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Design and Simulation of On-Grid Rooftop Solar Power Plant (Rooftop PV) System on Office Buildings with a PLN Grid System

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ABSTRAK

Energi Terbarukan memiliki peranan penting didalam pengembangan energi di Indonesia. Salah satu Penggunaan Energi terbarukan yang dapat diterapkan adalah energi matahari dari PhotoVoltaic (PV). Penggunaan PV di atap dengan kondisi terhubung jaringan ke sistem disebut Sistem PLTS Atap On Grid. Penelitian ini merencanakan pemasangan Sistem PLTS On Grid di Gedung Perkantoran PT.PLN UP3 Samarinda. Dari perancangan yang telah dilakukan dengan luas area atap sebesar 919,18 m2 menghasilkan 124,640 Kwp berdasrkan simulasi helioscope. Sementara itu didapat GHI (Global Horizontal Irridiance) sebesar 126.51 KWh/m2/yr, energi produksi 144.119 KWh/yr dan Performa Ratio yang dihasilkan sebesar 77.4 %. Peralatan ALL-TEST PRO On-Line II menghasilkan data beban pada Gedung Perkantoran. Simulasi HOMER menghasilkan Sistem PLTS Atap On Grid dan SIstem PLN sebesar 181,718 KWh (55.8%) dan 144.119 KWh (44.2%). Meter EXIM digunakan sebagai impor ekspor energi didalam Sistem.

***Kata kunci**: Energi Terbarukan, Sistem PLTS Atap On Grid, Meter EXIM*

ABSTRACT

Renewable energy is essential in developing energy use in Indonesia. One applicable renewable energy uses solar energy from PhotoVoltaic (PV). Rooftop PV with a network-connected condition to the system is called the On-Grid Rooftop solar power plant System. This research install the On-Grid Rooftop PV System in the office building of PT. PLN UP3 Samarinda. The design that has been prepared with a roof area of 919.18 m2 simulates that it will produce 124,640 KWp based on helioscope simulation. Meanwhile, the GHI (Global Horizontal Irradiance) is 126.51 KWh/m2/yr, with energy production of 144,119 KWh/yr and the Performance Ratio is 77.4%. The ALL-TEST PRO On-Line II Equipment generates a load on the Office Building. With the HOMER simulation, the On-Grid Rooftop solar PV System and the PLN System distribution is 181,718 KWh (55.8%) and 144,119 KWh (44.2%). An EXIM Meter is needed as an energy export import inside System.

***Keyword**: Renewable Energy, System PLTS Rooftop On Grid, Meter EXIM*

1. INTRODUCTION

For the upcoming years, the use of renewable energy should be optimized compared to the use of fossil energy. The use of Renewable Energy in Indonesia is stated in RUEN No 22 of 2017 **(Peraturan Presiden RI, 2017)** and the Electricity Supply Business Plan (RUPTL) of PLN 2021-2030 **(PLN, 2021)** by increasing the share of New Renewable Energy (EBT) plants in the National Electricity General Plan (RUKN) by 23% in 2025. Furthermore, for the long term, the use of NRE in 2050 is no less than 31%. Presently, the use of renewable energy from 2021 performance data of ESDM (Energy and Mineral Resources) BY the end of 2021 was still 13.5%. **(Direktorat Jenderal EBTKE - Kementerian ESDM, n.d.)**

Solar energy is one of the potential renewable energies in Indonesia because Indonesia's position is on the equator with a tropical climate; therefore, it tends to gain abundant sun exposure throughout the year. Solar Energy is effortless to obtain, environmentally friendly, with easy install and maintenance **(Hariyati et al., 2019)**. The use of solar energy requires a vast land area adjusted to the desired power. Solar power plants (PLTS) use PhotoVoltaic (PV) Modules to capture solar energy, which will then be converted into electrical energy in a cycle process. Installation of PV Modules can now be done in various ways, such as above-water, above-ground, or above-buildings PV modules installation, where the use of PV follows its functions and needs **(Tarigan & Kartikasari, 2017)**. PV modules on buildings are also known as Rooftop solar power plants. In using a Rooftop solar power plant, there are supporting aspects such as technical aspects, economic aspects, and the concept of use with installed electricity. The Configuration System of a Rooftop solar power plant consists of several systems, such as off-grid, on-grid, and hybrid systems. The On-Grid system is a system that is connected to the electricity supply network that obtains a permit from the Indonesian government, i.e., PLN. The Indonesian government has approved the use of Rooftop Solar Power, stated in the Regulation of Minister of Energy and Mineral Resources No. 26 of 2021, concerning Rooftop solar power plants that are connected to the electric power network of the holder of a business license to provide electricity for the public interest **(Kementerian ESDM, 2021)**. The approved limit for using a Rooftop solar power plant is up to 500 KW. An EXIM Meter is needed to use the On-Grid Rooftop solar power plant connected to the PLN Electricity Provider Network. The EXIM Meter is used as a reading of incoming or outgoing energy (Import/Export) from the two systems used.

Previous research by D J Dhamiri et al. discusses the design of a 52.5 KW Rooftop solar power plant on industrial roofs. This research analyzes engineering simulations of the performance of PV mini-grid construction along with economic studies with helioscope software and PV systems. **(Damiri et al., 2019)** Another research by D J Dhamiri et al. discusses the technical and economic feasibility of an On-Grid Rooftop solar power plant of 200 KWp installed in the Industrial Building Area with Helioscope software. **(Damiri & Nugraha, 2021)**

2. METHODS

This research method was conducted in the Office Building of PT PLN UP3 Samarinda with a PLN contract power of 197 KVA at the B2 Business rate. Based on the Regulation of the Ministry of Energy and Mineral Resources No. 26 of 2021 concerning Rooftop Solar Power Plants Connected to the Electric Power Network of the Holder of A Business License to Provide Electricity for the Public Interest, On-Grid Rooftop Solar Power Plant Systems can use 100% of the PLN contract power. Therefore, the On-Grid Rooftop Solar Power Plant can be designed for up to 197 KW. The concept of planning an On-Grid Rooftop Solar Power Plant System will be used using an on-grid Rooftop Solar Power Plant system, which has not used a battery

system in the design that will be carried out. (Figure 1). In general, the research methods carried out are:

1. Data collection such as Coordinate Points, Building Roof Area, and Office Building Load Data of PT PLN UP3 Samarinda using ALL-TEST PRO On-Line II equipment.(Figure 2)
2. The design of the On-Grid Rooftop Solar Plant System with the Building Roof area to be used is based on the standard reference of the Directorate General of EBTKE – MEMR **(Ing. Bagus Ramadhani, 2018)** and reference **(Baqaruzi et al., 2020) (Sihotang, 2019) (Umam et al., 2021) (Yakin & Rajagukguk, 2020)**
3. Simulating the Design of an On-Grid Rooftop Solar Power Plant System using Helioscope software which will produce several parameters of Global Horizontal Irradiance (GHI), Total Electrical Energy Production, and Performance Ratio (PR) with reference **(REGA et al., 2021)**
4. Simulating the Design of an On-Grid Rooftop Solar Power Plant System using the HOMER software, which will generate Electrical Energy Production Loads generated from the On-Grid Rooftop Solar Power Plant System and Grid System (PLN). **(Khalil et al., 2020)**
5. Using an EXIM Meter, records how much electrical energy is consumed by the Office Building of PLN UP3 Samarinda from PLN and the quantity of electrical energy exported to PLN from the On-Grid Solar Power Plant System.

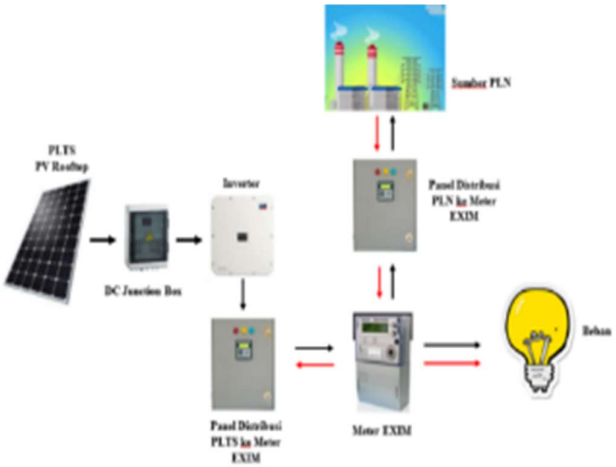

Figure 1. On-Grid Rooftop Solar Power Plant System

(a) **(b)**

Figure 2. All Test Pro On-Line II
(a) Equipment, (b) Installation

3. RESULT AND DISCUSSION

3.1 *Detail Of Location*

This research was carried out in the Office Building of PT. PLN (Persero) UP3 Samarinda uses the roof of the building as an On-Grid Rooftop Solar Power Plant System. The building location is at coordinates 0°30'02.3"S 117°08'14.9"E. The roof of the building generally has a slope of 16° from the West and East sides which will be used for PV installation. Installation of Roof PV used is an area of 459.59 m2 on the West and 459.59 m2 on the East side.

Figure 3. Office Building of PT. PLN (Persero) UP3 Samarinda Location

3.2 PV Design on the roof of Office Buildings

Designing the On Grid Solar PV System on the roof of an office building of 124,640 KWp uses a PV module capacity of 410 Wp and total use of 304 PV modules (figure 4). The type of PV module used is STP410S-C54/Nmhb+ 410Wp. The On-Grid Solar PV system uses 4 DC Junction Boxes and 4 inverters with the SunnyTripower 25000TL-US type, which can be monitored through an application. The number of Strings connected to the Inverter is 8 strings with 19 pieces each arranged in series (Figure 5).

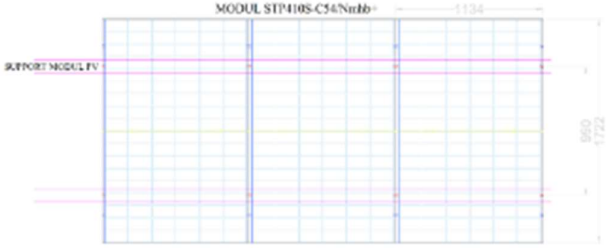

Figure 4. PV Modules Installation

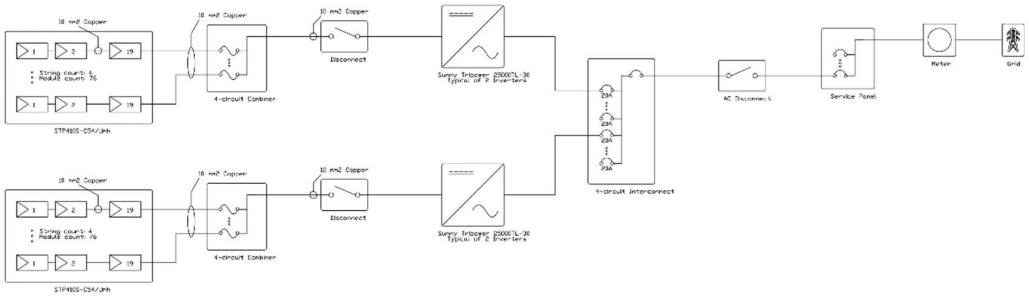

Figure 5. On-Grid Rooftop Solar Power Plant System SLD

3.3 Simulation Analysis of On-Grid Solar PV System

The use of the On-Grid Solar Power Plant System of 124.640 KWp on the roof of the Office Building of PT PLN UP3 Samarinda is simulated in the Helioscope and HOMER software. On-Grid Rooftop Solar Power Plant Installation with software Helioscope can be seen in Figure 6.

Figure 6. On-Grid Rooftop Solar Power Plant System on Office Building of PT. PLN (Persero) UP3 Samarinda

The simulated data in the helioscope software obtained the average GHI (Global Horizontal Irradiance) per year is 126.51 KWh/m2 (Figure 7 (a)). Furthermore, the produced production energy for a year is 144,119 Kwh (Figure 7 (b)). The resulting Performance Ratio is 77.4% (Figure 7 (c)). The energy generated by using the On-grid Rooftop Solar Power Plant System is highly dependent on the intensity of light generated from solar radiation. Judging from Figure 7 (d), the correlation between GHI and energy production.

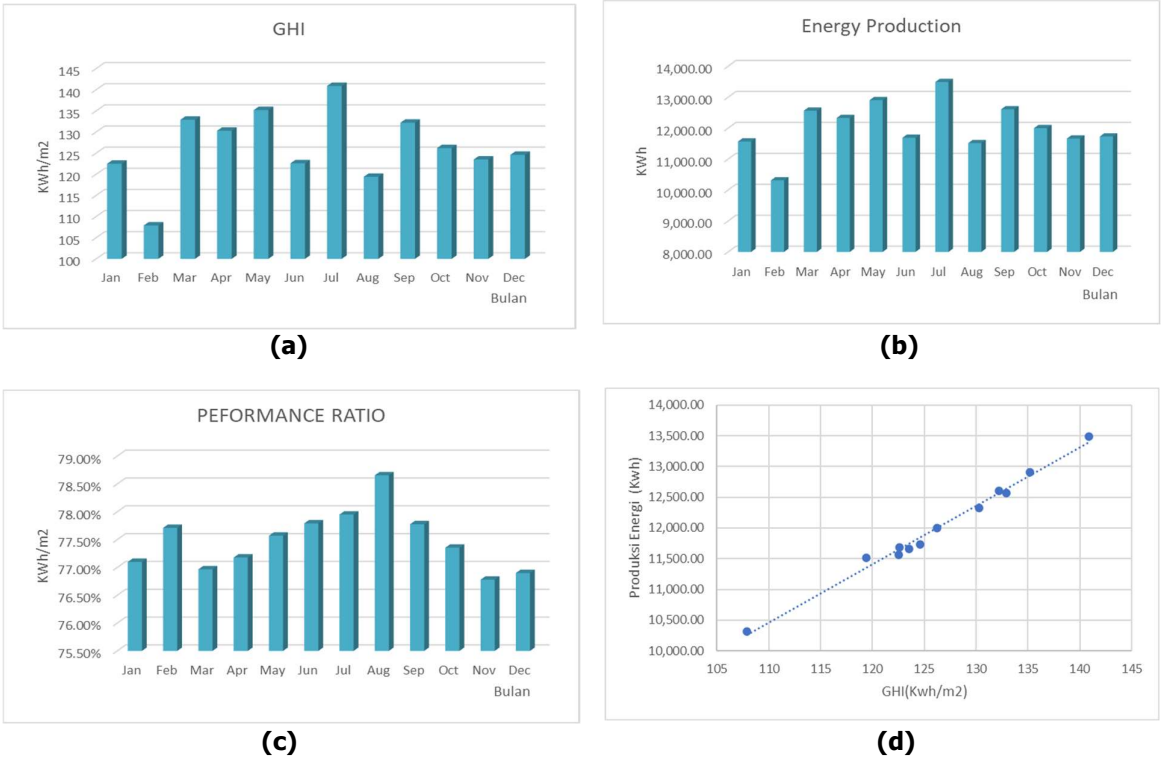

Figure 7. Result
(a) Global Horizontal Irradiance (GHI), (b) Energy Production (KWh)
(c) Performance Ratio, (d) Correlation between GHI and energy production

The performance ratio is the value of the effectiveness of the On-Grid Rooftop Solar Power Plant System, where the PR value occurs due to several factors such as losses in the module, the effectiveness of incoming sunlight, and weather shadows, temperature, use of inverters, and wiring. Based on the simulation, the resulting losses, as shown in Figure 8, are that the most considerable losses come from the module's temperature. Where if the temperature of the module is higher, the resulting PR will be smaller.

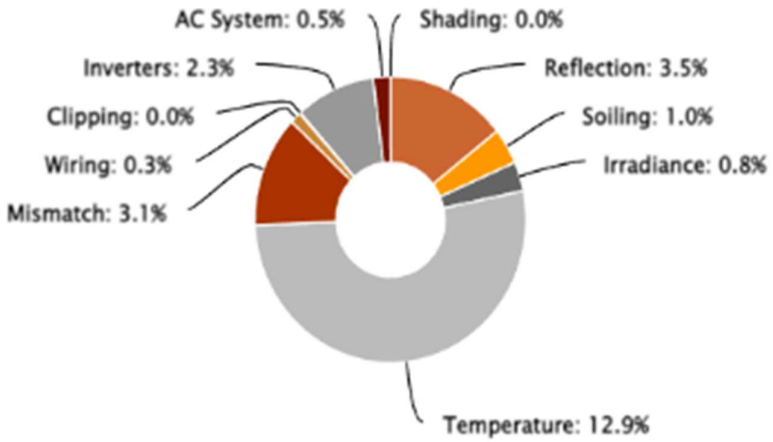

Figure 8. Losses Simulation of On-Grid Rooftop Solar Power Plant System

The load data for the Office Building of PT. PLN UP3 Samarinda was obtained by direct extraction using the ALL-TEST PRO On-Line II equipment installed at the distribution panel. ALL-TEST PRO On-Line II equipment is to read voltage, current, power factor, and power in real-time per second. The maximum load used in the Office Building of PT PLN UP3 Samarinda is 98.61 KW, and a minimum of 13.148 KW.(Figure 9)

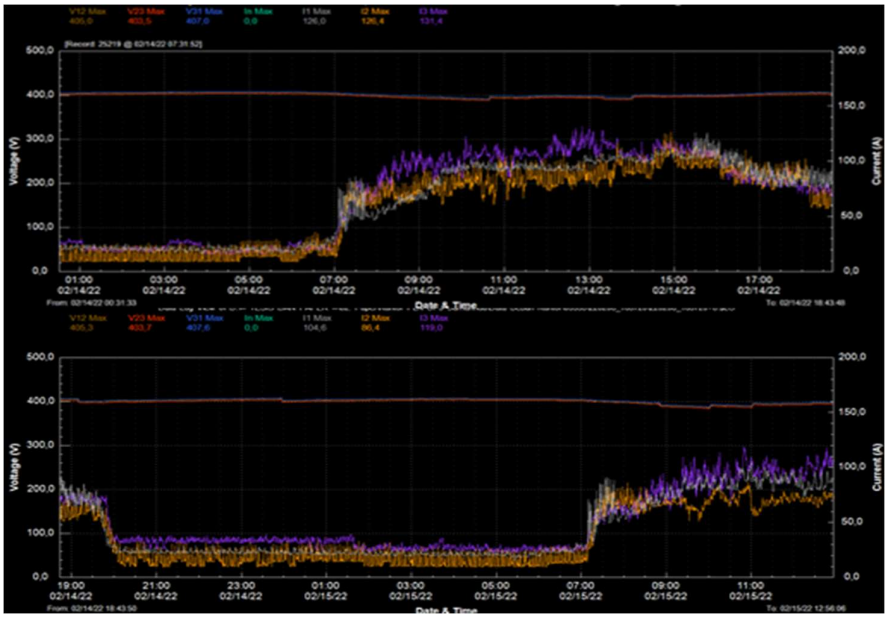

Figure 9. Load Measurement Data Using ALL-TEST PRO On-Line II equipment

The data and design results of the On-Grid Rooftop Solar Power Plant System which has been simulated in the Helioscope software, and the system load data for the Office Building of PT. PLN UP3 Samarinda was then reprocessed in the HOMER software.

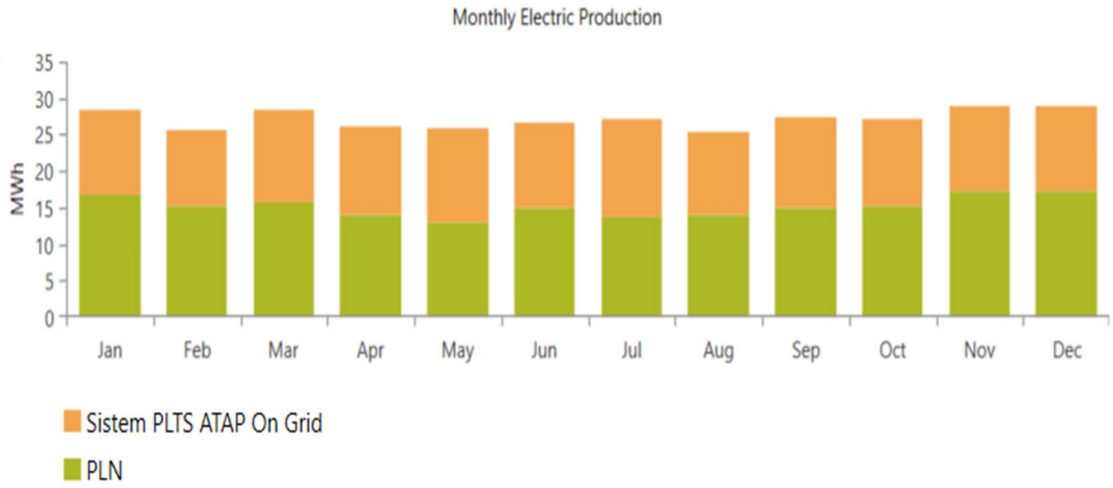

Figure 10. Energy Consumption of On-Grid Rooftop Solar Power Plant System and PLN System

Production	kWh/yr	%
Grid Purchases / PLN	181,718	55.8
Sistem PLTS ATAP On Grid	144,119	44.2
Total	325,837	100

Figure 11. Total Energy Consumption of On-Grid Rooftop Solar Power Plant System and PLN System

The energy that can be produced from the On-Grid Rooftop Solar Power Plant System and the PLN Grid System can be seen in Figure 10. The generated energy for 1 year from the two systems used by the PLN System is 181,718 KWh and for the On-Grid Rooftop Solar Power Plant System is 144.119 KWh to meet the needs of Load System from the Office Building of PT.PLN UP3 Samarinda with a percentage of the use of the PLN Grid System of 55.8 % and the On-Grid Solar PV System of 44.2% (Figure 11).

From the simulation results, the On-Grid Rooftop Solar Power Plant System operates from 06.00-18.00. The On-Grid Rooftop Solar Power Plant system can support the entire system load from the office building of PT. PLN UP3 Samarinda and the production of unused residual energy can be directed to the PLN system network (Figure 12). The energy that is distributed to the PLN system must use an Exim Meter, where this Meter can be used as an energy import-export. The tariff for the office building of PLN UP3 Samarinda Customers is 197 KVa. Then the On-Grid Solar PV System that can be planned is a maximum of 100% of the customer's power by using an import-export meter. Therefore, the maximum capacity of the On-Grid Solar PV system that can be used is 197 KW with a power factor considered 1.

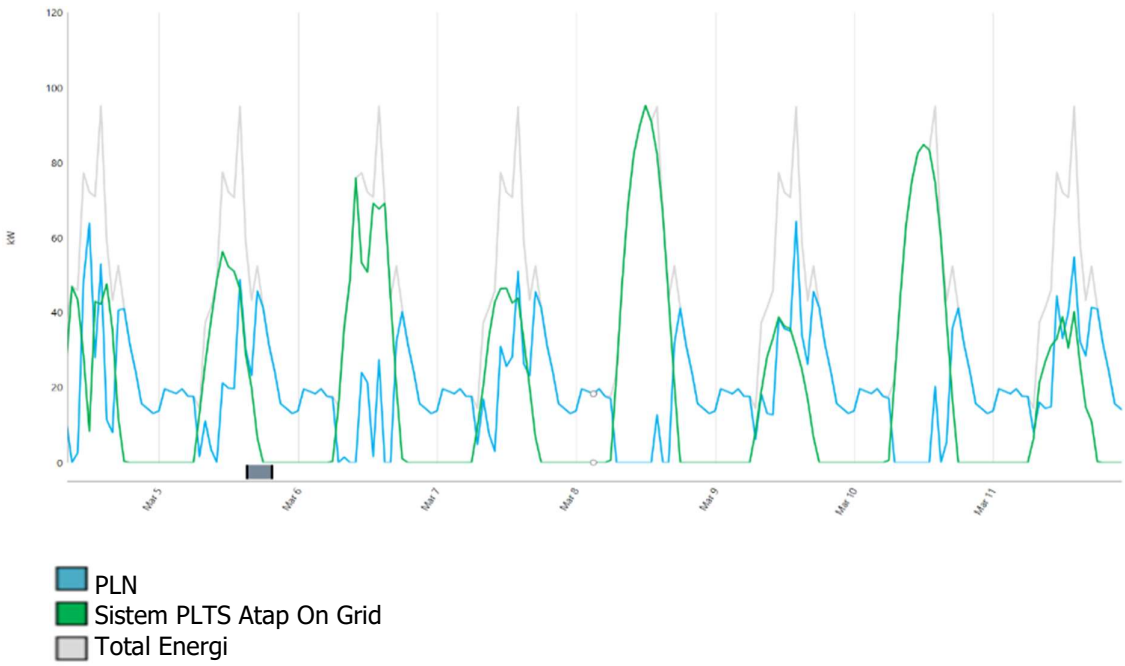

Figure 12. Time of Use of On-Grid Rooftop Solar Power Plant System and PLN

4. CONCLUSION

Conclusions from the Research on Designing the On-Grid Rooftop Solar Power Plant System at the office building of PT. PLN UP3 Samarinda has been carried out using a total roof area of 919.18 m2, height from the ground of 15m with a roof slope of 16 azimuths 97.94º east side and 278.2º west side. The capacity of the On-Grid Rooftop Solar Power Plant System obtained is 124,640 KWp using 304 units of PV Module 410Wp STP410S-C54/Nmhb+ 410Wp. The PV Module is connected to 4 DC Junction Boxes. From the DC Junction Box, it is then connected to 4 inverters with a capacity of 25 KVA SunnyTripower 25000TL-US with a total of 8 PV Modules arranged in series with 19 pieces arranged in series. The SunnyTripower 25000TL-US Inverter monitors the PV module's data and the output generated from the On-Grid Rooftop Solar Power Plant System. From the simulation results at the PT office building of PLN UP3 Samarinda, the average GHI per year is 126.51 KWh/m2, the energy production for a year is 144,119 KWh/yr, and the resulting Performance Ratio is 77.4%. The lack of effectiveness of the greatest Performance Ratio value is at the temperature of the PV Module. The load measurement results using the ALL-TEST PRO On-Line II equipment used in PT PLN UP3 Samarinda's office building are 98.61 KW and a minimum of 13.148 KW. From the load data generated and simulated, the energy required for the total system needs is 325,837 KWh/yr, whereas the Solar PLTS System usage is 144,119 KWh/yr (44.2%), and the PLN System is 181,718 KWh/yr (55.8 %). The On-Grid Rooftop Solar Power Plant system can support the entire load of the system at a particular time, and there is still energy remaining. The EXIM Meter can send the remaining energy to the PLN system network. Should the On-Grid Rooftop Solar Power Plant cannot meet the needs of the Office Building system load, it can use the PLN electricity network through the EXIM Meter. The designation of the EXIM Meter is a record of how much energy is consumed by the Office Building of PT. PLN UP3 Samarinda from the PLN system (Import), as well as providing energy to the PLN System from the On-Grid Rooftop Solar Power Plant (export). This research suggests building an On-Grid

Rooftop Solar Power Plant system in the Office Building of PT. PLN UP3 Samarinda uses BESS (Battery Energy Storage Systems) for energy storage and release.

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