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# Design and Implementation of Grounding On-Grid PV System 100 kWp in Pamulang University

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***Abstract* – The grounding system in a Solar Power Plant installation has an important role as a safeguard against external disturbances such as overcurrent and overvoltage due to lightning strikes or internal disturbances. Considering that solar modules are installed in open areas and at certain heights, the grounding system is crucial to protect equipment and personnel. This study discusses the design of a 100 kWp On-Grid PLTS grounding system at Pamulang University, including external lightning rod planning using the Early Streamer Emission (ESE) method with the NFC 17-102 standard and the rolling sphere calculation method based on IEC 62305-3. The calculation results show that the lightning rod protection radius in building B is >117.79 meters with a lightning rod height of 6 meters. The initial grounding resistance value of 11.6 Ω was obtained from a single vertical electrode 3 meters deep. To achieve a resistance value below 5 Ω according to the PUIL 2011 standard, equipotential bonding between floors and between electrodes is required. This research is expected to be a reference in designing lightning protection and grounding systems for PLTS installations in the Pamulang University environment.**

***Keywords: On-Grid PLTS, grounding system, ESE, earthing resistance, lightning arrester.***



## I. INTRODUCTION

The need for electricity is increasing day by day and has become a basic need for the Indonesian people to support their daily activities [1][2]. The increasing need for electrical energy is a concern because most energy sources in Indonesia still come from conventional energy such as coal which is limited and has an impact on environmental emissions [3][4]. As a commitment to environmental issues, alternative renewable energy such as solar power is a solution that can be widely implemented [5]. In its implementation, solar power systems and other electrical installations need to be equipped with a good grounding system to ensure user safety, prevent equipment damage due to voltage spikes, and reduce the risk of fire due to electrical disturbances.

Solar energy has many advantages, including as a clean and renewable energy source, as well as its abundant availability. Based on data from the Ministry of Energy and Mineral Resources (ESDM), as of October 2021 the installed capacity of PLTS in Indonesia reached 42.39 MWp, with a potential of more than 500 MWp. The government is targeting a rooftop PLTS capacity of 3.61 GW by 2025 and the development of utility PLTS of 4.68 GW to 30 GW in 271 locations in Indonesia [6].

The rapid development of solar energy has also had an impact on the growth of technology and the community's economy. However, the application of PLTS is not free from various technical problems, especially because the installation of solar modules is at a height and in an open area, so it is greatly influenced by environmental factors. Some common problems that can occur in PV systems include: damage due to Potential Induced Degradation (PID), loading problems, short circuits, over voltage, hot spots, and fires in PV array modules [7].

This problem can be overcome by implementing a good protection system design, including a grounding system. Grounding is an important system in electrical installations that functions to drain lightning currents or electrical disturbances to the ground in order to protect equipment and personnel safety [8]. In a rooftop on-grid PLTS system that has two different systems (DC/AC), the disturbance current can cause dangerous step voltages and touch voltages, so serious consideration is needed for the grounding system, including ground resistance, ground potential difference, and the effectiveness of the lightning protection system [9][10].

The increasing use of rooftop solar power plants (PLTS) as an environmentally friendly alternative energy source needs to be balanced with the implementation of a reliable electrical protection system, especially a grounding system. In large-capacity rooftop PLTS installations such as 100 kWp, the grounding system plays an important role in ensuring the safety of equipment and personnel against electrical disturbances, especially due to overvoltage and lightning strikes.

However, designing an effective grounding system that meets electrical safety standards is not a simple matter. Challenges arise from various factors, such as the characteristics of the installation environment (e.g. humidity and soil resistivity), the complexity of the two-sided system configuration (DC/AC), and the potential dangers of touch and step voltage differences due to fault currents

Solutions that can be applied include comprehensive equipment grounding and the installation of appropriate lightning rods. The goal is for the PLTS system to operate reliably and safely, both for equipment and personnel safety [11][12].

Based on the background and problems that have been described, the author is interested in conducting research on the design of a grounding system in a 100 kWp PLTS installation at Pamulang University. This research was conducted using a literature study approach, field observation, and technical and mathematical calculations to produce a grounding system design that meets the safety and reliability standards of the electrical system.

However, until now there are still few studies that specifically discuss the design of grounding systems in PLTS installations, especially in campus environments such as Pamulang University. In fact, campus areas have their own characteristics that are different from industrial and residential areas, both in terms of electrical load, building distribution, and soil conditions.

Based on the background and problems, the author is interested in conducting research on the design of grounding systems in PLTS installations with a capacity of 100 kWp at Pamulang University. This research was conducted using a literature study approach, field observations, and technical and mathematical calculations to produce a grounding system design that meets the safety and reliability standards of the electrical system.

## II. BASIC OF THEORY

Delamination failure in solar modules can have a multiplication effect, even though the percentage of damaged modules is relatively small compared to the total system. This condition can still cause serious damage, such as failure of a multistring inverter serving up to 10 solar modules [13]. Based on the international standard EN 61215, there are several levels of delamination, namely: first, the appearance of small-scale delamination on the surface of the solar module; second, progressive increase in delamination on the edges and cells of the solar module which leads to a decrease in the short-circuit current (Isc). The impact of delamination not only reduces the performance of the solar module, but also has the potential to damage protection systems such as relays, causing more severe damage to the inverter. In addition, in a solar power system with a high voltage in the range of 1100 to 1300 volts DC, the risk of delamination failure tends to be greater and can occur faster.

Degradation in photovoltaic systems is generally caused by damage to solar modules, such as cracks in the module shield, the emergence of hotspots, Potential Induced Degradation (PID) phenomena, delamination, and the formation of air bubbles on the surface of the module [14]. In addition, disturbances to the grounding system (ground fault) can occur due to unintentional connections, decreased insulation resistance, and poor insulation of solar modules from the roof or ground. These disturbances can pose a safety risk to humans, damage equipment, and reduce the efficiency of the overall photovoltaic system.

Photovoltaic (PV) arrays are often installed around supporting substations that are sometimes built in areas with high soil resistivity, such as mountainous areas. When the grounding systems of the PV array and the substation are made independently, disturbances in the substation can cause fault currents to flow through the PV array grounding system. This creates a significant potential difference between the two grounding systems, which then produces high step voltages and touch voltages, endangering the safety of personnel and disrupting the reliability of equipment operation [15].

Grounding or grounding system is an important part of an electrical installation that functions to eliminate potential differences [16]. When there is a current or voltage leak, the grounding system will channel the current directly to the ground, thus protecting the entire electrical system. In addition, grounding also acts as a path for conducting electric current to the ground if there is an insulation failure, for example in the chassis or electronic devices.

In a lightning protection system, grounding functions as a medium for channeling large capacity excess current to the ground due to lightning strikes. Although the basic principle is the same, the grounding system for lightning protection must be installed separately from the home grounding installation to avoid interference [17].

In electronic equipment and instrumentation, grounding plays an important role as a protection system to prevent damage due to voltage leaks and ensure optimal equipment performance. In the world of electronics, grounding also helps neutralize interference or noise originating from poor or non-standard electrical power quality.

By the requirements for electrical power installations based on the Indonesian National Standard (SNI 2011), the grounding resistance value must have a resistance of less than 5 Ohms in order to function effectively in protecting the system and connected equipment.

Referring to IEC (International Electrotechnical Commission) TC 81/1989 on the concept of Lightning Protection Zone (LPZ), a perfect lightning protection system consists of 3 parts, namely external protection (air termination), internal protection (Surge Protection Device) and Grounding:

Alternative system grounding as long as performance requirements are met. Article 690.42 explains that ground fault protection is provided where the system has ground-fault protection so that there should be no duplication of grounding. Where in general for DC system grounding is on the inverter, seen in Figure 1.

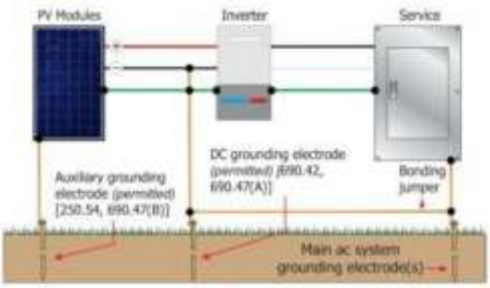


Figure 1. PV Output Grounding of DC Systems [18]

Several grounding methods are commonly applied in electrical installations, and their selection depends on factors such as the type of installation, environmental conditions, soil characteristics, and applicable regulatory standards. Each method offers its own strengths and limitations that must be considered during system design. One of the most widely used methods is rod or vertical grounding, which is easy to install, requires minimal land area, and performs well in locations with low soil resistivity. However, its effectiveness diminishes in rocky or dry soils with high resistivity, often requiring multiple rods in parallel to achieve acceptable resistance levels, which may increase installation costs. Another method is grid or mesh grounding, commonly implemented in high-voltage installations and substations. This method provides a low impedance path to ground and significantly enhances safety by minimizing step and touch voltages. Despite its effectiveness, it requires a large installation area and incurs higher costs due to its complexity.

Plate grounding is suitable for installations in areas with limited space. When properly sized and buried, grounding plates can achieve lower resistance values than single rods. Nonetheless, this method necessitates excavation and may suffer from corrosion issues if the plate material is not appropriately matched to the soil environment. In regions with high-resistivity soils, chemical grounding offers a viable alternative. It utilizes conductive compounds to maintain stable low resistance over time and is particularly effective in sandy or rocky terrains. The main drawback of this method lies in its higher cost and the need for periodic maintenance or replenishment of the chemical agents used. Finally, the choice between separated and integrated grounding systems-particularly for differentiating between lightning protection and equipment grounding, also presents trade-offs. A separate grounding system reduces the risk of interference and prevents circulating currents that could damage sensitive electronic equipment. However, it requires careful coordination in design to avoid ground loops and ensure consistent potential zones.

Understanding these advantages and disadvantages is crucial in selecting the most appropriate grounding strategy for a given installation, such as in the design of a grounding system for a 100 kWp rooftop solar power plant in a campus environment.

An inverter is a device that functions to convert direct current (DC) voltage to alternating current (AC) voltage, so that the electrical energy generated from solar modules can be used by AC loads or distributed to the electricity grid. In planning a PLTS system, determining the number of modules arranged in series or parallel must consider several important factors, including the minimum and maximum MPP (Maximum Power Point) voltage that can be accepted by the inverter, the number of MPPTs (Maximum Power Point Trackers) and strings available, maximum input current and voltage of the inverter, and the open circuit voltage of the solar module. In addition to these technical aspects, safety aspects are also a major concern. Therefore, inverters must meet international standards IEC 62109-1 and IEC 62109-2, which are important safety standards for inverter devices, especially in photovoltaic system installations [19].

The grounding system for PV arrays uses a green-yellow cable type NYY with a diameter determined based on calculations and adjusted to the SPLN/SNI standard, where the cable must be electrically connected to the PV Array terminal (Using bolts), with a grounding resistance of less than 5 Ohms [20].

In the PLTS grounding, it must be designed in such a way that the touch voltage on the grounding system is smaller than the touch voltage limit for humans (IEC 449, IEC60479 and PUIL 2011 (General Requirements for Electrical Installations) the upper limit of the voltage range is 50 Volts alternating current and 120 volts direct current). For touch voltage (Step Voltage) occurs when there is a potential difference at a distance of 1 meter to the equipment or components that are grounded with the design of the grounding system referring to IEEE no.80 of 2013. Body grounding and bonding protection against touch voltage is explained in PUIL 2011 in point 510.1.5.1 If metal boxes and metal frames need to be grounded or terminaled in accordance with 510.1.4.3, metal hinges or the like must be connected correctly and precisely [21].

In the context of campus-based rooftop solar installations such as the 100 kWp PLTS at Pamulang University, these standards are critical. The presence of students, staff, and non-technical personnel in close proximity to electrical infrastructure increases the importance of ensuring that the grounding system not only meets technical standards but also provides effective protection against electrical hazards. A well-designed grounding system helps to minimize the risks of electric shock, especially during maintenance or in the event of system faults, while also protecting sensitive equipment from lightning strikes or overvoltage conditions common in open rooftop environments.

Table 1. Comparison of grounding standards and methods for pv systems

| No | Standard / Grounding Method | Key Characteristics | Suitability for Campus PV Systems |
|---|---|---|---|
| 1 | PUIL 2011 (Indonesia) | National standard for general electrical installations in Indonesia | High |
| 2 | IEC 60479 | Defines current threshold limits affecting the human body | High |
| 3 | IEEE Std 80-2013 | Grounding design for substations and power systems | Medium |
| 4 | SPLN 1:1995 (Indonesia) | PLN's grounding installation guideline | Medium – High |
| 5 | Rod / Vertical Grounding | Uses metal rods driven vertically into the ground | High (if soil is suitable) |
| 6 | Grid or Mesh Grounding | Network of buried conductors forming a ground grid | Low – Medium |
| 7 | Chemical Grounding | Uses conductive chemical compounds to lower soil resistance | High (for difficult soil) |

## III. METHOD

The measurement system uses the Earth Tester 4150 A test tool, this tool is used to determine the grounding resistance value, where it is important to know the magnitude of the grounding resistance before securing the electrical power installation system. The earth tester is a measurement equipment consisting of several parts including pegs, measuring instrument cables, terminal probes (E: Earth Plate, P: Potential Spike, C: Current Spike), display. In general, the E probe is used for connecting the measurement cable to the electrode to be tested to determine its grounding resistance, the P probe for testing facilities with cable connections and pegs that are ± 5 meters from the electrode being tested, and the C probe is ± 5 meters from the P peg with the measurement condition of the electrode to be tested with the P and C pegs in a straight line (IKyoritsu Electrical Instrument Works, n.d.). Next, the measurement can be continued by setting the selector switch to the 20 Ω - 200 Ω - 2000 Ω position and continuing by pressing the orange push on (hunting) button, and looking at the display to find out the value of the resistance of the electrode being tested, the display shows the results of the resistance of the electrode being tested.

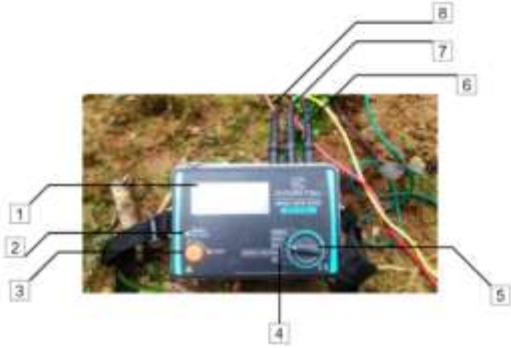


Figure 2. Components of the 4150A Earth Tester

In compiling this research more focused, it requires a research framework that contains the stages that will be carried out until the research process is complete. The research framework is presented in Figure 3.

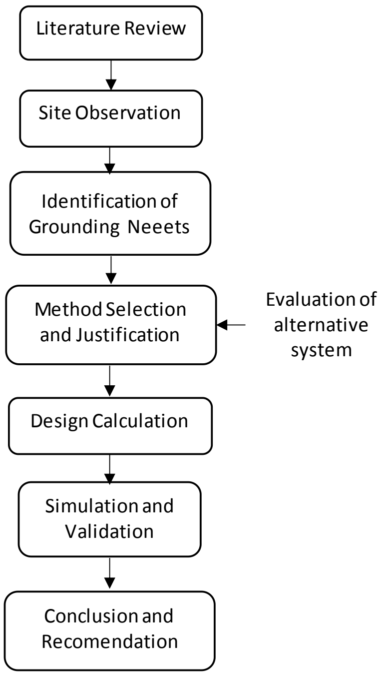


Figure 3. Flowchart research

Researchers use the grounding resistance reference standard based on the General Requirements for Electrical Installations 2011 (SNI 0225:2011) which is the result of an amendment to PUIL 2000/2009 implemented by the Technical Committee for Electrical Installation and Reliability (PTIK) with the Decree of the National Standardization Agency Number 32/KEP/BSN/1/2006 and the Decree of the Director General of Electricity and Energy Utilization No.01/PJK-DITTEK/II/2009.

The selection of the Early Streamer Emission (ESE) method is validated through a comparative analysis of coverage area, safety performance, and installation efficiency, showing that ESE offers superior protection for rooftop PV systems in compact campus environments compared to conventional lightning rods.

## IV. Results and Discussion

In the research methodology that has been explained by the author, a field survey has been conducted to design lightning protection for the PLTS (Solar Power Plant) system. The data needed by the researcher to design an external lightning protection system (direct lightning strikes) and internal (grounding) are as shown in Figure 4 which illustrates the condition of the area of the building that will be protected by the Viking V6 early streamer type lightning conductor, and Figure 4.5 which illustrates the height of the building at Pamulang University. Where the data presented by the author is per the conditions in the field of the campus area that the author uses as a research location related to the grounding design that will be applied.

Figure 4. Layout of the area of the Pamulang Viktor University building

Based on Figure 4 in the Pamulang Viktor University building, several supporting points can be seen to strengthen researchers in calculations to plan internal and external protection security in the design of the Pamulang University PLTS which are attached in table 2.

Tabel 2. Dimensions of the Pamulang Viktor University building

| Building Name | Length (m) | Width (m) | Height (m) |
|---|---|---|---|
| Building A | 42,5 | 42 | 36,9 |
| Building B | 84 | 35 | 40,5 |
| Building C | 73,5 | 35 | 36,9 |

Grounding is the process of connecting a point in an electrical circuit or a conductor that is not directly part of the circuit to the earth's surface through a certain method. The grounding system acts as a safety system for devices that use electricity. Therefore, this system has a very crucial role in the protection system, both for equipment protection and user safety. The main purpose of the grounding system is to provide a low-impedance path from electrical equipment to the earth's surface. This aims to minimize unwanted electric currents, whether caused by electrostatic discharge, circuit switching, or transient voltage. Thus, the grounding system can reduce the adverse effects that can endanger living things or damage electrical equipment.

Some of the components in the On Grid System (PLTS) Solar Power Plant are as shown in the following image.

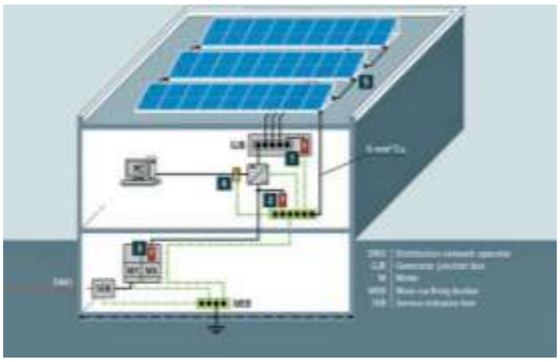

Figure 5. Connect the conductors to each PV module in series

The grounding connection on the PV module is designed in series to the photovoltaic module frame with the ends of the serial connection connected in parallel to the grounding junction box.

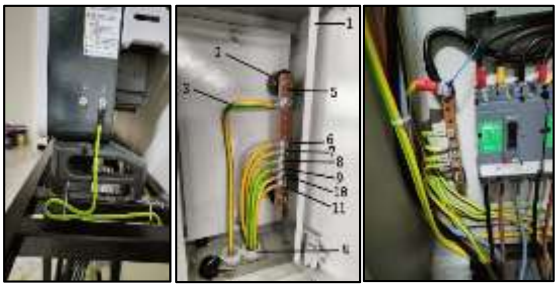

Figure 6. Grounding connection

For the cross-sectional area of the protective conductor (equipment grounding) of 2.5mm$^2$ Cu or 16mm$^2$ Al with mechanical damage protection provided, 4mm2 Cu or 16mm$^2$ Al without mechanical damage protection provided. For equipotential protection bonds with a cross-sectional area of not less than 6mm$^2$ copper, 16mm$^2$ aluminum, 50mm$^2$ steel.

Figure 7. The results of measuring the grounding resistance of the ground rod at point A

In this system, the output conductor from the junction box on the ground floor (1) of building B, Pamulang University uses an existing copper rod electrode with a diameter of 5/8 inch (1.5875 cm) with a length of 3 meters. The formula for the grounding resistance of the Single Rod electrode.

$$RG = R = \frac{\rho}{2\pi L}[\ln(\frac{4L}{D} - 1)] \tag{1}$$

Description:
RG : Grounding resistance (Ohm)
R : Grounding resistance for single rod (Ohm)
ρ : Soil type resistance (Ohm-meter)
L : Electrode length (m)
D : Electrode diameter (m)

$$RG = R = \frac{\rho}{2\pi L}[\ln(\frac{4L}{D} - 1)]$$
$$RG = R = \frac{30}{2x3{,}1416x3}[\ln(\frac{4x3}{0{,}015875} - 1)]$$
$$= \frac{30}{18{,}8496}[\ln(\frac{12}{0.015875} - 1)]$$
$$= 1{,}591546[\ln(755{,}90551 - 1)]$$
$$= 1{,}5923566878980[\ln(754{,}90551)]$$
$$= 1{,}5923566878980(6{,}6279)$$
$$= 10{,}5465\ \Omega$$

Based on the calculation results, the grounding resistance results for the single rod electrode are 10.55 Ω, based on the PUIL 2011 reference standard, the calculation results cannot be applied. The grounding resistance results for the single rod electrode are 10.55 Ω, based on the PUIL 2011 reference standard, the calculation results cannot be applied.

Mathematical calculations change the constant on the electrode radius to 0.888435 meters, with the basic formula of a single electrode:
ρ : Soil resistance (Ohm-meter) = 30 Ω-m
L : Electrode length (m) = 3 meters
D : Electrode radius: 0.888435 meters

$$RG = R = \frac{\rho}{2\pi L}[\ln(\frac{4L}{D} - 1)]$$
$$RG = R = \frac{30}{2x3{,}1416x3}[\ln(\frac{4x3}{0{,}888435} - 1)]$$
$$= \frac{30}{18{,}8496}[\ln(\frac{12}{0{,}888435} - 1)]$$
$$= 1{,}591546[\ln(2{,}603200 - 1)]$$
$$= 1{,}5923566878980(2{,}526280)$$
$$= 4{,}0207\ \Omega$$

From the calculation results above, assuming a change in the cross-sectional area of the electrode rod by 0.888435 meters, the grounding resistance value of a single electrode rod is 4.0207 Ω, but because electrode rods with a diameter of that size are not available on the market, they cannot be applied.

Mathematical calculations change the constant on the length of the electrode depth to 9.2 meters, with the basic formula of a single electrode:
ρ : Soil resistance (Ohm-meter) = 30 Ω-m
L : Electrode length (m) = 9.2 meters
D : Electrode radius: 0.015875 meters

$$RG = R = \frac{\rho}{2\pi L}[\ln(\frac{4L}{D} - 1)]$$
$$RG = R = \frac{30}{2x3{,}1416x9{,}2}[\ln(\frac{4x3}{0{,}015875} - 1)]$$
$$= \frac{30}{57{,}80544}[\ln(\frac{12}{0{,}015875} - 1)]$$
$$= 0{,}518983[\ln(755{,}90551 - 1)]$$
$$= 0{,}518983(6{,}626592)$$
$$= 4{,}01998\ \Omega$$

From the calculation results above, the results of the electrode resistance were obtained through mathematical calculations with a constant change in the electrode length of 9.2 meters, the single rod grounding resistance was obtained as 4.01998 Ω according to the measurement results obtained using the Kyoritsu Earth Tester.
The results of the calculation of soil resistance on the measurement results of 0.33 Ω

By using the following equation, the total resistance can be found from the measurement results at Pamulang University where the measurement results are arranged in parallel with 4 electrodes so as to ensure the resistance of a single electrode arranged in parallel with an approach with the parallel resistance formula.

$$R_{total} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$R_1, R_2, R_3, R_4$ The resistance of each single electrode is the same.
R_total: The result of calculating the total R arranged in parallel.

$$R_{total} = RG = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$
$$R_{total} = RG = \frac{1}{10{,}5465\ \Omega} + \frac{1}{10{,}5465\ \Omega} + \frac{1}{10{,}5465\ \Omega} + \frac{1}{10{,}5465\ \Omega}$$
$$R_{total} = RG = 0{,}379273\ \Omega$$

The results of this study indicate that the grounding resistance value obtained through parallel configuration of four electrodes is 0.38 Ω, with a field measurement result of 0.33 Ω using the Kyoritsu Earth Tester. This value is well below the maximum threshold of 5 Ohms as stipulated by PUIL 2011 (SNI 0225:2011), thus meeting national safety standards for electrical installations, especially for lightning protection and equipment grounding in PV systems. However, although the comparison with regulatory standards has been thoroughly addressed, there is no specific comparison provided with previous similar research studies on grounding systems for rooftop solar power plants. When compared to typical values found in similar studies-many of which report grounding resistance values between 1.5 to 4 Ohms depending on soil type, electrode configuration, and depth-the result of 0.33 Ω in this study is notably lower and indicates a superior grounding performance. This low resistance value is achieved through optimal electrode configuration, parallel arrangement, and appropriate spacing, all of which significantly reduce the total resistance. Therefore, this research provides a valuable contribution by demonstrating a grounding system design that not only complies with national standards but also outperforms common results found in comparable studies, especially in the context of rooftop PV systems in campus environments [22][23].

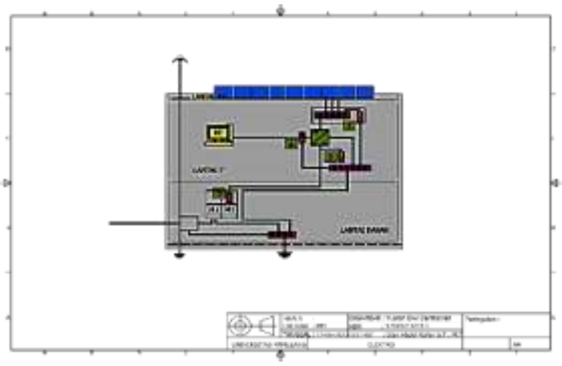

Figure 8. Grounding Design of Pamulang University PLTS

The grounding connection of the Solar Module and Lightning Conductor becomes one unit in an equipotential bonding bond. And for the grounding path from the Inverter, Combiner Box, SDP and PLN Distribution Panel, it has its own grounding path.

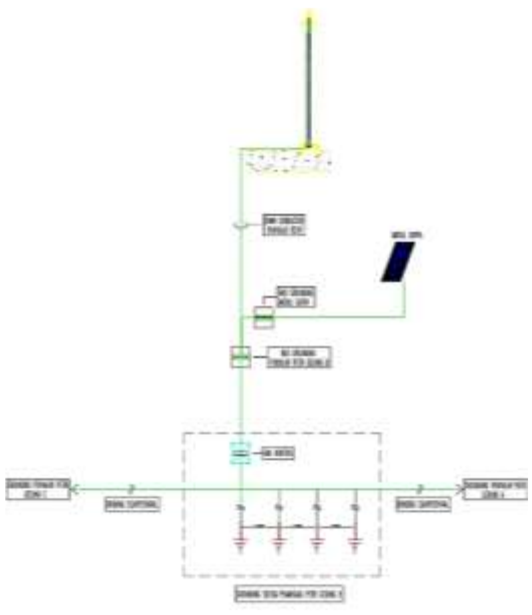

Figure 9. Design of Grounding Rod for Pamulang University Solar Power Plant

From the results of mathematical calculations related to determining the value of the grounding resistance at Pamulang University which will be applied to lightning conductors and protective earth on solar module equipment. The distance between electrodes is approximately 5 meters between electrodes with a depth of 3 meters, the resistance is 0.38 Ω with rounding up and with the arrangement of electrodes arranged in parallel with a total of 4 electrodes. In addition, based on mathematical calculations, the length or depth, and diameter of the electrodes that can affect the value of the grounding resistance are obtained, as well as the soil resistance coefficient which has been stated in PUIL 2011 for types of soil resistance

This graph10 shows that despite using the same electrode depth (3 meters), previous studies produced resistances above 1.5 Ohms, whereas this study with a parallel configuration approach produced a value of only 0.33 Ohms, indicating much better and more efficient grounding performance.

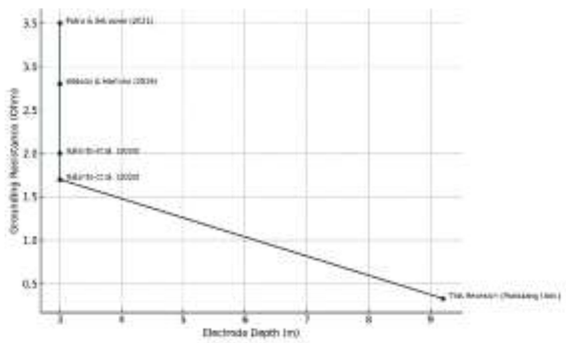


Figure 10. Using electrode depth (3 meters)

The results of grounding resistance measurements in this study-achieved through a parallel configuration of four copper rod electrodes, each with a length of 3 meters and spaced 5 meters apart-demonstrated a resistance value of 0.33 Ω. This value is significantly lower than the maximum limit of 5 Ω specified in PUIL 2011 (SNI 0225:2011), and it also outperforms results from several similar studies, which typically report resistance values between 1.5 to 4 Ω. Such performance highlights the effectiveness of the grounding design applied at the Pamulang University PLTS system, especially in optimizing electrode arrangement and leveraging favorable soil conditions. From a practical standpoint, this grounding design not only delivers strong technical performance but also offers cost-effective implementation. The use of standard 5/8 Inch copper rods, which are widely available in the market at a relatively affordable price (approximately IDR 300,000-400,000 per rod), along with simple parallel configuration, allows the total installation cost to remain under IDR 2 million, making it accessible for educational institutions or medium-scale rooftop solar projects. Furthermore, the design does not require special materials such as chemical compounds or extensive excavation, thereby simplifying installation and maintenance.

## V. CONCLUSION

This study successfully designed a grounding system for a 100 kWp on-grid rooftop solar power plant at Pamulang Viktor University using a parallel configuration of four vertical rod electrodes. The measured resistance value of 0.33 Ω complies with PUIL 2011 standards and outperforms results from similar studies. The use of a parallel electrode system significantly lowers resistance and enhances safety and reliability, particularly in moist tropical soil conditions. Each PV module is properly bonded to the lightning protection system, while other components are grounded separately to maintain equipotential bonding. The study contributes a practical and cost-effective grounding design applicable to educational institutions and offers a replicable model for similar campuses planning rooftop solar installations. Future research is recommended to evaluate performance under seasonal soil changes and to explore real-time monitoring integration for continuous grounding system assessmen.

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