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# Analysis of Shadow Effect on Solar PV Plant using Helioscope Simulation Technology in Palipi Village

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**Abstrak**

This research discusses the study of renewable energy potential in Palipi village, North Sumatra Province, renewable energy is an option in overcoming the problem of irrigating rice fields in Palipi village in the summer. The use of pumps in irrigation in Palipi Village, North Sumatra province for six hours requires 138,564 watts of electrical energy per day. Solar potential is the most feasible as an option in renewable energy development, through solar power plants. The research method uses a simulation of solar energy potential by determining the number of solar panels used in the electricity generation process. HelioScope was used as an assistive technology tool to find the maximum utilisation of the available space, the influence of shadows on solar panels was also taken into account for the feasibility study conducted. The total electrical energy obtained through PLTS generation in Palipi village is 10,345.5 kWh/year, with the largest loss of 13% influenced by temperature, while the shadow effect contributes to a loss of 0.9% due to the shadow factor of 1 building and an electricity tower pole at the location of the solar panel.

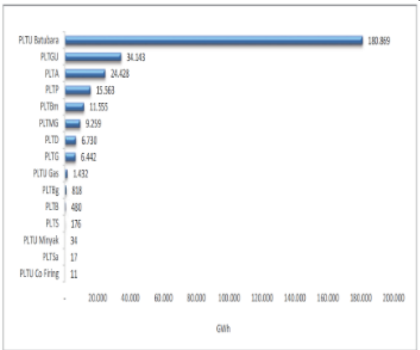
***Keyword: Solar energy, Energy potential, HelioScope, Shadow Effect***

## INTRODUCTION

Palipi is one of the villages on the island of Samosir, North Sumatra. Most of the population in Palipi village are farmers with 115 ha of agricultural land. The main problem of farmers in Palipi village is the frequent crop failure due to water shortage. The Samosir district government has built irrigation which is a form of support in increasing agricultural productivity. The problem of farmers' irrigation needs is solved by the technology of water pumps with solar electric energy. It is also expected to introduce the latest energy to farmers so that it can provide insight that farmers are able to produce electrical energy independently and are more environmentally friendly.[1]. How much solar power generation is needed to supply electrical energy to irrigation pumps is the question that is the topic of this research.

HelioScope technology, an application is a programme developed by Folsom Lab [2] It is presented to assist the designer in arranging the photovoltaics, mapping the location of the area, arranging the layout of the solar panels as well as the details of the modules with the complete inverter. HelioScope simulation technology is used as a tool in assessing the potential of Solar PV Plant. This potential is supported by the climate in Indonesia, which is in the equatorial zone, which has excellent sunlight potential that can be utilised for Solar PV Plant. It is recorded that the potential for solar radiation in Indonesia averages 4.8 kWh/m2/day. The value of 4.8 kWh/m2/day, known as insolation, is equivalent to 207,898 MW of solar energy.[3]

The utilization of 18.2% renewable energy sources is still low compared to coal power plants. Electricity production on grid and off grid in 2020 reached 292.0 TWh which came from the State Electricity Company (PLN) and non-PLN plants. About 62.0% of electricity production came from coal-fired power plants, 18.2% from renewable energy, 17.6% from gas, and only 2.3% from oil.[4]. An overview of electricity production by plant type is shown in Figure 1.




Sumber: HEESI, 2020

**Figure 1. Electricity Production by Type of Generator**

The realisation of new renewable energy (EBT) power generation capacity until the end of 2020 reached 10,467 megawatts (MW). The upward trend in EBT generating capacity is still continuing considering that in 2019 the realisation of installed capacity was 10,291 MW. Additional EBT power generation capacity in 2020 comes from a number of projects [5].

Indonesia's solar power potential is generally at a sufficient level, so it can be used as a guideline in planning the development of PLTS energy sources in the future. Based on the potential map, the greatest solar intensity is found in the northern coastal region of Banten, the southern coast of West Java, the northern region of Central Java, Nusa Tenggara and Papua. However, technically and theoretically, the areas with the greatest potential are found in West Kalimantan, South Sumatra, East Kalimantan and North Sumatra, but in general the potential in each province is relatively high. Specifically for the province of North Sumatra is ranked 4th out of 34 provinces. The potential of solar power plants of 11,851 MW is a consideration in the development of power plants, but this potential has not been optimally utilised. At present, the utilisation of renewable energy, especially solar power, is relatively low, as seen from the data reported by the National Energy Council evaluation report [6], as shown in table 1.

**Table 1. Electricity Production of On-Grid and Off-Grid Solar Power Plants**

(GWh)

| Tahun | *On Grid* | *Off Grid* | Total |
|---|---|---|---|
| 2015 | 5,3 | n.a | 5,3 |
| 2016 | 21,1 | n.a | 21,1 |
| 2017 | 29,1 | n.a | 29,1 |
| 2018 | 19,3 | 70,5 | 89,8 |
| 2019 | 54,3 | 63,6 | 117,9 |
| 2020 | 126,0 | 49,5 | 175,5 |

Sumber: HEESI, 2020

The low utilisation of solar power is influenced by several factors, mainly related to the intermittent nature of PLTS. PLTS has special characteristics compared to other power plants, namely first, intermittent nature characterised by frequency and voltage always changing and the amount of system frequency depends on solar radiation conditions.[7]. The amount of PLTS output power depends on solar radiation and the system frequency depends on the PLTS output power. The second property of PLTS is non-dispatchable, meaning that the amount of power capable cannot be regulated and planned so that the installed capacity cannot be a benchmark. its excellent prospects, it needs to be developed in an effort to support the development of PLTS[8].

The development of solar power plants by utilising solar energy in 2022 is a commitment of the government of the Republic of Indonesia through the Ministry of Energy and Mineral Resources (ESDM) to organise the Indonesia Solar Summit and is committed to encouraging solar power plants to be further developed both at the central government, local governments, BUMN, private developers and even to all electricity consumers through regulation number 180.Pers/04 / SJI / 2022. The rules and requirements for the installation of solar power plants are also based on the requirements in the IEC62548 standard which is the Installation and Safety requirements of PV Arrays. The National Electrical Code (NEC) specifies a maximum current for strings, sub-arrays and arrays of 1.25 times the short-circuit current of the strings, sub-arrays and arrays. For protection and isolation devices the NEC has a required safety margin of 1.25 (125%), thus having an effective overall oversize of 156% (1.56 times) the relevant short-circuit current. [9].

The main components of the on-grid PLTS system as a power generation unit are shown in Figure 2.

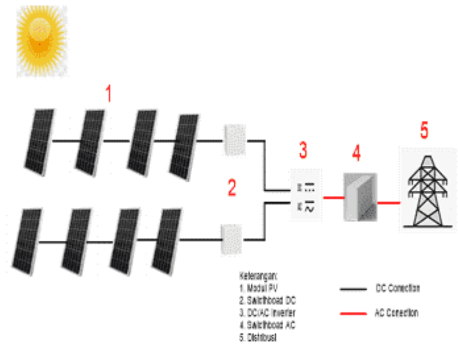



**Figure 2. PLTS on Grid System**

The main components in the PV system design, based on the block diagram in figure 2, are described in figure 3.

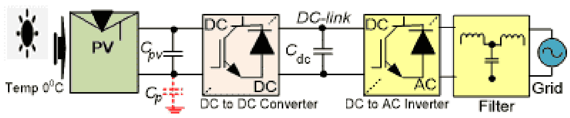



**Figure 3. Block diagram of on-grid solar power plant**

Figure 3 shows the principle of PLTS, solar panels absorb radiant energy from sunlight and produce DC electrical energy, then the solar inverter plays a role in converting DC electrical energy. to optimise the life and efficiency of the accumulator, a good accumulator charging method is needed. the output voltage of the solar cell changes according to environmental conditions, especially sunlight. the role of the dc to dc converter in the block diagram is as an automatic accumulator charger system for solar cell energy. providing stable energy, the system requires an accumulator.[10]. DC to AC converter through an inverter that is to be connected to the power grid or usage (load) that requires an AC source.

Analysis of Inverter Load Ratio (ILR) calculation which is determined by the DC capacity represented by the PV array against the AC capacity represented by the installed inverter, written by equation 1:

$$ILR = \frac{\text{DC Nameplate}}{\text{AC Nameplate}} \tag{1}$$

Analysis of the calculation of the Performance Ratio (PR) or performance ratio which is the percentage of the total PV array energy potential that can be converted into electrical energy in the form of alternating electric current, is expressed in equation 2:

$$PR = \frac{\text{Energy to Grid (Wh)}}{\text{POA Irradiance}\,\frac{Wh}{m^2} x \,\frac{\text{DC Nameplate (W)}}{\text{STC}(1000\frac{\text{W}}{m^2})}} \tag{2}$$

The fundamental step in calculating PV performance is to determine the radiation incident on the array plane (POA) as a function of time. The POA radiation depends on several factors, including sun position, array orientation (fixed or tracking), irradiation components (direct and diffuse), ground surface reflectivity (albedo), and shadows (near and far obstructions).

Total Solar Resource Fraction (TSRF) analysis, which is the amount of sunlight measured in an area that receives it for a year. TSRF is also a comparison of the existing insolation, including the effect of shading and Tilt and Orientation Factor (TOF) on total insolation at a location with an optimal slope and optimal orientation that makes no shadow losses, expressed in Equation (3). A 100% TSRF value is very rare to find due to trees and other factors that cast shadows. Solar Access in the TSRF calculation is stated in equation (4).

$$\text{TSRF} = \frac{\text{TOF}}{\text{Solar Access}} x\ 100\% \quad (3)$$

$$\text{Solar Access} = \frac{\text{haded Irradiance}}{\text{OA Irradiance}} \quad (4)$$

The study of solar power plant development is an effort to explore the potential of clean energy, with abundant energy sources, and environmentally friendly, so research on modelling and simulation in the field of solar power plants continues to be carried out[11]. Photovoltaic systems can be classified into three criteria namely; standalone or off-grid systems, grid-tied systems and on grid systems. [12]. On-grid systems work without the use of batteries as an energy storage medium, and are commonly used in remote areas with a small or no population. [13].

The Australian National University (ANU) has conducted research on Indonesia's potential to generate electrical energy from sunlight, with one of the greatest potentials located on the island of North Sumatra. Palipi is one of the areas located in North Sumatra, located on the island of Samosir. The construction of PLTS in the Palipi area has been carried out with the aim of helping the surrounding community in channeling water for their plantations. The solar power plant that has been built in Palipi village is an ongrid type solar power plant.

The process of installing a solar power generation system several influencing factors including shading that can affect the performance of solar power generation systems with tropical natural conditions, solar modules can be covered by trees, leaves or dirt in the period of use. Conditions like the above have the potential to form shadows for solar modules so that they will affect the performance of solar modules with reduced power output [14] and will affect the performance of PV modules so that the output power is directly reduced. On the other hand, due to the difference between the initial design and the actual conditions of the PV system, the inappropriate distance between the front and rear PV arrays may cause the shadow phenomenon, the installation site conditions with uneven surfaces may also cause shadows on the solar modules thereby reducing the efficiency value of the solar power plant.

Efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of energy output from the solar cell to the input energy from the sun. Besides reflecting the performance of the solar cell itself, efficiency also depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. Therefore, the conditions under which the efficiency is measured must be carefully controlled in order to compare the performance of one device with another.
Solar cell efficiency is determined as the fraction of incident power that is converted into electricity and is defined as:

$$P_{max} = V_{OC}.\ I_{SC}\ .\ _{FF} \quad (5)$$

$$\eta = \frac{V_{OC}\ .I_{SC}\ .FF}{P_{in}} \quad (6)$$

The voltage generated by the solar panel is DC voltage. The input power of the solar panel is the intensity of sunlight (W/m2) and the cross-sectional area of the solar panel (m2). To determine the input power of solar panels, the formula from the following equation can be used:

$$Pin = I_{Rad}\ x\ A \quad (7)$$

While the output of the solar panel is current and voltage. To determine the output power of a solar panel, the following formula is used:

$$Pout = V_{PV}\ x\ I_{PV} \quad (8)$$

To get the average power value during the test point is indicated by the equation:

$$P_{average} = \frac{P_1 + P_2 + P_3 + \cdots P_n}{n} \tag{9}$$

The formulation that can be used in analyzing the shadow factor is:

$$shadow\ factor = \frac{distance\ (m)}{height\ from\ the\ surface\ of\ the\ solar\ module\ (m)} \geq 2 \tag{10}$$

Several software tools can be used to simplify image analysis, for example, Pvsyst and Helioscope. This software allows designers to design a system layout, complete with a graph of the trajectory of the sun at a given location and an estimate of the amount of energy output that takes into account losses when the array of photovoltaic modules is exposed to shadows. Simulation of the design of a solar power plant can be carried out based on a web design known as a helioscope, the introduction of the helioscope was introduced by Folsom labs to be able to plan a complete simulation modelling and display a 3D version so that it can produce potential values that can be obtained from this solar power plant. Potentials that can be identified in solar power plants such as shading potential, and potential locations for placing inverters using panels whose position and location can be determined.

## METHODOLOGY

### A. Research Stages

The research was carried out in the electrical engineering computer laboratory, Faculty of Science and Technology UNPAB. The laboratory is used as a medium for analysis and simulation as well as computer-assisted mapping. The research location to obtain primary data was carried out in Palipi Samosir Village, North Sumatra Province. The stages of the research are shown in Figure 4.

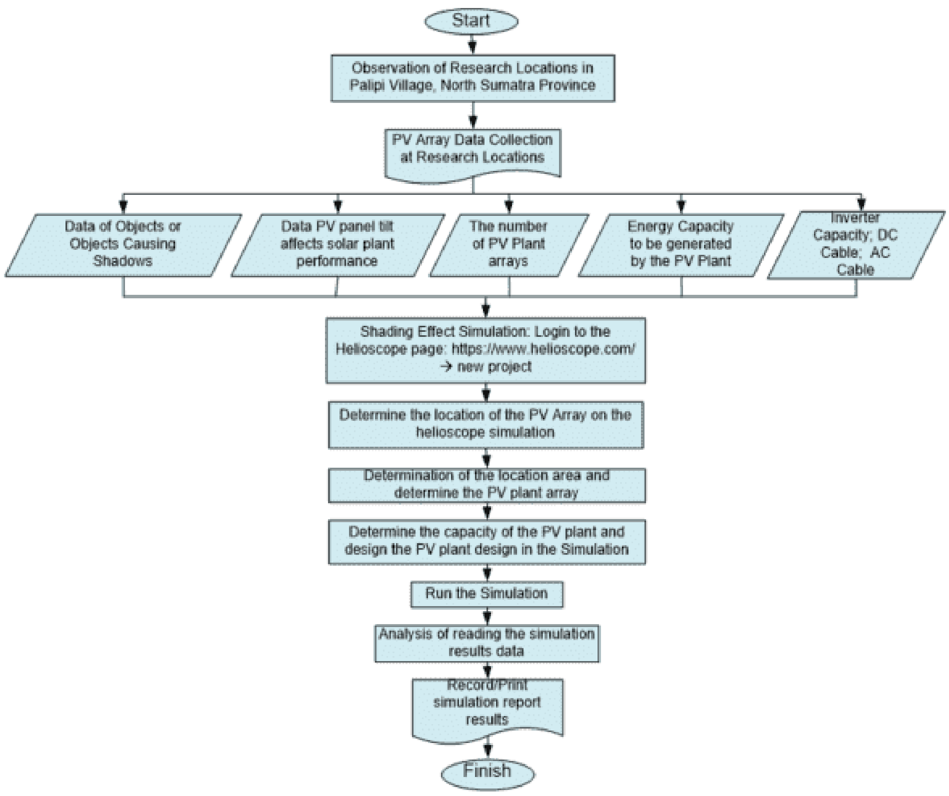



**Figure 4. Research stages**

Figure 4 shows the stages of the research, starting with data observations in Palipi village, North Sumatra. The second stage is collecting primary research data at the research location, the data includes Building objects or trees that can cast a shadow effect on the PV plant, tilt angle data (PV Panel tilt), number of PV plant arrays, area, inverter and AC and DC cable data. The simulation step is to enter data on the helioscope simulation device and observe the simulation results including the capacity of the PV plant as well as the effect of the shadow effect on the performance of the PV Plant which is measured every month using the simulation.

**B. Research Location**

The location of the research location at the PLTS position 2.508726, 98.766624, as shown in Figure 5.


**Figure 5. Position of PLTS 2.508726, 98.766624**

The location of the array installation in Palipi village, as shown in Figure 6.

**Figure 6. The condition of the PLTS Array at the research location in Palipi**

After observing and collecting research data in the village of Palipi, then log in to the helioscope page or web (https://www.helioscope.com/). Researchers who already have a helioscope account can immediately enter and click the "existing user login" button, while users who don't have an account and if they want to do a free trial can register first. All you have to do is fill in your email, first name, last name, company origin, and password. The next step for researchers or users will be to direct them to the live project creation page or to see the training video first. The next step is to input data on the helioscope by opening a new project. The new project means a series of data entries based on real data at the research location, then conducting a simulation to obtain the simulation results of the effect of shadow on the capacity of the PV plant in Palipi Village.

## RESULTS AND DISCUSSION

### A. Simulation Results

Fill in the data by inputting it to "New Project" to carry out a new design simulation and fill in some data about the project to be carried out (project name, address, building profile, and project description), as shown in Figure 6.

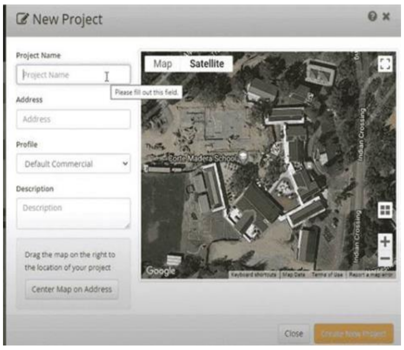



**Figure 6. New Project on Olioscope Device Simulation**
**(Source [https://www.helioscope.com/](https://www.helioscope.com/))**

Simulations using HelioScope technology were carried out to find the effect of the shadow effect on the performance of solar panels in Palipi village. The report results from data entry in the simulation are shown in table 2.

**Table 2.** Simulation Results Report

| Report | |
|---|---|
| Project Name | Model Shading PLTS Palipi |
| Project Description | Analisis Shading PLTS Pump Palipi |
| Project Address | PALIPI, SAMOSIR |
| Prepared By | niar rahma<br>rahmaniar4n01@gmail.com |
| **System Metrics** | |
| Design | Model 1 |
| Module DC Nameplate | 9.75 kW |
| Inverter AC Nameplate | 36.0 kW<br>Load Ratio: 0.27 |
| Annual Production | 10.35 MWh |
| Performance Ratio | 67.1% |
| kWh/kWp | 1,061.1 |
| Weather Dataset | TMY, 10km Grid, meteonorm (meteonorm) |
| Simulator Version | 7fcfed6b7f-c73bc584e3-60fabe3f4f-3e4a7ea9f7 |

### B. Annual production

Energy (kWh) that can be distributed every month (January to December, with a total energy that can be distributed to the electricity network, is 10,345.5 kWh. A graph of energy production every month for one year is shown in Figure 7

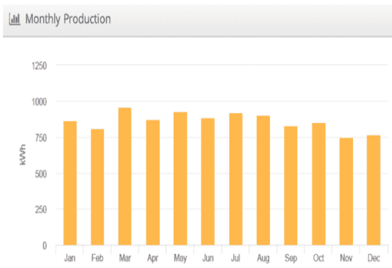



**Figure 7. Simulation Results of Monthly PLTS Electrical Energy Production in Palipi Village**

The output of this simulation produces a total collector radiation of 1,480.1 kWh/m2 and an average operating ambient temperature of 21.70C and an average operating cell temperature of 39.30C. Complete data from the simulation results are shown in Table 3.

**Tabel 3.** Simulation Result Data

| Annual Production | | | |
|---|---|---|---|
| | Description | Output | % Delta |
| Irradiance (kWh/m$^2$) | Annual Global Horizontal Irradiance | 1,580.9 | |
| | POA Irradiance | 1,582.3 | 0.1% |
| | Shaded Irradiance | 1,567.5 | -0.9% |
| | Irradiance after Reflection | 1,510.1 | -3.7% |
| | Irradiance after Soiling | 1,479.9 | -2.0% |
| | **Total Collector Irradiance** | **1,480.1** | **0.0%** |
| Energy (kWh) | Nameplate | 12,688.4 | |
| | Output at Irradiance Levels | 12,556.1 | -1.0% |
| | Output at Cell Temperature Derate | 10,884.2 | -13.3% |
| | Output After Mismatch | 10,559.4 | -3.0% |
| | Optimal DC Output | 10,529.6 | -0.3% |
| | Constrained DC Output | 10,529.1 | 0.0% |
| | Inverter Output | 10,350.1 | -1.7% |
| | **Energy to Grid** | **10,345.5** | **0.0%** |
| Temperature Metrics | | | |
| | Avg. Operating Ambient Temp | | 21.7 °C |
| | Avg. Operating Cell Temp | | 39.3 °C |
| Simulation Metrics | | | |
| | | Operating Hours | 4691 |
| | | Solved Hours | 4691 |

Estimated losses in the solar panel system simulation in Palipi village can be seen in Figure 10.

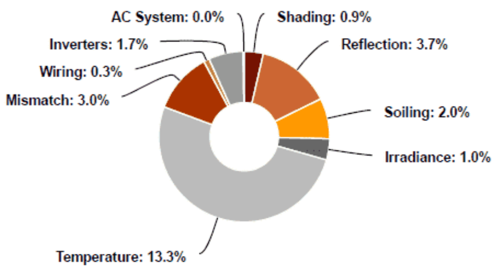



**Figure-8: Overall system losses for the Shadow Effect Simulation Case at solar panel Palipi village**

The potential for electrical energy on solar panels in Palipi village is 28.3 kWh, obtained from annual energy data that can be distributed to the electricity grid of 10,345.5 kWh. The process of solar irradiation on solar panels with a total overall loss of 25.9% based on the simulation results of Figure 8. This is in line with the results of research studies The potential for solar irradiation in the PT PJB UP Muara Karang area is 4.77 kWh/m2 / day with simulations using HelioScope to evaluate the energy production generated from PLTS.[15]

## CONCLUSION

Solar module operating temperature is the biggest contributor to power losses with a value of 13%. The shadow effect contributes to a loss of 0.9%, this is seen from the research location in the village of Palipi, it is only affected by 1 house building and electricity tower poles. Loss of wiring loss of 0.3%. So that the total electrical energy obtained through the PLTS generator in the Palipi village is 10,345.5 kWh/per year

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