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Increasing the Soil Resistance Value in the 20kV Medium Voltage Distribution Network using the Soil Treatment Method

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Abstract **- This study aims to enhance soil resistivity in a 20 kV electrical distribution network using a mixture of rice husk ash and mangrove wood charcoal. Rice husk ash is an additive known to reduce grounding resistance due to its water-absorbing properties, maintaining soil moisture. Effective grounding system is crucial to ensure fault currents can safely dissipate into the ground, protecting equipment and maintaining electrical distribution continuity. PUIL 2000 standards mandate soil resistivity below 5 Ω. The study method involved initial soil resistivity measurements using a Digital Earth Tester 4015 A, adding various mixtures of rice husk ash and mangrove wood charcoal around electrode planting areas, and periodic resistivity measurements over five days after four mixture additions. Scheme 1, 70% mangrove wood charcoal and 30% rice husk ash. Scheme 2, 30% mangrove wood charcoal and 70% rice husk ash. Scheme 3, 100% rice husk ash. Scheme 4, 100% mangrove wood charcoal. Results showed significant resistivity reduction, with the 30% rice husk ash and 70% mangrove wood charcoal mixture lowering resistivity to an average of 3.78 Ω, reflecting a 43.5% decrease from the initial value. Adding rice husk ash and mangrove wood charcoal to field soil enhanced soil conductivity, enabling resistance reduction to meet safety standards. This study recommends this blend as an effective and economical alternative to reduce grounding resistance in 20 kV electrical distribution systems.**

Keywords : Soil Resistivity,Grounding Resistance,Rice Husk Ash,Mangrove Wood Charcoal,Electrical Grounding System

I. INTRODUCTION

Grounding system is an essential part that must be considered to ensure the safety and reliability of electrical power system operations[1], The grounding system is described as the connection between electrical equipment or circuits and the ground. In the distribution of electrical energy, the power distribution system can cause various disturbances that can result in interruptions in the distribution of electrical energy to customers. Moreover, these disturbances can cause damage to electrical devices. To avoid such disturbances, protection and safeguarding of workers and electrical devices are necessary, one of which is by connecting these devices to the grounding system [2].

Because the power distribution system is a very extensive system, connecting one point to another[3], it is highly vulnerable to disturbances typically caused by short circuits or lightning strikes[4]. hese faults can lead to significant voltage drops, impacting system stability, posing risks to human lives, and damaging electronic equipment or 20 kV equipment components. Therefore, these devices require a grounding system. According to PUIL 2000, the total grounding resistance of the medium voltage network must not exceed 5 Ω[5].

The most important component in the grounding system is the electrode. Commonly used materials for electrodes include copper, chromium iron, and steel. Basic requirements for grounding electrodes include resistance to corrosion (non-corrosive metals), mechanical strength against pressure and impact, and high electrical conductivity[6].Medium voltage distribution networks generally use rod electrodes. Technically, these types of electrodes are easy to install and do not require extensive land. Rod electrodes are made from galvanized steel pipes or bars with a minimum diameter of 5/8” or 1.5”, which are installed into the ground. Besides rod electrodes, there are other types of grounding electrodes, such as strip electrodes and plate electrodes.[7]

During electrode installation, there is no continuous monitoring of the network resistance value. Over time and with seasonal changes, the resistance value around the medium voltage network poles will fluctuate. If the grounding resistance is high, several actions are typically taken to reduce it, such as replacing the installed grounding electrodes and adding additives to the soil [8]. One method to decrease the grounding resistance value is by improving the soil using bentonite as a grounding medium around the electrode. Bentonite is a chemical substance capable of absorbing and retaining water, and it contains electrolytic elements.[9]

When soil is mixed with bentonite or other additives aimed at reducing grounding resistance, blending bentonite with soil makes it more moist as bentonite can absorb and retain water .[10]However, it requires other substances to maintain this moisture. Another material that can be used to maintain soil moisture is charcoal and rice husk ash from burning. Charcoal is the black residue from burning wood and plants, which has a porous texture and hygroscopic properties, meaning it has a high water absorption capacity. The main content of wood charcoal is carbon, which reaches 25.04%. Activated carbon in charcoal functions to enhance soil conductivity [11]. Besides wood charcoal, rice husk can also be processed into charcoal. Waste from rice plants includes straw, bran, and husk. Straw contributes about 55.6% of the total rice yield, while paddy contributes 44.4%. About 65% of paddy is processed into rice, while the rest consists of husk and bran [12]

The method of adding additive substances to reduce grounding resistance in soil composition, known as the soil treatment method, indeed involves the use of chemicals such as ash, charcoal, gypsum, cement, bentonite, and others. These additives serve to maintain soil moisture. Among these additives, ash and charcoal are the most readily available and affordable. To achieve successful results according to IEEE standards (142-1983), the changes resulting from mixing additives must achieve a difference between 15% and 90% [13].

The selection of mangrove wood charcoal as the carbon material in this study is based on the fact that mangrove wood charcoal has a higher carbon value compared to other types of charcoal. According to SNI No 06-3730-1995, the optimal activated carbon test results of mangrove wood charcoal are achieved at an activation temperature of 500 °C, with a carbon content reaching 87.68%.

In this research, we utilized mangrove wood charcoal and rice husk ash in field soil to enhance soil resistivity. Rice husk ash is considered beneficial for electrical grounding due to its good conductivity stemming from its silica and carbon content, which facilitate more efficient electric current flow into the ground. Conversely, mangrove wood charcoal contains minerals like potassium, found in forms such as sylvite (KCl) and carnallite (KMgCl2.6H2O), which are deposited from seawater and gradually accumulate through dust and soil along the coastline. Potassium, represented by K with an atomic number of 19, holds significant electrolytic properties in saline solutions. The utilization of mangrove wood charcoal in electrical grounding can augment soil conductivity and diminish resistivity, thereby enhancing the overall efficiency of the grounding system. We conducted tests on a single electrode rod blended with fine charcoal to achieve the desired increase in resistivity value.

II. LITERATURE REVIEW

A. Rice Husk Ash

Rice husk ash has a high silica content. The chemical composition of rice husk ash consists of 50% cellulose, 25%-30% lignin, and 15%-20% silica. Rice husk charcoal is a ligno-cellulosic material like other biomasses but is formed from incomplete combustion or partial burning of rice husks. The raw material for rice husk charcoal can be easily obtained from rice mills. With the lab test results and contents such as those in Table 1 [12]

Table 1, Rice husk ash content

No	Component	Contents
1	Karbon, C	10,99%
2	Magnesium Oksida, MgO	1,49%
3	silikon Dioksida SiO_2	76,98%
4	Fosfor Pentoksida P_2O_5	4,38%
5	Kalium Oksida K_2O	1,87%
6	Kalsium Oksida CaO	3,16%
7	Tembaga (II) Oksida, CuO	1,14%

B. Mangrove wood charcoal

Figure 2 depicts mangrove wood charcoal, which is produced through the carbonization process of mangrove wood, as an initiative by the community around mangrove forests to utilize unused mangrove wood. Mangrove wood is typically used as firewood. Additionally, mangrove wood can be processed into charcoal of high quality due to its high calorific value, ranging from 4,400 kcal/kg to 7,300 kcal/kg

Figure 1, Mangrove wood charcoal

1. Fixed carbon

Fixed carbon is a parameter that describes the amount of carbon bound from activated carbon at a certain temperature range. The fixed carbon content required by SNI 06-3730-1995 is 65%. The fixed carbon content of this activated carbon ranges from 68.13%-70.25% indicating that all activation temperature ranges and phosphoric acid concentrations used have met the fixed carbon requirements. The highest fixed carbon content of mangrove charcoal activated carbon is 70.51% occurring at 725°C thermal activation operating conditions and 1.0 M phosphoric acid concentration. [14]

2. Potassium Element

The primary source of potassium is seawater in the form of sylvite (KCl) and carnallite (KMgCl2.6H2O). The formation of potassium minerals occurs over extended periods. Minerals from seawater evaporate, leaving salts that precipitate as minerals. These minerals slowly accumulate through dust and soil, resulting in many deposits being found near coastlines today. Saltwater solutions are electrolytes capable of conducting electricity. Potassium, a chemical element in the periodic table, is symbolized by K with atomic number 19. It belongs to the alkali metals group, possessing one valence electron that is easily dissociated, making potassium highly reactive. It can ignite in air and react vigorously in water, producing flames with a distinct color and causing explosions. Alkali metals exhibit excellent electrical and thermal conductivity.

C. Soil Specific Resistivity

Table 2 represents estimated values of resistivity for various types of soil. Researchers have measured the resistivity of different soil types over time through sampling and using specialized instruments, which are less affected by soil mass. Both methods are challenging but more likely to yield accurate results.

Table 2 ground resistance value

No	type of soil	Resistivity
1	Paddy land	30
2	Clay and field soil	100
3	Wet sand	200
4	Wet gravel	500
5	Dry sand and gravel	1000
6	Rocky soil	3000

D. Rod Electrode

Grounding rods are essential components in electrical systems that provide a pathway for unwanted electrical currents or surges that may occur due to disturbances or lightning strikes. These rods are typically made of metals such as copper or copper-coated steel, and are buried into the ground to ensure good contact with the soil. Rod electrodes are chosen because they provide excellent soil contact, efficient dispersion of fault currents, ease of installation, and are more economical compared to other types of electrodes such as plates or tapes. This research is expected to provide insights into the effectiveness of this material mixture in grounding systems.

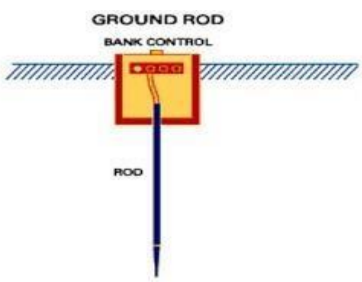

Figure 2, Rod Electrode

Figure 3, depicts a control box electrode, which functions as a terminal to connect the grounding rod to the electrical system.

$$R = \frac{\rho}{2 \times \pi \times L} In\left(\frac{4L}{a}\right) - 1$$

With :

ρ = Soil density resistance (Ωm)
Rbt = Electrode grounding resistance (Ω)
L = Electrode length (m)
a = Cross-sectional area (m)[15]

III. METHOD

Figure 4 is the research flowchart. This research was conducted in the Medium Voltage network area of PT. PLN ULP Sumber, Cirebon Regency, at one of the poles on the Wanasaba feeder, over 5 days of measurement. The study employed the method of adding additive substances from mangrove wood charcoal and rice husk ash with several mixing methods: a mixture of 30% mangrove wood charcoal and 70% rice husk ash, 70% mangrove wood charcoal and 30% rice husk ash, 100% rice husk ash, and 100% mangrove wood charcoal

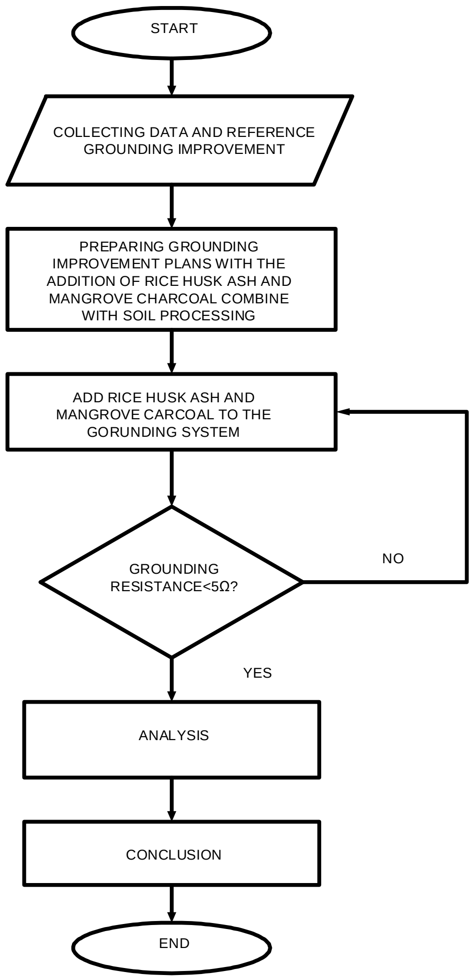

Figure 4, research flowchart of resisntation value improvement

A. Test Design

Figure 5 illustrates the schematic design of a copper electrode utilizing various charcoal mixtures. The aim of this study is to enhance grounding resistance in a 20 kV distribution system by using a blend of rice husk ash and finely ground mangrove wood charcoal. The experimental setup involves embedding a rod electrode 120 cm into the soil, with four different testing scenarios: (1) a mixture of 30% rice husk ash and 70% mangrove wood charcoal, (2) a mixture of 70% rice husk ash and 30% mangrove wood charcoal, (3) 100% mangrove wood charcoal, and (4) 100% rice husk ash.

Table 3, comparison of the addition of additives

No	Material	
	Rice Husk Ash	Mangrove Wood charcoal
1.	30 % (2400 grams)	70 % (5600 grams)
2.	70 % (5600 grams)	30 % (2400 grams)
3.	100 % (8000 grams)	-
4.	-	100 % (8000 grams)

The bottom 20 cm of the hole is filled with native soil. Light-colored ash represents rice husk ash, and dark-colored ash represents mangrove wood charcoal. To expedite the compaction process, the mangrove wood charcoal is finely ground..

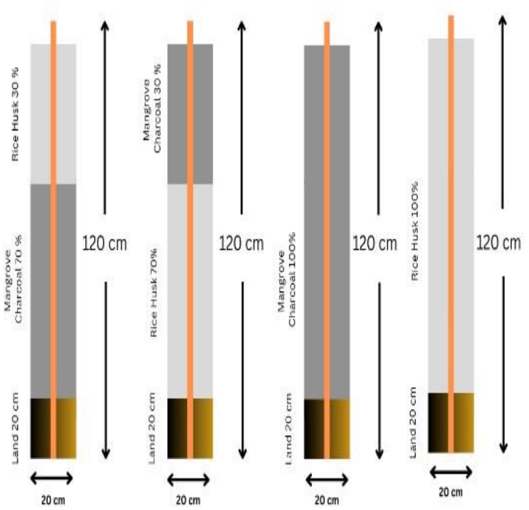

Figure 5, Mixed Material Scheme

IV. Results and Discussion

Based on the initial results of soil resistivity measurements for the 20 kV distribution grounding system, the soil resistivity reached 6.94 Ω at a depth of 120 cm, exceeding the PUIL 2000 standard, which sets the maximum value at 5 Ω. This condition prompted further research on the use of rice husk ash and mangrove wood charcoal mixtures to optimize the performance of the grounding system. Evaluation of the mixture containing 70% mangrove wood charcoal and 30% rice husk ash showed a reduction in soil resistivity to 3.59 Ω. This success indicates the effectiveness of the mixture in enhancing soil conductivity and significantly reducing resistivity.

ground.he consideration of not using a 50% mangrove wood charcoal and 50% rice husk ash mixture is likely based on the effective results already achieved with the 70/30 mixture. A higher proportion of mangrove wood charcoal in the mix can offer additional benefits in moisture absorption and improved soil conductivity, potentially providing long-term stability for the grounding system.

Although the PUIL 2000 standard sets a maximum limit of 5 Ω for soil resistivity, mixtures such as 70% mangrove wood charcoal and 30% rice husk ash have proven to meet or even exceed this requirement. Utilizing a mixture that has been effectively verified can provide consistency in the operational performance of the grounding system while considering practical factors such as material availability and cost, as well as the long-term impact on system stability and performance.

Table 4, Initial measurement data

Electrode diameter	Depth	Resistance Value (ohms)
14 mm	120 cm	6,94 Ω

1. A Mixture Of 70% Mangrove Wood Charcoal And 30% Rice Husk Ash.

Table 5 presents a planting scheme demonstrating the effects of adding a mixture consisting of 70% mangrove wood charcoal and 30% rice husk ash. Daily measurements indicate a steady decrease in resistivity values. The method involves placing 30% rice husk ash at the base of the planting hole, followed by 70% mangrove wood charcoal on top. This method successfully decreased the soil resistivity progressively each day, as documented in Table 4.

Table 5, Measurement Of 70% Mangrove Wood Charcoal And 30% Rice Husk Ash.

Day	Test			Average Resistance value Ω
	I	II	III	
1	5.02 Ω	4.76 Ω	4.21 Ω	4.47 Ω
2	4.35 Ω	4.03 Ω	3.51 Ω	3.96 Ω
3	4.87 Ω	3.67 Ω	3.75 Ω	4.09 Ω
4	4.76 Ω	3.74 Ω	3.89 Ω	4.13 Ω
5	4.43 Ω	3.70 Ω	3.90 Ω	4.01Ω

2. Mixture of 70% rice husk ash and 30% mangrove wood charcoal

Based on Table 6, one of the mixture combinations that significantly reduces soil resistance is composed of 70% rice husk ash and 30% mangrove wood charcoal. According to the data, this mixture continuously decreases the resistance value each day. On the first day, the resistance value was recorded at 4.05 ohms, then decreased to 3.90 ohms on the second day. This decrease continued until it reached the lowest value of 3.59 ohms by the fifth day.Table 3 mixture of 70% rice husk ash and 30% mangrove wood charcoal. With this composition, the mix successfully improved the conductivity of the soil and increased the efficiency of the grounding system, as listed in Table 5.

Table 6, mixture of 70% rice husk ash and 30% mangrove wood charcoal

Day	Test			Average Resistance value Ω
	I	II	III	
1	4.2 Ω	4.03 Ω	3.97 Ω	4.07 Ω
2	4.3 Ω	4 Ω	3.4 Ω	3.90 Ω
3	4.19 Ω	3.45 Ω	3.46 Ω	3.70 Ω
4	4.12 Ω	3.29 Ω	3.58 Ω	3.67 Ω
5	4.43 Ω	3.23 Ω	3.1 Ω	3.59 Ω

3. 100% mangrove wood charcoal

Based on Table 7, the use of electrodes using 100% mangrove wood charcoal also results in a decrease in soil resistivity. According to the recorded data, on the first day, the soil resistivity reached 4.19 ohms. This value then decreased to 4.01 ohms on the second day. The decrease continued, reaching 3.98 ohms on the third day. The most significant decrease occurred on the fourth day, with a resistivity of 3.73 ohms. Finally, on the fifth day, the lowest resistivity recorded was 3.14 ohms. Therefore, the use of 100% mangrove wood charcoal effectively reduces soil resistivity gradually, achieving a decrease of 24.6% compared to the initial value.

Table 7 . Measurement Of 100% Mangrove wood charcoal

Day	Test			Average Resistance value Ω
	I	II	III	
1	4.17 Ω	4.57 Ω	3.85 Ω	4.19 Ω
2	4.18 Ω	4.35 Ω	3.52 Ω	4.01 Ω
3	4.56 Ω	3.65 Ω	3.73 Ω	3.98 Ω
4	4.06 Ω	3.25 Ω	3.89 Ω	3.73 Ω
5	3.01 Ω	3.31 Ω	3.1 Ω	3.14 Ω

4. 100% rice husk ash

been shown to decrease soil resistivity. According to the recorded data, on the first day, the soil resistivity was 3.65 ohms. This value slightly increased to 3.87 ohms on the second day. However, there was a significant increase in resistivity on the third day, reaching 3.96 ohms. The resistivity continued to increase on the fourth day to 4.02 ohms. Nonetheless, by the fifth day, using 100% rice husk ash resulted in the lowest resistivity recorded at 3.24 ohms. Thus, despite temporary increases on some days, the variation using 100% rice husk ash effectively reduced the overall soil resistivity by 53% compared to the initial value Table 8. Measurement Of 100% Rice Husk Ash.

Table 8, Measurement Of 100% rice husk

Day	Test			Average Resistance value Ω
	I	II	III	
1	3.98 Ω	3.75 Ω	3.22 Ω	3.65 Ω
2	3.82 Ω	3.88 Ω	3.91 Ω	3.87 Ω
3	4.28 Ω	3.93 Ω	3.67 Ω	3.96 Ω
4	4.24 Ω	3.89 Ω	3.93 Ω	4.02 Ω
5	3.07 Ω	3.37 Ω	3.28 Ω	3.24 Ω

5. Average comparison of mixed schemes

Based on Figure 5, the initial soil resistivity measured before any additives were introduced was 6.94 ohms, which was the highest compared to the average values across all five planting schemes. The planting scheme that showed the greatest average decrease in soil resistivity compared to the initial value was the mixture of 70% mangrove wood charcoal and 30% rice husk ash, with an average value of 3.75 ohms, representing a decrease of 45.97%. This was followed by the planting scheme using 100% mangrove wood charcoal and 100% rice husk ash, which decreased by 49.71% (3.49 ohms) and 52.45% (3.78 ohms) respectively. Meanwhile, the scheme with a mixture of 70% rice husk ash and 30% mangrove wood charcoal reduced the average value to 4.10 ohms, or 40.92%.

From the comparisons above, it can be concluded that adding a mixture of mangrove wood charcoal and rice husk ash to the planting scheme significantly reduces the baseline resistance value of the grounding system by more than 40% from the initial value of 6.94 ohms.

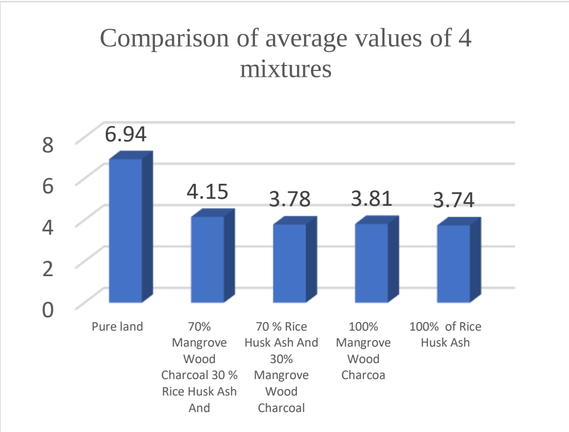

Figure 6 Comparison Of Average Values Of 4 Mixtures

V. CONCLUSION

Based on the research findings, it can be concluded that the addition of a mixture of rice husk charcoal and mangrove wood charcoal in electrode planting areas significantly reduces the resistivity of the grounding system. The initial resistivity value of 6.94 Ω can be lowered to 3.78 Ω with the addition of the mixture, representing a decrease of approximately 43.5% from the original value. These results demonstrate the effectiveness of using rice husk charcoal and mangrove wood charcoal mixtures in enhancing soil conductivity. This study aligns with previous research indicating that the use of additional electrodes and additives such as zeolite, salts, and charcoal can effectively reduce soil resistivity below standard levels. The difference lies in this study's use of local materials, specifically rice husk charcoal and mangrove wood charcoal. The outcomes suggest that these natural materials can also be applied as mixtures to significantly reduce soil resistivity. With further refinement, this mixture is expected to be developed as a sustainable alternative solution for improving grounding systems in areas with high soil resistivity.

V. Advice

Based on the findings and conclusions of the study, the researchers provide the following recommendations. First, to obtain a lower ground resistivity value that complies with PUIL standards, it is recommended to use a mixture of rice husk ash and mangrove wood charcoal in the electrode planting area, with a composition of 30% rice husk ash and 70% mangrove wood charcoal. Secondly, further tests need to be conducted to explore various percentages of rice husk ash and mangrove wood charcoal to identify the most optimal combination to reduce ground resistivity. Third, due to the different soil types between the test area and the actual ground placement, preliminary testing is required to determine the appropriate type and composition of the mixture. Fourth, consideration should be given to weather conditions, rainfall, and soil moisture when determining the resistance measurement cycle for more accurate results. Fifth, the findings from this study can be applied to improve ground resistivity values in other medium voltage distribution systems. Lastly, for field applications, the cost implications of adding admixtures over a larger grounding area should be taken into account

References

[1] I. Israq, M. Muhammad, A. Bintoro, And B. B. Pokhrel, "Analysis Of A Grounding System In 20 Kv Distribution Transformer Line In Pltd Gayo Lues," *International Journal Of Advances In Data And Information Systems*, Vol. 3, No. 2, Pp. 66–73, Nov. 2022, Doi: 10.25008/Ijadis.V3i2.1239.

[2] F. Lubis, H. Hamdani, And A. Info, "An Analysis Of The Grounding System In The 20 Kv Transformer Using Rod Electrodes In Pt. Pln (Persero) Ulp Parapat," *Jurnal Scientia*, Vol. 12, No. 03, P. 2023, 2023, [Online]. Available: Http://Infor.Seaninstitute.Org/Index.Php

[3] S. M. Myint, K. T. Hla, And T. T. Tun, "Effective Earthing System Of Electrical Power Engineering Department Using Optimal Electrodes," *International Journal Of Advanced Technology And Engineering Exploration*, Vol. 7, No. 63, Pp. 28–35, Feb. 2020, Doi: 10.19101/Ijatee.2019.650084.

[4] S. Hardi, A. Kristian, A. Hasibuan, A. Nasution, And M. Alfhisyari, "Mitigation Of Soil Resistivity Using Composition Of Zeolite, Nacl, And Charcoal," In *Journal Of Physics: Conference Series*, Institute Of Physics, Feb. 2022. Doi: 10.1088/1742-6596/2193/1/012032.

[5] D. E. Putra, R. A. Yani, M. S. Siahan, And C. Rizal, "Decreasing Ground Potential Rise By Lessening Soil Resistance In Arrester Grounding System," *International Journal Of Electrical Engineering And Information Technology*, Vol. 06, 2023.

[6] C. Zhang, Y. Liao, X. Gao, J. Zhao, Y. Yuan, And R. Liao, "Research Advances Of Soil Corrosion Of Grounding Grids," *Micromachines (Basel)*, Vol. 12, No. 5, 2021, Doi: 10.3390/Mi12050513.

[7] Y. T. Nugraha, L. Rahmani Laia, And B. Ismail, "Comparative Analysis Of Earthing Resistance On Rod And Plate Electrodes For Improvement Of Earthing Resistance Values," *Journal Of Electronics*, Vol. 1, No. 2, Pp. 41–49, 2022, [Online]. Available: Http://Jurnal.Unprimdn.Ac.Id/Index.Php/Jteprima

[8] A. Azmi, N. A. Ahmad, L. K. Yiew, And Z. Abdul-Malek, "The Use Of Enhancement Material In Grounding System: A Review," *Indonesian Journal Of Electrical Engineering And Computer Science*, Vol. 13, No. 2. Institute Of Advanced Engineering And Science, Pp. 453–460, Feb. 01, 2019. Doi: 10.11591/Ijeecs.V13.I2.Pp453-460.

[9] N. M. Karmiathi And P. M. P. Yoga, "The Grounding Resistance Improvement Of Distribution Substation Using Multiple Rods And Wood Charcoal As Soil Treatment," *Matrix : Jurnal Manajemen Teknologi Dan Informatika*, Vol. 13, No. 1, Pp. 33–41, Mar. 2023, Doi: 10.31940/Matrix.V13i1.33-41.

[10] Ismujianto, Isdawimah, And N. Nadhiroh, "Improvement Of Electrical Grounding System Using Bentonite," In *Journal Of Physics: Conference Series*, Institute Of Physics Publishing, Dec. 2019. Doi: 10.1088/1742-6596/1364/1/012063.

[11] P. H. Partaoanan Harahap And W. K. A. Al-Ani, "The Effect Of Charcoal On The Improvement Of Grounding Resistance As A Soil Treatment In Reducing Grounding Resistance," *Journal Of Renewable Energy, Electrical, And Computer Engineering*, Vol. 1, No. 1, P. 12, Mar. 2021, Doi: 10.29103/Jreece.V1i1.3619.

[12] J. K. W. Wira, H. Halomoan Sinaga, N. Purwasih, And D. Permata, "Kinerja Arang Sekam Padi Untuk Memperbaiki Nilai

Resistansi Pentanahan Dengan Menggunakan Elektroda Baja Galvanis Dan Tembaga," 2022.

[13] Y. Martin, "Composition Of Mixing Gypsum Additives As Environmentally Friendly Material In Tropical Soil To Reduce Grounding Resistance," In *Iop Conference Series: Earth And Environmental Science*, Institute Of Physics Publishing, Aug. 2019. Doi: 10.1088/1755-1315/314/1/012019.

[14] A. Budianto, E. Kusdarini, S. S. W. Effendi, And M. Aziz, "The Production Of Activated Carbon From Indonesian Mangrove Charcoal," In *Iop Conference Series: Materials Science And Engineering*, Institute Of Physics Publishing, Jan. 2019. Doi: 10.1088/1757-899x/462/1/012006.

[15] D. E. Putra, Z. Nawawi, And M. I. Jambak, "Earth Resistance And Earth Construction To Interference Currents On Swamp Land," 2022. [Online]. Available: Http://Creativecommons.Org/Licenses/By-Sa/4.0/