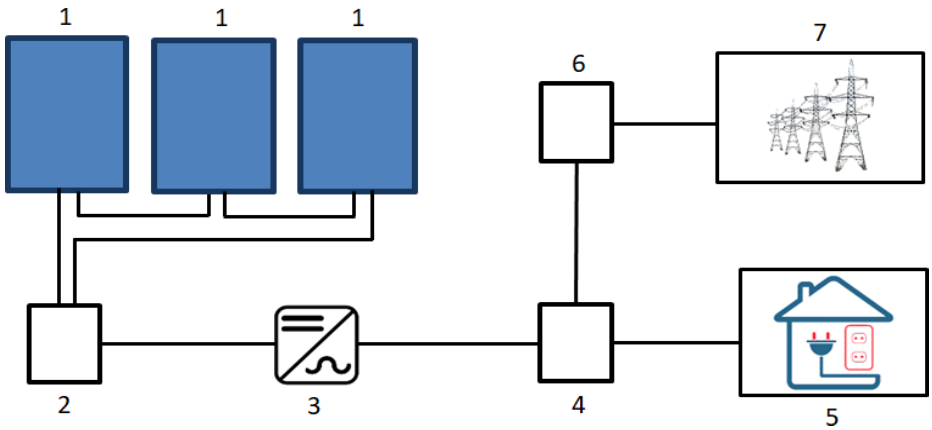

Fig 4. Schematic of the PLTS Series

Information :
1. Solar Panels
2. Combiner Box
3. Inverters
4. Share Connection Panel
5. Burden
6. kWh Exim
7. PLN utility network

Calculating above, the solar panel circuit for this research uses a series of 3 panels, so the solar panel output power is:

Solar panel output voltage = 3 Panels × 35.8 V = 107.4 V
Solar panel output current = 8.38 A
Solar panel output power = 107.4 V × 8.38 A = 900 W

Calculating PLTS Output Power

The assumption of system losses is considered to be 15% because all the components used are new components (Bien, L. E., Kasim, I., & Wibowo, W. (2008). To determine the PLTS output power, use the following calculation:
Number of Panels × Nominal Power Module = 3 Panels × 300 Watts = 900 Watts

$$Pi = \text{Amount of Power Used} \times (100\% - 15\%)$$
$$= 900 \text{ Watt} \times 85\%$$
$$= 765 \text{ Watt}$$

The energy produced by solar panels, if using the lowest radiation value, namely 4.22 kWh/m^2, is as follows:
$Pout = Pi \times$ Minimum Solar Radiation = 0.765 kW × 4.22 kWh/m^2 = 3.22 kWh/m^2

The energy produced by solar panels, if the highest radiation value is used, namely 5.74 kWh/m^2, is as follows:
$Pout = Pi \times$ Maximum Solar Radiation = 0.765 kW × 5.74 kWh/m^2 = 4.39 kWh/m^2

To calculate the average energy per year, use the PSH (Peak Sun Hour) radiation value with a value of 4.91 kWh/m^2.
Then: $Pout = Pi \times$ PSH = 0.765 kW × 4.91 kWh/m^2 = 3.75 kWh/m^2
Energy Yield = Energy Output × 365 days = 3.75 kWh/m^2 × 365 days = 1,370.99 $kWh/tahun$

Performance Ratio (PR)

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Performance Ratio is a measure of the quality of a system in producing annual energy. A PLTS system is said to be feasible if the Performance Ratio value is at 70-90% (Taufik, 2020). Calculation of the Performance Ratio uses equation 3.10 as follows:

$$P_R = \frac{E_{Yield}}{E_{ideal}} \, x \, 100\%$$

Before calculating the Performance Ratio, the following calculations are carried out:
$Htilt$ = PSH × 365 days
$Htilt$ = 4.91 kWh/m²× 365 days
$Htilt$ = 1,792.15 kWh/m²

Ideal Energy = Solar Module Specification Power × Number of Modules × $Htilt$
= 300 Wp × 3 Modules × 1,792.15 $h/tahun$
= 1,612,935 W$h/tahun$ ≈ 1,612.93 kW$h/tahun$

Then the Performance Ratio is:

$$P_R = \frac{E_{Yield}}{E_{ideal}} \, x \, 100\%$$

$$P_R = \frac{1.370{,}99 \; kWh/ahun}{1.612{,}93 \; kWh/tahun} \, x \, 100\%$$

= 0,84 ≈ 84%

A Performance Ratio value of 84% was obtained, so the PLTS system in this research can be said to be feasible.

Analysis of PLTS Design Costs

The cost of designing a PLTS includes the costs of purchasing components and installing the PLTS. The prices of the PLTS components that have been determined are adjusted to the prices circulating in the market (market place).

Table 4. Components of PLTS

No.	Components	Units (Pcs)	Unit Price (Rp.)	Total Price (Rp)
1	Panel Surya ST Solar 300 WP Polikristalin	3	Rp. 2.260.000	Rp. 6.780.000
2	Solis On-Grid Inverter Mini 4G 1000 W	2	Rp. 4.950.000	Rp. 4.950.000
3	1 Set Combiner Box	1	Rp. 960. 000	Rp. 960.000
4	MCB Box 4 Module	1	Rp. 77.200	Rp. 77.000
5	MCB 4A	2	Rp. 60.500	Rp. 139. 000
6	Conector MC4	2	Rp. 6.600	Rp. 13.200
7	Solar Panel Cables	15	Rp. 9.200	Rp. 138.000
	Total			Rp. 13.057.000

From table 4 it is known that the cost required to purchase PLTS components is IDR. 13,057,400.

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Material Costs for Assembly and Installation of Frames for Solar Panels

The process of assembling and installing the solar panel frame requires several components as follows:

Table 5. Solar Panel Frame Materials

No	Components	Units (Pcs)	Unit Price (Rp.)	Total Price (Rp)
1	Hollow Iron (mm) 40 x 60 x 2 (m	1	Rp. 318.300	Rp. 318.300
2	Alumunium Rail (2.1 m) Mounting System	3	Rp. 168.500	Rp. 559.500
3	Dynabolt IB 10 x 50	12	Rp. 1.400	Rp. 16.000
4	Bolt M8 x 20 mm	6	Rp. 750	Rp. 4.500
5	Middle Clamp 40 mm	4	Rp. 15.000	Rp. 60.000
6	End Clamps 40 mm	4	Rp. 15.000	Rp. 60.000
7	Rail Joint Splite kit	2	Rp. 28.500	Rp. 57.000
		Total		Rp. 1.076.100

The cost required to purchase solar panel frame components is IDR. 1,076,100.

Break Even Point (BEP) Calculation

Before calculating BEP, the value of cash inflow or savings obtained after using PLTS in a month must be known. To find out the cash inflow in a month, use the following calculation, where the average annual energy production value (Energy Yield) is 1,370.99 $kWh/tahun$ × Basic Electricity Tariff (TDL) per kWh applicable in Indonesia with the R1M 900VA group, namely amounting to Rp. 1,352 per kWh then divided by 12 months. So the values obtained are:

$$\text{Saving per year} = \frac{Energi\ Field\ x\ TDL\ per\ kWh}{12\ Months}$$

$$= \frac{1.370{,}99\,\frac{kWh}{Year}\,x\ Rp1.352}{12\ Months}$$

$$= \frac{1.370{,}99\ kWh/\text{year} \times \text{Rp.}1.352}{12\ \text{Months}}$$

$$= \text{Rp.}154.464$$

The savings obtained after using the On-Grid PLTS system are IDR. 154,464. So the average billing cost each month will be IDR 212,366 - IDR 154,464 = IDR 57,902.

So the calculation for BEP is as follows:

$$\text{BEP} = \frac{PLTS\ Manufacturing\ Cost}{savings\ per\ month}$$

$$= \frac{Rp\ 17.500.000}{Rp\ 154.464}$$

$$= 113{,}2\ \text{months} \approx 9\ \text{year}\ 6\ \text{months}$$

From the calculation results, it is known that the initial capital will return in the 9th year and 6th month.

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The power installed in the PLTS at Mega Regency Housing is 0.9 kW. The average annual energy value (Energy Yield) that PLTS can produce is 1,370.99 $kWh/tahun$. It is known that the Performance Ratio value is 84%, in other words this PLTS system can be said to be feasible to design.

The PLTS system that will be designed at Mega Regency Housing is assumed to be able to operate for 20 years, which refers to the guarantee provided by the solar panel manufacturer. The initial capital required to build a PLTS in Mega Regency Housing is IDR 17,500,000. the savings obtained each month is IDR. 154,464. From the results of the BEP calculation, it is known that the capital will return in the 9th year and 6th month. So in the 10th year the designed PLTS system will provide benefits to the owner.

4. CONCLUSION

From the results of the discussion of the On Grid Solar Power Plant (Solar Home System) for Household Scale in Bekasi, several conclusions were obtained, namely: 1)The design of On-Grid PLTS in Mega Regency Housing aims to reduce the cost of using PLN electricity, 2)The installed PLTS system is easy to maintain, because the maintenance process does not require special skills and everyone can do it, 3)From the results of the Performance Ratio (PR) calculation, it is known that the PLTS design was declared feasible with a PR value of 84%, 4)From the results of economic analysis calculations, the designed PLTS system is said to be feasible because the initial investment will return in the 9th year and will make a profit in the 10th year.

5. REFERENCES

Anwar, A. S. (2021). *Tenaga Surya Rooftop Di Gedung Fakultas Teknik*. Bagaskoro,

B., Windarta, J., & Denis. (2019). Perancangan Dan Analisis Ekonomi Teknik Pembangkit Listrik Tenaga Surya Sistem Offgrid Menggunakan Perangkat Lunak Homer Di Kawasan Wisata Pantai Pulau Cemara. *TRANSIENTJurnal Ilmiah Teknik Elektro UNDIP*, *8*(2), 152–157.

Berkat Akin, A., Hidayat, S., & Darmana, T. (2020). *Perencanaan PLTS On-GridPemakaian Sendiri Di Gi 150 kV Makale*. INSTITUT TEKNOLOGI PLN.

Bien, L. E., Kasim, I., & Wibowo, W. (2008). Perancangan sistem hibrid pembangkitlistrik tenaga surya dengan jala-jala listrik PLN untuk rumah Perkotaan. Universitas Trisakti.Bien, L. E., Kasim, I., & Wibowo, W. (2008). P. sistem hibrid pembangkit listrik tenaga surya dengan jala-jala listrik P. untuk rumah P. U. T. (n.d.). *No Title*.

ESDM. (2018). *Peraturan Menteri ESDM Nomor 49 Thn 2018 Tentang PenggunaanSistem Pembangkit LIstrik Tenaga Surya Atap oleh Konsumen PT. PLN (Persero)*. 18.

Gifson, H. A., Siregar, M. R., & Pambudi, M. P. (2020). R. B. P. L. T. S. (Plts) O. G.D. E. A. T. J. T. E. L. U. https://creativecommons. org/licenses/by-sa/4. 0. (n.d.).*No Title*.

Indonesia, M. K. R. (2022). Peraturan Menteri Keuangan Republik Indonesia Nomor108/PMK. 02/2022 Tentang Jenis dan Tarif Jenis Penerimaan Negara Bukan Pajak Yang Bersifat Volatil Yang Berlaku Pada Kementerian Perindustrian.Indonesia, M. K. R. (2022). P. M. K. R. I. N. 108/PMK. 02/2022

T. J. dan T. J. P. N. B. P. Y. B. V. Y. B. P. K. P. (n.d.). *No Title*.International, C., & Commission, E. (n.d.). *Te c h n i c al*.

Iskandar, N. C. S. (2018). Sistem Listrik Tenaga Surya disain, dan Operasi Instalasi. *Yogyakarta: CV BUDI UTAMA*.