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Engineering Study of Grounding Systems Through Experimental Methods on Down Rod Conductors

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Abstract

The grounding system plays a crucial role in the performance of electrical systems in Indonesia. It functions as protection for electrical equipment, electronics, industrial machinery, multi-storey buildings, and houses. This protection is essential to safeguard sensitive areas from disturbances caused by lightning strikes or electrical leakage, which can be safely directed into the ground through grounding installations. This study focuses on the down conductor grounding engineering system. The research aims to measure soil resistance values and compare the resistance at three conductor points, tested with and without a medium. Rod electrodes were installed at predetermined points (A, B, and C). Measurements were performed in seven stages using a grounding instrument (Earth Tester) at the Kupang State Polytechnic campus. Results show that electrode A, using a PVC pipe medium, had the highest resistance of 358 Ohms and the lowest of 234 Ohms. Electrode B, with a bamboo medium, recorded a maximum resistance of 78 Ohms and a minimum of 56.4 Ohms. Electrode C, without any medium, showed a highest resistance of 138 Ohms and a lowest of 65.9 Ohms. From these results, the electrode at point B demonstrates the most favorable resistance value, aligning most closely with the PUIL standard.

Keywords: Three-point Conductor Grounding Engineering, grounding system, electrical system

INTRODUCTION

The grounding system is generally part of the electrical power installation system found in low-voltage electrical installations, medium-voltage electrical installations, and high-voltage electrical installations. The grounding installation system is designed to function as protection for the electrical installation network, main electrical equipment, electronic equipment, industrial equipment, and commercial buildings (Ahmad et al., 2018). There are several types of grounding systems, namely *conventional grounding*, *Faraday damming*, and *grounding* (Gouda et al., 2024). The grounding system used on the main components of the electrical network can be applied individually, where each piece of main equipment has its own soil installation line (Araújo et al., 2022). In the design of the soil system, there needs to be an engineering overview of the characteristics of the grounding system, where grounding engineering is used to determine the resistance value (Resistance) (Bos et al., 2025). Based on current electricity laws and regulations, and considering the geographical conditions in East Nusa Tenggara with very high rainfall, the level of lightning strikes on the electricity grid, houses, and other buildings is significant.

Grounding systems have two types, namely circuit/system grounding and equipment grounding. Circuit/system grounding aims to connect the neutral point of the electrical system to the ground, while equipment grounding aims to protect equipment and individuals from high-voltage hazards (International Electrotechnical Commission, 2024). Grounding functions to discharge excess current into the ground, thereby securing humans and electrical equipment from the danger of electric shock and damage. It can also protect equipment from lightning strikes and maintain voltage stability.

Another problem faced is the limited infrastructure and knowledge among the public in the current industrial context regarding how to secure household appliances, buildings, and electrical systems that are still substandard (Riyanto, 2021). This lack of protection causes frequent damage originating from the power grid system (Widodo, 2022). The low reliability of the protection system makes it more susceptible to lightning strikes. Therefore, academics have explored ideas and concepts through *engineering land systems* that are environmentally friendly and affordable (Li et al., 2022).

The main purpose of grounding systems is to ensure the safety of people and electrical equipment, as well as to protect systems from interference such as short circuits (Triyanto, 2020). The grounding system conducts interference current to the ground, prevents dangerous contact voltages and step potentials, and protects equipment from damage (Saleh & Ramadan, 2016). In addition, grounding helps channel the energy of lightning strikes to the ground. The general requirements implemented are based on PUIL 2011, or the General Requirements for Electrical Installations, which serve as the main guidelines for electrical installations in Indonesia, including grounding systems. The standard resistance value for grounding is 5 Ohms, ensuring that the current flowing to the earth has a low resistance value (Tleis, 2015). An effective grounding system provides protection to installations and electrical equipment (Nawir, 2018). According to the General Regulations of Electrical Installations, the resistance value produced by the grounding system must not exceed 5 Ohms. For lightning rod systems, which provide greater protection against lightning strikes, the specified resistance value is 1 Ohm.

The factors that affect grounding resistance include soil moisture, soil type, and the construction of the grounding system (Rimbawati, 2019). The resistance value obtained in the grounding system comes from testing copper rod electrodes implanted and connected to the soil, using a testing device. Based on the IEC (International Electrotechnical Commission) Standard IEC 62305-3:2011, the recommended grounding resistance value is below 10 Ohms, with the application of equipotential bonding to ensure all parts are well connected.

Grounding installation in a series of electrical installations is generally used to provide safety for main electrical equipment. In this system, the grounding line is connected directly to the ground through a vertically planted electrode rod, to achieve good resistance values depending on the soil composition. Different soil types—rocky, gravel, clay, sandy, valley, and swamp—affect resistance differently. Among these, valley soil typically produces resistance values closest to grounding standards. Damage to electronic equipment often results when surge currents cannot be properly directed, leading to failure of sensitive components. High grounding resistance values also increase the risk of electric shock to users and cause system instability. Without a proper grounding reference, electrical systems are far more susceptible to disruptions (Yulianto, 2024). The construction methods of land installations are categorized into several types, including *conventional types*, *Faraday assumptions*, and others (Hardi, 2021).

Previous studies on grounding resistance provide valuable benchmarks but also reveal a research gap due to differences in context and application (Hermansyah, 2019). Pandu Widodo, (2024) in the scientific journal *Grounding System Design in Wind Power Plants*, Agus Riyanto, (2019) in his journal *Soil System Analysis of the 150 KV Substation Network at PT Bekasi Power Cikarang*, and Aripin Triyanto, (2020) in his journal at the University of Pemulang, each measured grounding resistance under highly specific conditions. The results cannot be generalized across different installations. Widodo emphasized improving soil retention systems to achieve optimal resistance below standards in wind power plants. Riyanto found substation resistances between 1.13–1.21 Ohms, compliant with PUIL standards. Triyanto's measurements in office buildings showed extreme variability, from 0.15 Ohms to 69 Ohms, reflecting soil heterogeneity and different structural conditions. These disparities highlight a gap: limited research compares grounding resistance performance across multiple installation types in varied soil and environmental conditions, particularly in hybrid or mixed-use infrastructures.

This study fills that gap by examining grounding resistance across multiple types of installations—industrial, commercial, and utility networks—using consistent measurement protocols and soil characterization methods. By systematically comparing resistance values and identifying environmental and structural factors that influence grounding performance, this research provides practical recommendations to optimize grounding systems across diverse applications. The study aims to enhance safety, reduce electrical hazards, and ensure compliance with national and international standards. Furthermore, the findings can guide engineers and facility managers in designing and maintaining grounding systems that are resilient, cost-effective, and adaptable to local soil conditions, ultimately improving operational safety and reliability in varied electrical infrastructure contexts.

RESEARCH METHOD

This research is experimental research, by designing an engineering land system used in households, multi-storey buildings, industrial buildings and other commercial buildings. This research is the result of the work of Kupang State Polytechnic Lecturers in groups to spark new ideas on the grounding system. The design of this study uses a quantitative approach with *the Experimental* method, Land Engineering system. The results of the grounding engineering were measured using a measuring tool, then compared the results of A, B and C based on the results of the resistance obtained.

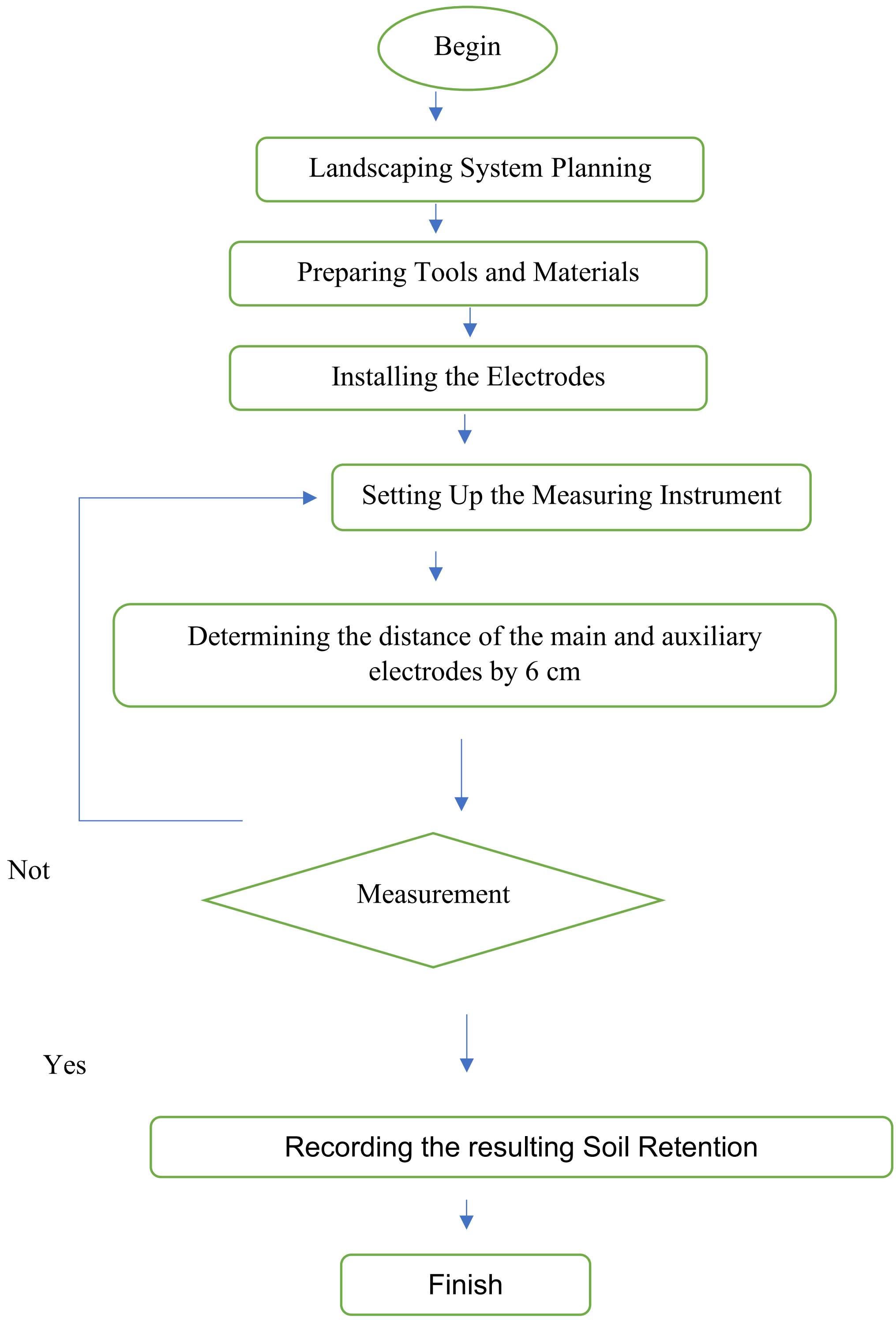

Figure 1, Flowchart

Data collection in this study is through the following methods: The method is carried out using primary data as a reference and experimental in real life with the process of installing grounding in the form of engineering a grounding system on the variable f (t) using a 4-inch PVC pipe, round bamboo and without media. There are several schematic processes carried out in the installation of this grounding engineering system with several schemes as follows:

1. Design Making
2. Procurement of Goods and Equipment
3. Installation
4. Testing

For data analysis, the resistance values obtained from the different grounding configurations were statistically processed using descriptive and comparative methods. Descriptive statistics such as mean, minimum, maximum, and standard deviation were calculated to summarize the central tendency and dispersion of grounding resistance. Comparative analysis was then performed to evaluate the differences in resistance values across the three-grounding media. The effectiveness of each grounding system was assessed relative to national and international standards (PUIL 2011, NFPA 780, IEC 62305-3), and the results were visualized using charts and tables for clarity.

RESULT AND DISCUSSION

System design

The result of the design of the grounding system, using 4-inch PVC pipe media, 4-inch bamboo media and without media.

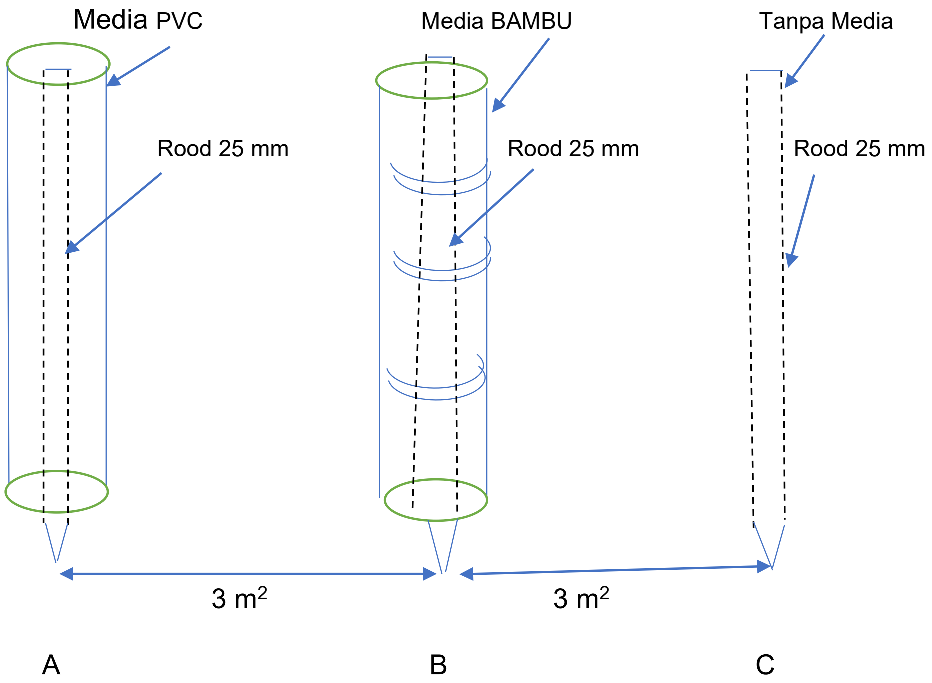

Figure 2. A,B,C Land Engineering Plans

Figure 2 above is a form of grounding system engineering scheme, where this system is designed to create a form of engineering with real experimentation. This form of engineering on the land is a reference for construction on the soil system, then tests are carried out on each electrode point to determine the base of the resistance value obtained. The engineering method is carried out at three points, where the first point uses PVC pipe media, the second point uses Bamboo media and the third point uses no media.

Grounding Construction

The first process of making rood is put into the pipe and positioned in the middle, then the liquid is inserted together until it is broken on the surface of the pipe and bamboo, then dried. The creation of this land engineering can be seen in figure 3.

a b c

Figure 3. a,b,c Points of cultivated land

Figure 3 a above is a down soil conductor that has been planted, using PVC pipe media, a down image of a soil conductor that has been planted using bamboo media and a down image of a soil conductor that has been planted without using media. This form of engineering is made to determine the amount of resistance produced at each land point. After construction, measurements can be continued. Measurements are carried out to take data on the resistance value at each land point.

Soil Measurement

Soil measurement is carried out in a three-point method, where you clip 2 connecting wires to the down conductor and make sure the connecting wires can be connected to the down conductor to be measured. Then attach the two ends of the cable to the Earth Tester on ports C1 and P1, then stick the ground nails into the ground 5 to 10 meters apart. Clip the connecting cable to the grounding nail, then attach the end of the connecting cable to the Earth test port C1 and make sure all connecting cables are connected correctly. Turn on the Tester and rotate the range to the 200 ohm position, then press the test button and record the resistance value listed on the Testter.

a b c

Figure 4. a,b,c Results of Measurement of three Landing points

Figure 4 a is the result of the resistance value listed on the measuring instrument at the down point of the conductor using PVC pipe media, figure b is the result of the resistance value listed on the measuring instrument at the down point of the conductor using bamboo media. Figure c results of the resistance value listed are measured at the down point of the conductor without using media. The test was carried out for 7 times, the data taken every week was then recorded in table 1.

Table 1. Soil Test Results

Date	Hour	Test Results		
		Down Rood (Ohm) Media pipa PVC	**Down Rood (Ohm) Media Bambu**	**Down Rood (Ohms) Without Media**
May 19, 2025	13.00 WELCOME	267	69,5	59,5
May 26, 2025	13.00 WELCOME	296	82,0	72,9
02 June 2025	13.00 WELCOME	234	65,3	65,9
09 June 2025	13.00 WELCOME	316	66,0	78,9
16 June 2025	13.00 WELCOME	265	56,4	93,9
23 June 2025	13.00 WELCOME	328	67,6	66,2
03 July 2025	13.00 WELCOME	358	78,6	138,4

Table 1. The above are the results of the measurement of down conductors from PVC pipe media, bamboo media and without media. The test will be carried out from May 19 to July 3, 2025 at the same time, namely at 13.00 WITA. The resistance value listed on the special down conductor table coated with pvc pipe media has the highest value of 358 Ohms and the lowest value of 234 Ohms. The resistance value listed on the special down conductor table coated with the Bamboo median is 82.0 Ohm and the lowest value is 56.4 Ohm. The resistance value listed in the table where the uncoated down conductor has a value of 138.4 Ohms and the smallest value is 59.5 Ohms. The experiment of points A, B and C on down conductors using pipe, bamboo and without media can be depicted in the form of a compression graph of the three grounding points can be seen in the figure 5.

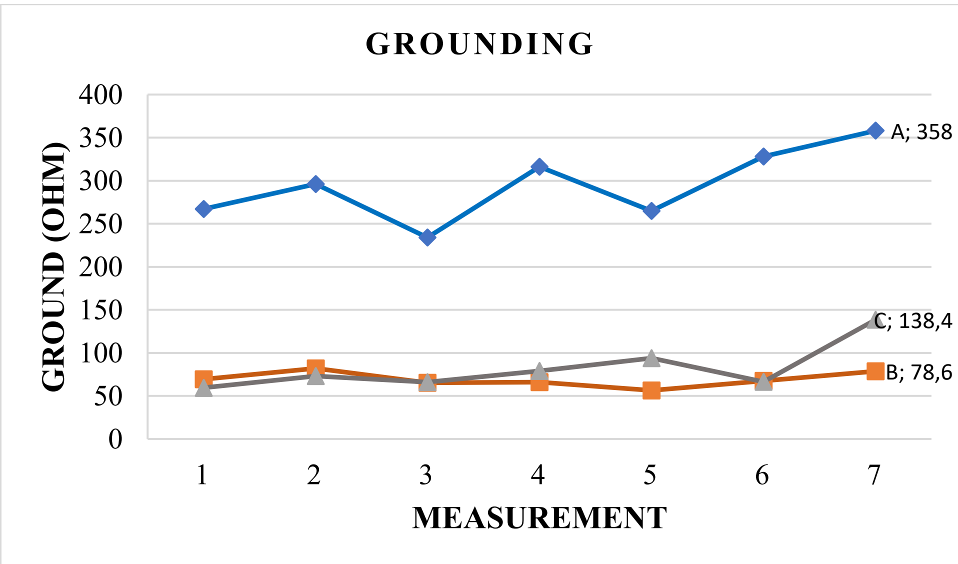

Figure 5. Comparison Graph of Points A, B and C

The comparison of the measurement results on the grounding of points A, B and C, where the resistance value listed on the graph above point A reaches 358 Ohms, point B reaches 78.6 Ohms and point C reaches 138.4 Ohms. When compared to the three grounding points, the value that is close to the PUIL standard is at the B grounding point which uses bamboo media

The results show that the grounding resistance values vary significantly depending on the media used. The PVC pipe media produced the highest resistance values (234–358 Ω), the bamboo media produced moderate values (56.4–82.0 Ω), and the conductor without media produced intermediate values (59.5–138.4 Ω). These results indicate that the type of media significantly affects the soil's ability to conduct electrical current, which aligns with the findings of Widodo (2022) in wind power plants, where improvements to the retention system of the grounding electrode were required to reduce resistance. Similarly, Riyanto (2021) in 150 kV substations demonstrated that proper selection of grounding material and installation techniques could maintain resistance within acceptable standards.

The bamboo media's resistance values were closest to the PUIL 2011 standard (<5 Ω for general installations), suggesting that natural materials with appropriate moisture retention can improve grounding effectiveness. This finding supports Triyanto (2020), who argued that soil characteristics, moisture content, and electrode material significantly influence grounding performance. Unlike previous studies that focused on industrial installations or specific infrastructure types, this study applies experimental measurements to small-scale, site-specific grounding systems, filling a gap in research for practical applications in diverse soil and environmental conditions. By evaluating multiple media under controlled conditions over time, this research provides empirical data for selecting cost-effective and efficient grounding solutions for both urban and rural electrical installations.

CONCLUSION

From the results of the design of engineering experiments and measurements on the grounding system, it can be concluded that, the grounding points A and C that use PVC Pipe media and Without using large media, the resistance value is above the PUIL 2000 standard value, namely point A of the conductor electrode with the highest resistance value of 358 Ohm, the lowest of 234 Ohms and point C of the conductor electrode with the highest resistance value of 138.4 Ohm, lowest 59.5 Ohm and grounding point B of the conductor electrode using Bamboo media the highest resistance value is 78.6 Ohm, the lowest is 56.4 Ohm. The measurement results at three grounding points are very dynamic because they affect the medium used and soil humus. This grounding engineering needs to be continuous in research in order to find out the resistance value obtained according to expectations according to PUIL standards. This grounding engineering method is a further reference for students to practice grounding and as a reference for further research.

REFERENCES

Ahmad, N. N., Ab Kadir, M. Z. A., Izadi, M., Azis, N., & Radzi, M. A. M. (2018). Analysis of soil resistivity and its impact on grounding systems design. *International Journal of Electrical and Computer Engineering, 8*(4), 2364–2372. https://doi.org/10.11591/ijece.v8i4

Araújo, M. A., Farias, P. C. M., Gomes, A. L. M., & Costa, E. G. (2022). A systematic review on grounding impedance measurement in electrical installations. *Electric Power Systems Research, 214,* Article 108921. https://doi.org/10.1016/j.epsr.2022.108921

Aripin, T. (2022). Analisa sistem pentanahan di Universitas Pamulang. *EPIC (Journal of Electrical Power, Instrumentation and Control).*

Bos, P., Chmura, L., & Wiater, J. (2025). Impact of seasons on industrial grounding resistance. *Scientific Reports, 15,* Article 96702. https://doi.org/10.1038/s41598-025-96702-3

Gouda, O. E., Amer, G. M., Abou El-Ela, A. A., & Salem, W. A. A. (2024). Investigation of soil resistivity impacts on the electrodes of grounding system subjected to lightning strikes. *IET Generation, Transmission & Distribution, 18*(19), 3761–3776. https://doi.org/10.1049/gtd2.13287

Hardi, S. (2021, March). Economic design of substation grounding grid using ETAP software: A case study of 2 x 500 MVA Galang Substation. In *Journal of Physics: Conference Series* (Vol. 1811, No. 1, p. 012055). IOP Publishing.

Hermansyah. (2019). Evaluasi kehandalan sistem grounding pada instalasi listrik rumah tinggal di Kabupaten Banteng. *Jurnal Ilmiah d'Computare, 9*(5).

International Electrotechnical Commission. (2024). *Protection against lightning – Part 3: Physical damage to structures and life hazard (IEC 62305-3:2024).* IEC.

Li, J., Yuan, D., Li, Z., He, J., & Zou, J. (2022). On the impact of soil resistivity measurement and modelling on grounding performance. In *2022 IEEE International Conference on High Voltage Engineering and Applications (ICHVE)* (pp. 1–4). IEEE. https://doi.org/10.1109/ICHVE56629.2022.9942653

Nawir, H. (2018). Rancang bangun sistem pentanahan penangkal petir pada tanah basah dan tanah kering pada Laboratorium Teknik Konversi Energi. *Jurnal Ilmu-Ilmu Teknik Elektro dan Rekayasa (JEEE-Umsida), 2*(2), 48-55.

Rimbawati, R. (2019). Analisis pengaruh perubahan arus eksitasi terhadap karakteristik generator (Aplikasi laboratorium mesin-mesin listrik Fakultas Teknik-UMSU). *RELE (Rekayasa Elektr. dan Energi) Jurnal Teknik Elektro, 2*(1), 37-44.

Riyanto, A. (2021). Soil system analysis of the 150 kV substation network at PT Bekasi Power Cikarang. *Technical Journal of Electrical Engineering, 5*(2), 45–52.

Riyanto, A. (2019). Analisis sistem pentanahan jaringan gardu induk 150 kV PT Bekasi Power Cikarang. *Journal,* EISSN: 2502-8464.

Saleh, S. A., & Ramadan, M. (2016). Soil resistivity and ground resistance for dry and wet soil. *Journal of Modern Power Systems and Clean Energy, 4*(2), 203–210. https://doi.org/10.1007/s40565-015-0153-8

Tleis, N. (2015). The influence of seasonal soil moisture on the behavior of soil resistivity and power distribution grounding systems. *Electric Power Systems Research, 115,* 95–100. https://doi.org/10.1016/j.epsr.2014.08.013

Triyanto, A. (2020). Grounding resistance measurement in office buildings. *Journal of Electrical Engineering Research, 7*(3), 112–120. Universitas Pamulang.

Widodo, P. (2022). Grounding system design in wind power plants. *Indonesian Journal of Electrical Engineering, 9*(1), 28–35.

Widodo, P. (2024). Perancangan sistem grounding pada pembangkit listrik tenaga bayu. *Jurnal Ilmiah Mahasiswa Teknik (JIMT), 4*(3), 228–233.

Yulianto, A. (2024). Peer group discussion "grounding" peer group di engineering. *PLN Nusantara Power Service.*