Design and Analysis Performance Solar Power Plant 15 kW
By Maximizing Final Yield and Performance Ratio
In Small-Medium Office

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Abstract. The 15 kW solar power plant (PLTS) is a new certain in the application of small-
medium solar energy usage, especially for the campus environment in Indonesia which can
support and become proof of realization green campus program. The existence of 15 kW PLTS
become an attention to do advanced analysis in order that production of the specific electric
energy or final yield ($Y_f$) and performance ratio (PR) from a PLTS can be monitored based on
installation location. The value of $Y_f$ and PR can be used as reference to do identification, trouble
operation analysis, and developing of a PLTS. The optimum value of $Y_f$ and PR on the 15 kW
PLTS resulted by doing simulation from a simulator software, which the value resulted from
location and configuration of the system installation without watch shading factor. And then the
simulation value compared with electric energy real production resulted on this 15 kW PLTS. The
15 kW PLTS divided be two lines, that are 5 kW and 10 kW line. From simulation result, showed
that in the 5 kW line have value of optimum production is $5264.8$ kWh with PR $83.1\%$ and in the
10 kW line have value of optimum production is $7687.2$ kWh with PR $83.12\%$. Real production
in line 5 kW is $1326.9$ kWh with difference $74.79\%$ with simulation and in line 10 kW is $1643.3$
kWh with difference $78.62\%$ with simulation. The shading and existing disturbances resulted in
a decrease in electrical energy production and performance in the line 5 kW is $Y_f$ 0.91 hours/day
with CF $2.79\%$ and in the line 10 kW is $Y_f$ 3.07 hours/day with CF $11.73\%$.

1. Introduction

The development of technology will increasingly encourage the increase in meeting the needs of
electrical energy to support the performance of a technology. In Indonesia itself has a 35,000 MW
electricity infrastructure development acceleration program (Kementerian ESDM, 2020) which must be
fulfilled immediately in order to support the pace of technological development. One way to meet these
targets is by building power plants using Renewable Energy (EBT), ranging from biofuel energy,
biomass energy, geothermal energy, water energy, wind energy, ocean wave energy and solar energy are
types of energy which can be updated. One of the most potential types of energy to be applied in
Indonesia is the type of solar energy [1].

Utilization of solar energy to meet the needs of electrical energy is often referred to as Solar Power
Generation (PLTS). Indonesia itself has a geographical location on the equator that makes it one of the
countries that is very suitable to establish a PLTS to meet an electrical energy needs. Many regions in
Indonesia are suitable for a PLTS, starting from a small to large scale PLTS. The scale starts from houses,
buildings and terrain that spreads throughout Indonesia [2]. To convert sunlight energy into electrical energy, a device that is often called a Solar Panel is needed.

Solar Panel itself is a component that can be used to convert sunlight energy into electrical energy using a principle called the photovoltaic effect. The photovoltaic effect itself is a phenomenon where an electric voltage arises because of a connection or contact of two electrodes, both of which are connected to a solid or liquid system when getting light energy [3]. For this reason, solar panels are often called photovoltaic (PV) cells. Solar panels themselves can be applied to meet a variety of needs with permanent and portable installation installations. The application of solar panels to meet the needs of permanent installations, for example, for making small and large scale solar power plants. Meanwhile, to meet the needs of the installation of a portable installation for example, namely as a source of power in electric vehicles, solar water pumps and others [4]. The application of solar panels to meet the needs of the permanent installation is an example of the PLTS at the Faculty of Engineering, Sebelas Maret University Surakarta (UNS) with 15 kW capacity.

PLTS in the Faculty of Engineering UNS itself is divided into two lanes, namely the 10 KW line which is installed in the parking area of the Faculty of Engineering UNS and the 5 KW line which is installed in the hallway near Building 3 of the Faculty of Engineering UNS. The installation of PLTS is also a form of support for realizing UNS as a green campus in Indonesia. But over time, the installation of PLTS at the UNS Faculty of Engineering has not had a real impact on meeting the electricity needs of the Faculty of Engineering, both when it is in the peak load phase and when it experiences a power failure. The PLTS has not been able to provide temporary supplies to overcome these conditions. Therefore, a further analysis is needed to determine the potential for electricity production, performance and obstacles faced in the operation of the PLTS in a certain period. The analysis is carried out by doing a simulation which is then compared with the real conditions.

In simulating the PLTS system, it can be done using the PVSyst software, where the parameters can be adjusted according to the system that has been installed and the system to be built. The results of this simulation will then be compared with the real conditions in order to know the real production of electrical energy, performance and constraints that exist in the PLTS system.

2. Theory

2.1 Solar Power Plant (PLTS)

PLTS is a power plant that converts sunlight energy into electrical energy through the process of energy conversion from a solar cell (photovoltaic). Solar cells contain thin layers made of pure silicon (Si) semiconductor material or other semiconductor materials which are then arranged into a unit that can be called a solar cell module. How solar cells work can be seen in Figure 1 below [5].

![Figure 1. Solar Cell Working System](image)

PLTS utilizes the energy of sunlight to produce DC electrical energy (can be converted into AC electrical energy if needed). In general, PLTS consists of several main components, namely solar cell
generators which are solar module arrays in a buffer system, inverters used to convert DC electricity into AC electricity in either single phase or three phase systems for large capacities, charge controllers used as a control system or monitoring PLTS operation, and also the battery used for storage.

Based on the location of installation, the PV-VP system is divided into two types of patterns namely the distributed PV system and the centralized PV plant. Meanwhile, based on the application and its configuration, it can be classified into two, namely the PV-system not connected network (off-grid PV plant) or standalone and the PV-connected PV plant system. If in its use, a PLTS system is combined with other types of power plants, it can be said as a hybrid system.

Some of the main factors that can affect variations in the production of electrical energy in solar power plants are the value of solar irradiation, temperature of solar modules, and shading in an operating time. The value of Irradiation will affect the value of the electric current generated by a solar power plant, the value of a module temperature will affect the value of the voltage generated by a solar power plant, while the value of the shading will affect the value of solar irradiation received by solar modules in the generation process which will indirectly affect the performance of a PLTS.

The performance or performance of a PLTS when viewed from the kWh meter itself is very easy to report, but when it is intended as an equal comparability between plants, it is not that simple. The first thing to consider is the climate of the sun, which values will differ from one location to another and weather data cannot always be estimated in more detail. Furthermore, the installed real energy is generally not precisely known due to the effects of unknown shading, overheating and network availability. However, the standard of evaluation for the performance or performance of PV-VPs differs from those that have been developed over time, and the most commonly used in general is to determine the energy output of a PV-VP during an annual or monthly period based on the following [7]:

1. Performance details in net kWh (net kWh) sent to the network per kW from the nominal power of the installed solar module is equal to the equivalent value of the total load for the plant.
2. The capacity factor is obtained as a result of the full load hour equation in% of the previous time.
3. Monthly and annual performance ratios are described as the actual amount of solar energy to the network in a period divided by the theoretical amount according to STC data from the solar module.

2.2 Analysis Performance PLTS

2.2.1 Final Yield \( (Y_F) \)

The final yield \( (Y_F) \) can be interpreted as a net output (net kWh) of AC energy in a system divided by the peak power value in a PV array that is installed with the provisions of the standard test conditions (STC) on solar irradiation \( 1000 \text{ W/m}^2 \) and \( 25^\circ \text{C} \) cell temperature or can be formulated as follows [8]:

\[
Y_F = \frac{E_{PV} \text{ kWh} \text{ AC} / \text{ kWp}_{\text{DC}}}{P_0} \tag{1}
\]

Note:
\( Y_F = \text{final yield} \)
\( P_0 = \text{peak power [kWpDC]} \)
\( E_{PV} = \text{energy to the network [kWhAC]} \)

2.2.2 Reference Yield \( (Y_R) \)

The reference yield \( (Y_R) \) is a total of solar insulation in a field \( (H_T) \) in units \( \text{kWh/m}^2 \) which is divided by the irradiation of the reference array \( (1 \text{ kW/m}^2) \), then the \( (Y_R) \) can be interpreted as the sum of peak sun-hours or can be formulated as follows [8]:

\[
Y_R = \frac{H_T}{G_{\text{STC}}} (\text{kWh/m}^2/\text{kWp}) \tag{2}
\]

Note:
\( Y_R = \text{reference yield} \)
H_T = irradiation in the array field [kWh/m^2]
G_STC = reference irradiation STC [

2.2.3 Performance Ratio (PR)

Performance ratio (PR) can be interpreted as a ratio that shows the total loss in a PLTS system quality when converting from DC to AC output, which can be formulated as follows [9]:

\[ \text{PR} = \frac{Y_F}{Y_R} \]  \hspace{1cm} (3)

Note:

PR = performance ratio
Y_F = final yield
Y_R = reference yield

2.2.4 Capacity Factor (CF)

The capacity factor (CF) in a solar power plant can be interpreted as a ratio of actual energy output in a one-year period provided that it operates on nominal power for a full year (24 hours a day for a year) on its output or can be formulated as follows [10]:

\[ \text{CF} = \frac{Y_F}{8760} \]  \hspace{1cm} (4)

2.3 PVsyst

Figure 2. PVsyst Software Logo [17]

PVsyst is a software package used for the learning process, measurement (sizing), and data analysis of the complete PV mini-grid system. PVsyst was developed by the University of Geneva, which is divided into grid-connected systems, stand-alone systems, pump systems, and direct-current networks for public transportation (DC-grid). PVsyst is also equipped with a database of extensive and varied meteorological data sources, as well as PV-VP component data. Some examples of meteorological data sources that can be used on this PVsyst are from MeteoNorm V 6.1 (interpolated 1960-1990 or 1981-2000), NASA-SSE (1983-2005), PVGIS (for Europe and Africa), Satel-Light (for Europe), TMY2 / 3 and SolarAnywhere (for USA), EPW (for Canada), RetScreen, Helioclim, and SolarGIS (paid)

3. Research Method

3.1 Tools and Materials

In this research, some software is run on the laptop with the following specifications:

Operating System : Windows 7 Pro 64-bit
Processor : Intel (R) Core (TM) i3-7 @ 1.8GHz
Memory : 6 GB
VGA : NVIDIA GeForce
VGA Memory : 2GB

Then the software used to carry out this research is as follows:
1. Browser Google Chrome
2. PVsyst Versi 6.7.0
3. Microsoft Word
4. Microsoft Excel
3.2 Research Steps

The research methodology is a problem solving framework by processing and analyzing data. In general, the research methodology is structured to achieve the stated research objectives, then the entire research activity is designed to follow the flow chart as shown in Figure 2.

![Flowchart Simulation](image)

**Figure 3.** Flowchart Simulation

3.3 System Modelling

3.3.1 Location Coordinate

Geographically the 15 kW PLTS Faculty of Engineering UNS is located at coordinates -7.561328 South Latitude and 110.854319 East longitude with a height of ± 93 m above sea level can be seen in the following figure.

![Location of PLTS Faculty of Engineering UNS](image)

**Figure 4.** Location of PLTS Faculty of Engineering UNS

3.3.2 Modelling Solar Power Plant System

System modeling is carried out in accordance with the installed PV system specifications. The modeling step starts from filling in the location coordinates as in Figure 3.2, then selecting the type of...
installation of the PV system as in Figure 3.3, and filling in the component parameters according to the specifications as in Figure 3.4.

Figure 5. Input Location Coordinate

Figure 6. Choose Type Installation

Figure 7. Input Component Parameter

4. Results and Discussion

After the design and parameter filling, then run on the menu in the PVsyst application. Based on these treatments the following results were obtained:

4.1 Desain The Line of Solar Power Plant

4.1.1 Line 5 kW

Figure 8. Block Diagram Line 5 kW Of Solar Power Plant

Figure 8 shows a series of component installations in the PLTS system for a 5 kW line, where the system uses a monocrystalline 100 Wp Solarimba brand solar module with a total of 40 units installed in series-parallel. Each of the eight solar modules are arranged in series into one series and
then combined into a series of parallel strings connected to an inverter with a total capacity of 5.5 kW. The end of the system circuit is connected to the PLN grid system.

4.1.2 Line 10 kW

Figure 9. Block Diagram Line 10 kW Of Solar Power Plant

Figure 9 shows a series of component installations in the PLTS system for a 10 kW line, where the system uses a Canadian Solar 330 Wp polycrystalline type solar module with 16 units installed in series-parallel. Each of the four solar modules are arranged in series into one series then each of the two series is connected to one parallel series of strings connected to an inverter with a total capacity of 5.5 kW. Where the 10 kW line has two inverters and the end of the system circuit is connected to the PLN grid system

4.2 PVsyst Simulation

4.2.1 Line 5 kW

Based on the simulations that have been carried out, it can be obtained that the data on the 5 kW line has the optimum potential in producing electrical energy, which is 5264.8 kWh per year, with details as in table 1 and a performance ratio of 81.4% as in table 2 provided that no there is shading on the attached location.

Table 1. Optimum Potential of Electrical Energy Production on a 5 kW Line

| Month    | GloHor kWh/m² | DiffHor kWh/m² | T Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | E Load kWh | E User kWh | E Grid kWh |
|----------|---------------|----------------|----------|----------------|----------------|------------|------------|-----------|
| January  | 128.2         | 75.92          | 27.20    | 144.2          | 109.5          | 155.7      | 50.83      | 322.8     |
| February | 120.2         | 73.68          | 26.93    | 112.0          | 87.8           | 140.7      | 42.94      | 323.8     |
| March    | 143.4         | 81.62          | 27.38    | 141.0          | 136.3          | 155.7      | 51.84      | 407.1     |
| April    | 144.5         | 75.35          | 27.69    | 151.1          | 146.5          | 150.7      | 53.49      | 438.0     |
| May      | 159.1         | 71.50          | 28.30    | 178.8          | 173.9          | 155.7      | 58.96      | 522.7     |
| June     | 150.6         | 58.69          | 27.53    | 175.6          | 171.0          | 150.7      | 57.95      | 514.8     |
| July     | 162.5         | 66.38          | 27.55    | 186.9          | 182.0          | 155.7      | 58.11      | 551.4     |
| August   | 165.4         | 73.58          | 27.71    | 197.5          | 194.5          | 155.7      | 57.95      | 524.8     |
| September| 170.0         | 73.30          | 27.93    | 171.9          | 166.8          | 150.7      | 51.11      | 495.6     |
| October  | 170.5         | 89.84          | 28.57    | 161.9          | 156.4          | 155.7      | 60.25      | 463.3     |
| November | 136.9         | 87.29          | 27.79    | 123.8          | 118.9          | 150.7      | 56.49      | 349.8     |
| December | 139.3         | 89.32          | 27.45    | 122.9          | 117.7          | 155.7      | 54.01      | 350.5     |
| Year     | 1790.4        | 916.47         | 27.68    | 1819.7         | 1761.4         | 1833.8     | 660.97     | 5264.8    |

Table 2. Normal Performance Coefficient on the Line 5 kW

| Month       | Vc kWh/m²/day | Le kWh/Wp/d | Le kWh/Wp/d | Lf kWh/Wp/d | Lcr | Lsr | PR  |
|-------------|---------------|-------------|-------------|-------------|-----|-----|-----|
| January     | 3.68          | 0.632       | 3.05        | 0.038       | 3.01| 0.172| 0.010| 0.818|
| February    | 4.00          | 0.686       | 3.31        | 0.038       | 3.27| 0.172| 0.009| 0.819|
| March       | 4.55          | 0.811       | 3.74        | 0.038       | 3.70| 0.178| 0.008| 0.813|
| April       | 5.04          | 0.905       | 4.13        | 0.037       | 4.10| 0.180| 0.007| 0.813|
The PV grid production chart with a period of one year on the 5 kW line can be seen in Figure 10 and the flow chart of PLTS losses on the 5 kW line can be seen in Figure 11.

### 4.2.2 Line 10 kW

Based on the simulations that have been carried out, it can be obtained that the data on the 10 kW line has the optimum potential in producing electrical energy, which is 7687.2 kWh per year with details as in table 3 and a performance ratio of 83.0% as in table 4 with the provision that there is shading on the attached location.

#### Table 3. Optimum Potential of Electrical Energy Production on a 10 kW Line

| Month    | GlobHor kWh/m² | DiffHor kWh/m² | T Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | E Load kWh | E User kWh | E Grid kWh |
|----------|----------------|----------------|----------|----------------|----------------|------------|------------|------------|
| January  | 128,3          | 75,89          | 27,20    | 144,5          | 111,0          | 62,74      | 24,64      | 480,9      |
| February | 120,2          | 73,67          | 26,93    | 112,2          | 109,0          | 56,67      | 21,43      | 474,0      |
| March    | 143,3          | 81,64          | 27,38    | 141,1          | 137,6          | 62,74      | 24,17      | 594,9      |
| April    | 144,4          | 75,39          | 27,69    | 151,1          | 147,6          | 60,72      | 23,78      | 637,9      |
| May      | 159,0          | 71,57          | 28,30    | 178,8          | 175,0          | 62,74      | 24,80      | 756,4      |
| June     | 150,6          | 58,69          | 27,53    | 175,4          | 172,1          | 60,72      | 24,33      | 745,3      |
| July     | 162,4          | 66,49          | 27,55    | 186,7          | 183,0          | 62,74      | 25,12      | 793,3      |
| August   | 165,7          | 73,43          | 27,71    | 179,8          | 176,1          | 62,74      | 25,13      | 760,1      |
| September| 169,9          | 73,37          | 27,93    | 171,9          | 168,2          | 60,72      | 24,33      | 722,3      |
| October  | 170,4          | 89,92          | 28,57    | 162,0          | 158,0          | 62,74      | 25,71      | 680,0      |
| November | 136,7          | 87,30          | 27,79    | 124,0          | 120,3          | 60,72      | 25,39      | 522,0      |
| December | 139,2          | 89,33          | 27,45    | 123,2          | 119,2          | 62,74      | 25,09      | 520,1      |
| Year     | 1790,2         | 916,69         | 27,68    | 1820,4         | 1777,2         | 738,76     | 293,93     | 7687,2     |

#### Table 4. Normal Performance Coefficient on the Line 10 kW

| Month    | Y_c kWh/m²/day | L_c kWh/kWp/d | Y_s kWh/kWp/d | L_s kWh/kWp/d | L_cr | L_sr | PR   |
|----------|----------------|---------------|---------------|---------------|------|------|------|
| January  | 3,69           | 0,573         | 3,12          | 0,033         | 3,09 | 0,155| 0,009| 0,836|
| February | 4,01           | 0,621         | 3,39          | 0,034         | 3,35 | 0,155| 0,009| 0,836|
| March    | 4,55           | 0,734         | 3,82          | 0,037         | 3,78 | 0,161| 0,008| 0,831|
| Month    | PVsyst E Grid (kWh) | Real E Grid (kWh) | Difference E Grid (kWh) | Difference in % |
|----------|---------------------|-------------------|-------------------------|----------------|
| January  | 322,800             | 91,140            | 231,660                 | 71.76          |
| February | 323,800             | 89,088            | 234,712                 | 72.48          |
| March    | 407,100             | 104,160           | 302,940                 | 74.41          |
| April    | 438,000             | 136,800           | 301,200                 | 72.48          |
| May      | 522,700             | 111,600           | 411,100                 | 78.64          |
| June     | 514,800             | 122,760           | 392,040                 | 76.15          |
| July     | 551,400             | 123,504           | 427,896                 | 77.60          |
| August   | 524,800             | 122,760           | 402,040                 | 76.60          |
| September| 495,600             | 119,520           | 376,080                 | 75.88          |
| October  | 463,300             | 102,300           | 361,000                 | 77.91          |
| November | 349,800             | 104,400           | 245,400                 | 70.15          |
| December | 350,500             | 98,952            | 251,548                 | 71.76          |
| Total Production | 5,264,8 | 1,326,9 | 3,937,816 | 74.79 |

The performance of the PLTS system installed on the 5 kW line will also be affected due to the decrease in electrical energy production. The system has a specific performance value of 0.91
hours / day, which is lower than the simulation results of 4.06 hours / day. In addition, the capacity factor of the system in producing actual energy for a full day (24 hours) has a value of 3.79% which is lower than the simulation results. Details of specific performance and capacity factors on the 5 kW line can be seen in Table 6.

### Table 6. Specific Performance and Capacity Factors on the 5 kW Line

| Month   | PVsyst E Grid (kWh) | Real E Grid (kWh) | \(Y_P\) (P) (h/d) | \(Y_P\) (R) (h/d) | CF (P) (%) | CF (R) (%) |
|---------|--------------------|-------------------|------------------|------------------|------------|------------|
| January | 322,800            | 91,140            | 3.01             | 0.73             | 12.54      | 3.06       |
| February| 323,800            | 89,088            | 3.27             | 0.78             | 13.63      | 3.19       |
| March   | 407,100            | 104,160           | 3.70             | 0.83             | 15.42      | 3.49       |
| April   | 438,000            | 136,800           | 4.10             | 1.14             | 17.08      | 4.75       |
| May     | 522,700            | 111,600           | 4.69             | 0.93             | 19.54      | 3.87       |
| June    | 514,800            | 122,760           | 4.77             | 1.02             | 19.88      | 4.26       |
| July    | 551,400            | 123,504           | 4.92             | 0.99             | 20.50      | 4.15       |
| August  | 524,800            | 122,760           | 4.70             | 0.98             | 19.58      | 4.12       |
| September| 495,600           | 119,520           | 4.61             | 0.99             | 19.21      | 4.15       |
| October | 463,300            | 102,300           | 4.22             | 0.82             | 17.58      | 3.43       |
| November| 349,800            | 104,400           | 3.39             | 0.87             | 14.13      | 3.62       |
| December| 350,500            | 98,952            | 3.26             | 0.79             | 13.58      | 3.32       |
| Total Production | 5,264,8  | 1,326,9          | 4.06             | 0.91             | 16.89      | 3.79       |

4.3.2 Line 10 kW

The comparison between the simulation results using PVSyst and the real conditions can be analyzed that the real production of electrical energy within a year on the 10 kW line from the installed PLTS system has a difference of 78.62% lower than the simulation results. The results obtained from the simulation results show a value of 7,687,200 kWh while the real production of electrical energy is 1,643,305kWh. Details of the comparison of electrical energy production on the 10 kW line can be seen in Table 7.

### Table 7. Comparison of Electrical Energy Production on a 10 kW Line

| Month   | PVsyst E Grid (kWh) | Real E Grid (kWh) | Difference E Grid (kWh) | % |
|---------|--------------------|-------------------|-------------------------|---|
| January | 480,900            | 113,430           | 367,470                 | 76.41       |
| February| 474,000            | 101,059           | 372,941                 | 78.67       |
| March   | 594,900            | 103,118           | 491,782                 | 82.66       |
| April   | 637,900            | 161,368           | 476,332                 | 74.67       |
| May     | 756,400            | 176,299           | 580,101                 | 76.69       |
| June    | 745,300            | 184,377           | 560,922                 | 75.26       |
| July    | 793,300            | 152,222           | 641,078                 | 80.81       |
| August  | 760,100            | 157,132           | 602,968                 | 79.32       |
| September| 722,300           | 147,312           | 574,988                 | 79.60       |
| October | 680,000            | 122,760           | 557,240                 | 81.94       |
| November| 522,000            | 114,523           | 407,477                 | 78.06       |
| December| 520,100            | 109,501           | 410,598                 | 78.94       |
| Total Production | 7,687,200 | 1,643,305         | 6,043,895               | 78.62       |

The performance of the PLTS system installed on the 10 kW line will also be affected due to the decrease in electrical energy production. The system has a specific performance value of 3.07 hours / day, which is lower than the simulation results of 4.71 hours / day. In addition, the capacity factor of the system in producing actual energy for a full day (24 hours) has a value of 11.73% which is lower than the simulation results. Details of specific performance and capacity factors on the 10 kW line can be seen in Table 8.

### Table 8. Specific Performance and Capacity Factors on the 10 kW Line

| Month   | PVsyst E Grid (kWh) | Real E Grid (kWh) | \(Y_P\) (P) (h/d) | \(Y_P\) (R) (h/d) | CF (P) (%) | CF (R) (%) |
|---------|--------------------|-------------------|------------------|------------------|------------|------------|
| January | 480,900            | 113,430           | 3.09             | 2.29             | 12.87      | 9.52       |
4.3.3 Analysis Performance

The production of electrical energy that is not optimal in this system is caused by several things, namely differences in irradiation climates, low solar irradiation values received by the PLTS system due to shading, dust and lack of periodic maintenance. This has an impact on decreasing the specific performance value within one year, which is 0.91 hours per day with a capacity factor of 3.79% for the 5 kW line and by 3.07 hours per day with a capacity factor of 11.73% for 10 kW line. The shading in the PLTS system causes the sun's rays to fall, either because of shadows from buildings or trees and dust sticking to the solar module. This condition can be seen in Figure 14 and Figure 15 below.

![Figure 14. Real Condition in Line 5 kW](image1)

![Figure 15. Real Condition in Line 10 kW](image2)

5. Conclusions

Based on the results and discussion, conclusions can be drawn, namely:

1. 15 kW PLTS Faculty of Engineering UNS has the optimal potential to produce electrical energy for one year on the 5 kW line of 5264.8 kWh with a performance ratio of 81.4% and on the 10 kW line of 7687.2 kWh with a performance ratio of 83.0% with notes without taking the shading factor.
2. The production of 15 kW PLTS electrical energy at the Faculty of Engineering UNS during a period of one year is smaller than the optimum potential for electrical energy production from the simulation results, which is 1,326.9 kWh with a difference of 74.79% to the simulation results of 5,264.8 kWh in 5 kW line and 1,643,305 kWh with a difference of 78.62% of the simulation results worth 7,687,200 kWh on the 10 kW line.
3. The non-optimum production of electrical energy is caused by several things, namely differences in irradiation climates, low solar irradiation values received by the PLTS system due to shading, presence of dust and lack of regular maintenance. This has an impact on decreasing the specific performance value within one year, which is 0.91 hours per day with a capacity factor of 3.79% for the 5 kW line and by 3.07 hours per day with a capacity factor of 11.73% for 10 kW line.

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