Optimization of Rooftop Area on Building K Faculty of Engineering Universitas Indonesia for Grid-Connected PV

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Abstract. This study aims to design and assess the simulation of the On-Grid PV System that will be implemented in Building K at the Faculty of Engineering, Universitas Indonesia (FTUI), Depok, West Java. In addition, this research is also to find out the amount of energy potential and issued by the 66 kW PLTS On-Grid design and its energy saving value. On-Grid PV System was designed and simulated by PVsyst and the results were analyzed. Load profile data from Building K FTUI are used. The simulation shows that the energy produced by PV is 97,889 MWh per year, the performance ratio is 82% with the contribution rate to Building K is 23.79% in a year, and the reduction in energy consumption from utilities is 19.48% during workdays and 49.01% during the weekend.

1. Introduction

Electricity needs are increasingly becoming the basic needs of every human being [1]. Humans need a huge amount of Electricity for education, industry, commercial, domestic, agriculture, and transportation use. In Indonesia, electricity needs are mostly fulfilled by fossil fuel energy such as petroleum, coal and natural gas. In 2014 based on World Bank Data, Indonesia created 464176,194 kiloton CO₂ emission which effects could damage the earth environment [2]. For this reason, it is necessary to innovate to use alternative energy as a resource to produce electricity, especially from unlimited resources which called renewable energy, such as solar, geothermal, air, water, and biomass. Photovoltaic (PV) System is one alternative that is often applied in the use of generation technology in the renewable energy category. PV system is a power plant system that utilizes solar energy (photon energy) as an energy source for generating electricity or can also be said as a generating system that converts photon energy into electrical energy [3-5]. Considering that PV system is an intermittent energy source that produces electricity in a fluctuating amount, the operation of a backup generator or battery is needed in anticipation when the intensity of sunlight has decreased due to clouds or night conditions.

PV system is differentiated based on the presence or absence of a grid system that is integrated with it, which are the Off-Grid PV System and On-Grid PV System [6]. In this case, On-Grid PV System will be applied to Building K at the Faculty of Engineering, Universitas Indonesia (FTUI). One of the key benefits using On-Grid PV system is that the system does not have to supply enough electricity to cover the property’s power demand as in an off-grid system. The property can be powered by the PV system, the electricity grid or a combination of the two, meaning that the system can be as small or large as the owner desires. Excess power generated by the PV system will be exported to the power grid. The
system owner is paid for the exported power. With the application of PV System in Building K FTUI, it may decrease the use of electricity from the grid and make the Building K FTUI an environmentally friendly building. To find out whether PV system can save the electrical energy of a building, it is necessary to do a PV system design simulation in Building K and the results will be compared with conventional use without a PV system. This simulation is very important and will later be able to find out whether the PV System is feasible to be applied to the Building K FTUI.

This paper is organized as: Section 1 presents the research introduction, Section 2 proposes the design of the rooftop PV System in Building K FTUI, Section 3 provides the simulation and results, and Section 4 is the conclusion of this paper.

2. Design of The Rooftop PV System in Building K FTUI

Building K FTUI has been established since 1986. It is one of the campus facility buildings used as academic activities, seminar activities, student corner centers, and other activities that support students’ academic potential at Universitas Indonesia. To support all of the activities, Building K consists of 19 classrooms, a lobby, and an auditorium.

![Figure 1. Front View of Building K FTUI](image)

The design of the PV system depends on many factors which are the location (sun path and climate data), module, inverters, load profile, and losses [7,8]. PVsyst is the best tool for energy modelling and simulating the energy harvest of the potential project site in the solar industry.

First, the proposed research location is located at coordinates 6°36'44.5 "south longitude and 106° 82'26.6" east longitude to get geographic and climate data on the location using Meteonorm Data which is shown in Table 1. The shading is assumed to clear sky which is shading scene defined.

| Month     | Global Horizontal Irradiation kWh/m² | Diffuse Horizontal Irradiation kWh/m² | Ambient Temperature °C | Wind Velocity m/s | Global Inclination Irradiation kWh/m² | Diffuse Inclination Irradiation kWh/m² | Albedo Inclination Irradiation kWh/m² |
|-----------|-------------------------------------|--------------------------------------|-------------------------|-------------------|--------------------------------------|---------------------------------------|---------------------------------------|
| January   | 106.4                               | 62.57                                | 24.87                   | 1.6               | 100.9                                | 60.95                                 | 0.178                                 |
| February  | 110.5                               | 69.31                                | 24.53                   | 1.6               | 107.1                                | 67.99                                 | 0.184                                 |
| March     | 140.2                               | 78.72                                | 25.19                   | 1.5               | 140.3                                | 78.55                                 | 0.234                                 |
| April     | 146.6                               | 74.21                                | 25.25                   | 1.3               | 151.6                                | 75.58                                 | 0.245                                 |
| May       | 149.5                               | 77.03                                | 25.70                   | 1.1               | 159.5                                | 79.92                                 | 0.250                                 |
| June      | 142.5                               | 63.21                                | 24.97                   | 1.1               | 155.0                                | 66.50                                 | 0.237                                 |
| July      | 148.0                               | 69.80                                | 25.01                   | 1.1               | 159.5                                | 72.90                                 | 0.246                                 |
| August    | 166.6                               | 77.35                                | 25.15                   | 1.2               | 175.5                                | 80.19                                 | 0.276                                 |
| September | 160.5                               | 76.28                                | 25.17                   | 1.2               | 162.6                                | 77.00                                 | 0.268                                 |
| October   | 155.3                               | 83.93                                | 25.78                   | 1.2               | 152.2                                | 84.89                                 | 0.259                                 |
| November  | 172.6                               | 87.24                                | 25.13                   | 1.2               | 164.0                                | 84.90                                 | 0.290                                 |
| December  | 132.4                               | 87.00                                | 24.95                   | 1.4               | 125.4                                | 84.20                                 | 0.221                                 |
| Average   | 1731.3                              | 908.64                               | 25.15                   | 1.3               | 1753.6                               | 913.57                                | 2.890                                 |
Then, the load profile in Building K FTUI from Monday, March 11, 2019, to March 18, 2019, (during semester course activities) is shown in Figure 2. In this research, the maximum value load every hour in weekday and weekend are used based on PVsyst software needs [9]. The purpose is to make weekly energy need modulation per month for K Building FTUI for PVsyst Software which result is 411 MWh/year with.

![Figure 2. Load Profile on Building K FTUI](image)

Then the On-Grid PV System is proposed in this research. The Type of PV module is Canadian Solar which Si Poly and 300 W capacity [10]. Total PV module on this research is 220 modules with 66 kW output energy based on area availability 366 m² from 382.04 m². The collector position is Tilt 10.5° and Azimuth 0° based on Optimization Orientation Tool PVsyst which use climate data before. ABB Inverter is used in this project which total inverter 20 units the total Power of kW 60 AC and the nominal power of 3 kW AC [11]. Its Operating Voltage is about 335-500 V.

3. Simulation Result

International energy agency (IEA) performance parameters are used for analyzing the On-Grid PV System performances [12]. The main simulation results have been shown in Table 2 from PVsyst. The parameters contain such an irradiance value captured by the PV Module and the irradiance value captured by the PV Module after being exposed to a loss. In addition, the energy produced by the PV system, energy supplied to the grid with losses - losses, and the efficiency of the PV system is also simulated. The value calculated from each variable mentioned earlier results are obtained in terms of monthly and annual values. The annual value of the variable is possible as a mean for temperature, efficiency, and addition for radiation and energy.

If seen, such as the irradiance value captured by the PV Module and the irradiance value captured by the PV Module after the losses respectively are 1753.6 kWh / m² and 1675.6 kWh / m². Then, the annual energy generated from the PLTS Module is 97,889 MWh in a year and the Energy required by Building K is 411,402 MWh in a year. So that it can be concluded that 23.79% of the load on Building K is energized by the PV system with the energy injected to the grid is 24,732 MWh in a year. Detailed, the largest energy injected to grid occurred in September, which is 3200 kWh. Meanwhile, the lowest is 1156 kWh which occurred in January.

The PVsyst simulation obtained maximum hourly inverter power values generated by proposed On-Grid PV system which is being merged with load profile each maximum weekend and weekday to know detailed PV system power flow. For Grid Connected PV system proposed design, the maximum and minimum output power values are 35,618 kW and 0.847 kW. Electricity savings at maximum weekday and weekend each day are 10.14% and 39.468% of the 24-hour consumption. For power supplied to the grid, the power given at the maximum value of weekday and weekend each day is 0 kW or none and 13,160 kW. Detailed PV system power flow is shown in Figure 3. To fulfil K Building FTUI needs between load and PV system power generation, power from the grid is used.
Table 2. Main Result from PVsyst

| Month     | Irradiance Value Captured by the PV Module (With Losses) kWh/m² | Irradiance Value Captured by the PV Module (With Losses) kWh/m² | Building Energy Needed kWh | The energy produced by PV System kWh | Energy from Grid kWh | PV System Energy Supplied to The Load kWh | Energy Injected to the Grid kWh |
|-----------|---------------------------------------------------------------|---------------------------------------------------------------|----------------------------|--------------------------------------|----------------------|------------------------------------------|--------------------------------|
| January   | 100.9                                                         | 95.8                                                         | 36119                      | 5613                                 | 31848                | 4271                                     | 1156                           |
| February  | 107.1                                                         | 101.9                                                       | 31529                      | 6007                                 | 27327                | 4202                                     | 1615                           |
| March     | 140.3                                                         | 134                                                         | 34705                      | 7817                                 | 29006                | 5598                                     | 1879                           |
| April     | 151.6                                                         | 145                                                         | 33175                      | 8456                                 | 27983                | 6992                                     | 2111                           |
| May       | 159.5                                                         | 152.5                                                       | 36119                      | 8900                                 | 29701                | 6418                                     | 2220                           |
| June      | 155                                                           | 148.6                                                       | 33175                      | 8676                                 | 27013                | 6162                                     | 2255                           |
| July      | 159.5                                                         | 152.9                                                       | 34705                      | 8940                                 | 28475                | 6229                                     | 2445                           |
| August    | 175.5                                                         | 168.3                                                       | 36119                      | 9801                                 | 28741                | 7377                                     | 2133                           |
| September | 162.6                                                         | 155.6                                                       | 31761                      | 9050                                 | 26180                | 5581                                     | 3200                           |
| October   | 152.2                                                         | 145.3                                                       | 36119                      | 8445                                 | 29993                | 6126                                     | 2067                           |
| November  | 164                                                           | 156.5                                                       | 34589                      | 9154                                 | 27430                | 7159                                     | 1727                           |
| December  | 125.4                                                         | 119.2                                                       | 33291                      | 7029                                 | 28401                | 4890                                     | 1925                           |
| Total     | 1753.6                                                        | 1675.6                                                      | 411402                     | 97889                                | 341198               | 70205                                    | 24732                          |

Figure 3. (a) PV system power flow on maximum weekday; (b) system power flow on maximum weekend

The performance ratio (PR) are simulated which is shown in Figure 4. The annual average PR value is 82.00%. In a theory, the closer the Performance ratio (PR) value is closer to 100%, the more efficient each PV system will operate. In real life, a value of 100% cannot be achieved, because the inevitable losses always arise with the operation of it.
4. Conclusion
Based on the results and analysis of 60 kW On-Grid PV System in Building K FTUI, the following conclusions were obtained. The On-Grid PV System has been designed with a capacity of 66 kW which produces a performance ratio of 82%. The annual energy produced from the PV Module is 97,889 MWh in a year and the energy required by Building K is 411,402 MWh in a year. From that, it can be concluded that 23.79% of the load on Building K is contributed by the PV system.

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