TELKOMNIKA Telecommunication Computing Electronics and Control
Vol. 23, No. 3, June 2025, pp. 781~788
ISSN: 1693-6930, DOI: 10.12928/TELKOMNIKA.v23i3.26647

Clustering of swamp land types against soil resistivity and grounding resistance

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Article Info

Article history:

Received Sep 5, 2024
Revised Jan 30, 2025
Accepted Mar 11, 2025

Keywords:

Comparison resistivity
Grounding resistance
Potential of hydrogen
Soil type resistivity
Swamp land clustering

ABSTRACT

In theory, the resistivity value of the soil is one of the factors that must be taken into account when planning a grounding installation. The resistivity value of swamp soil is 30 Ωm, as per the general requirements for electrical installation of 2011 (PUIL 2011). This value is identical to the resistivity of the soil type in The Institute of Electrical and Electronics Engineers (IEEE standard 80 in 2000), where the wet soil type has a resistivity value of 100 Ωm. It is difficult for electrical engineers to design construction on swamp land because the standard's representation of the features of swamp land does not accurately reflect the types of swamps or wetlands that exist in reality. The focus of this investigation is the resistivity value of swamp soil types. The results of this investigation will make a scientific contribution to the clustering of land at each soil resistivity value in freshwater, brackish water, saltwater, and acidic water swamp land. These soils have pH values that range from 3.5 to above 6. The research on swamp land clustering has revealed that each swamp has a distinctive resistivity value for the different types of swamp soil.

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1. INTRODUCTION

The installation and use of electrical equipment that is powered by voltage and electric current is currently required in a variety of sectors, including homes, offices, and industry [1]. The electrical equipment is not only installed on dry land but also on wet land [2]. The installation of both high-voltage and low-voltage electrical equipment is necessary to protect and prevent the danger of touch voltage from electrical equipment [3]. The presence of touch voltage is caused by fault current or leakage current, which can be caused by lightning strikes [4], [5], or the induction of the use of electrical equipment [6]. Of course, one of the safest protections for living things is the grounding system [7], which is designed to ensure that the fault current flowing in parts of the equipment made of metal [8] or made of metal [9] is quickly distributed evenly into the ground [10]. These numbers show that the goal of the grounding system is to lower the ground potential rise in the areas around electrical installations. This can stop insulation from failing or currents from leaking out by sending electricity into the ground [11].

Soil conditions, such as soil moisture and pH (potential hydrogen) content, influence the resistivity and grounding resistance of soil [12]. However, the soil type characteristics of each land are unique, with some being dry or wet. Consequently, research on soil type characteristics is very intriguing. The installation of electrical equipment and the construction of electrical installations on swamp land with varying types of swamp land will present a unique challenge due to the increasingly intricate characteristics of swamp land.

Although swamp land or wetlands possess distinctive characteristics that influence soil resistivity, there is still a scarcity of information regarding the resistivity of these types of land. This lack of data consequently hinders the planning of a safe and effective grounding system on swamp land.

At present, soil resistivity and grounding resistance research is frequently conducted on dry land or land with low water content [13]. This is due to the fact that testing practices are straightforward to conduct on such land or fields and are easily accessible [14]. It is also predictable. Nevertheless, the expansion of construction on the distribution system, the interconnection of generation systems within or between archipelagos, and the use of electrical energy not only on dry land but also on wetlands or swamps has resulted in the necessity of an effective grounding planning system on swamps. This is due to the development of technology and electrical system installations, including generation systems, distribution systems, and electrical energy utilization systems [15]. The difficulty in designing an appropriate grounding system is further compounded by the limited information available on the characteristics of wetlands or swamps, including pH (hydrogen potential), conductivity, humidity, and the types of swamps based on water taste (fresh, salty, brackish, and acidic). Where the resistivity value of the soil type in question, such as 30 Ωm from that the general requirements for electrical installation of 2011 (PUIL 2011) [16], [17], is illustrated in Table 1. The grounding system in swampy areas may be at risk of safety and reliability due to the fact that PUIL 2011 does not accurately reflect the actual conditions. Table 2 displays the soil resistivity value of 100 Ωm for wet soil, as specified in The Institute of Electrical and Electronics Engineers (IEEE) 80 in 2000 [18].

In order to address the issue of the established standards failing to accurately represent the actual conditions of swamps in the field, it is necessary to conduct comprehensive research on the soil resistivity of various types of swamp land, as determined by the taste of the swamp water. The resistivity of soil types and grounding resistance should be measured in this study, taking into account the environmental conditions, including water pH conditions and swamp water conductivity, as well as variations in the taste of swamp water [19]. We can offer new information that is more precise and pertinent for the planning of grounding systems by classifying swamp land according to the characteristics of water taste [20]. Moreover, tailoring test methods to the specific conditions of wetland environments will yield significant benefits.

Table 1. Resistivity of PUIL 2011 soil types

Soil types	Resistivity (Ω-m)
Marshland	30
Clay and farmland	100
Wet sand	200
Wet gravel	500

Table 2. Resistivity of IEEE std 80-2000 soil types

Type of earth	Average resistivity (Ωm)
Wet organic soil	10
Moist soil	10^2
Dry soil	10^3
Bedrock	10^4

Engineers, practitioners, and academics in the field of electricity will derive a substantial scientific contribution from this research. By using more accurate data on the resistivity of soil types in swampy areas [6], [21], engineers and practitioners can lower the risk of system failure that could hurt living things or damage electrical installations. Consequently, they can design a more effective and secure grounding system. Furthermore, it is anticipated that the research conducted will serve as a reference for relevant parties in the development of more comprehensive technical standards for the design of electrical installations in swampy areas or wetlands. With this information, policymakers can make rules that encourage the use of technology and best practices in grounding systems. This will lead to safer and more long-lasting construction or electrical infrastructure in swampy areas.

This study not only provides technical data but also benefits or contributes to public safety and sustainable electrical infrastructure. It reduces the risk of grounding system failure, protects equipment, and will establish a more reliable and safe electrical system, particularly on land that is susceptible to grounding issues. This study also paves the way for additional research on the management and utilization of swamp land resources in the context of electrical infrastructure.

2. METHOD

The research on soil type resistivity in swamp land was conducted using direct field observation and experimental methods. For direct measurements of soil type resistivity, the ECTR 2000C measuring tool was used along with the 3-point method [22], [23]. The Earth Tester Kyioritsu Digital R 1405 was used along with the earth resistance measuring tool to find the grounding resistance. This was done to demonstrate that swamp land has varying soil type resistivity based on the type of swamp water taste, including freshwater swamp land, brackish water swamp land, saltwater swamp land, and acidic water swamp land. The grounding resistance value was determined from the direct measurement results of a calibrated measuring instrument with serial number W8205886. This value was converted to soil resistivity using the Wenner and U.Dwight methods [24]. To back up the research results, it was important to look into how much hydrogen might be in the water from the different types of swamps in the Palembang City Environmental and Sanitation Service's environmental lab.

- Wenner method: $\rho = 2\pi lR$ (1)
- U. Dwight method: $\rho = \frac{2\,\pi\,l\,R}{ln\frac{4l}{a}-1}$ (2)

The research locations were conducted in different places, including:

a. Resistivity research on freshwater swamp soil types at the Keramasan Main Substation Rawa and Jakabaring Main Substation Rawa, Palembang City, Indonesia.
b. Research on the resistivity of salt water swamp soil types in Muara Sungsang Village, Banyuasin Regency, Indonesia.
c. Resistivity research on brackish water swamp soil types in Tanjung Lago Village, Banyuasin Regency, Indonesia
d. Resistivity research on acid water swamp soil types in Karang Anyar Village, Banyuasin Regency, Indonesia

Furthermore, Table 3 presents the measuring tools and research equipments as the materials data for conducting research.

Table 3. Measuring tools and research equipments

Information	Electrode type and size
Electrode shape	Round rod
Electrode materials	Galvanized plated iron (zinc coated steel)
Electrode length	200 cm (2 meter)
Electrode diameter	0,01656 meter
Electrode radius	0,00828 meter
Electrode embedding depth	1 meter
Resistance earth tester	Kyoritsu R 1450 A Digital
Resistivity soil tester	ETCR 2000C

3. RESULTS AND DISCUSSION

In comparison to other types of swamps, such as freshwater swamps, saltwater swamps, and brackish water swamps, this study discovered that low pH swamps, particularly acidic swamps, exhibited a higher soil resistivity, as shown in Figure 1. This finding means that higher resistivity has a big impact on how grounding systems are made, since acidic water has a high conductivity that is inversely proportional to its soil resistivity. For instance, acidic swamp water (T4) exhibited the highest conductivity of 162 µs/cm and the lowest pH of 3.12, whereas freshwater swamp (T3) exhibited a conductivity of 106.6 µs/cm and a pH of 6.75. There were big differences in the chemicals present in the different types of swamps. For example, the lower conductivities of the saltwater swamp (T2) and the brackish water swamp (T1) were 28.1 µs/cm and 6.82 µs/cm, respectively.

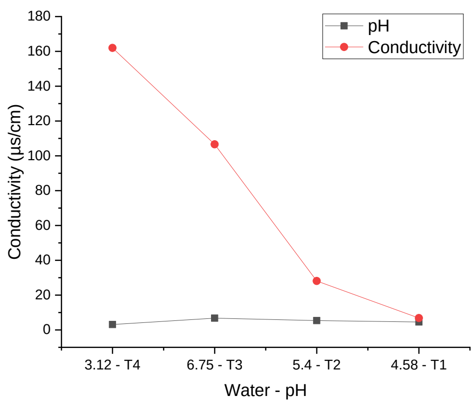


Figure 1. Swamp water conductivity graph

From the measurement results, the average resistivity of the swamp soil shows that acidic swamps have higher resistivity than other types of swamps. Although acidic water should have low resistivity due to its high conductivity, in reality the resistivity of the soil in acidic swamps is higher than in freshwater and brackish swamps. The soil in saltwater swamps, brackish swamps, and freshwater swamps generally consists of mud with clay on the surface, while acidic swamps have clay soil coated with mud. There are four places in Figure 2 where the soil resistivity (in Ωm) is shown to be related to the pH of the swamp water. These are T1 (Brackish Swamp), T2 (Salt Swamp), T3 (Fresh Swamp), and T4 (Acid Swamp). T4, with the lowest pH of 3.12, has a high resistivity reaching 350 Ωm, indicating better insulating properties due to its acid content. In contrast, T3 with a pH of 6.75 has a lower resistivity, around 150 Ωm, indicating more conductive soil. T1 and T2 showed lower resistivity compared to T4 but were higher than T3, with a pH of 4.58 and 5.4, respectively. The variation of pH at each location affects the soil resistivity, which can affect the grounding system in swampy areas.

From the results of the study with direct measurements in the field, it was found that the grounding resistance varied significantly in each type of swamp land. This shows that soil resistance and resistivity values need to be grouped in a way that helps researchers and engineers choose the right electrode materials and grounding structures for each site. Geographically, saltwater swamps have lower soil resistance and resistivity values compared to the other three types of swamps. The graph in Figure 3 compares soil resistivity (in Ωm) and soil resistance (in Ω) using two measurement methods: Wenner and U. Dwight. T4 has the highest resistance of 46 Ω, indicating better insulating properties, while T2 shows the lowest resistance of 1 Ω, indicating highly conductive soil due to its high salt content. T3 and T1 have resistance of 24 Ω and 16 Ω, respectively, indicating moderate conductivity. The resistivity values vary, but they reveal the soil and environment in each swamp and how consistent the measurement methods were.

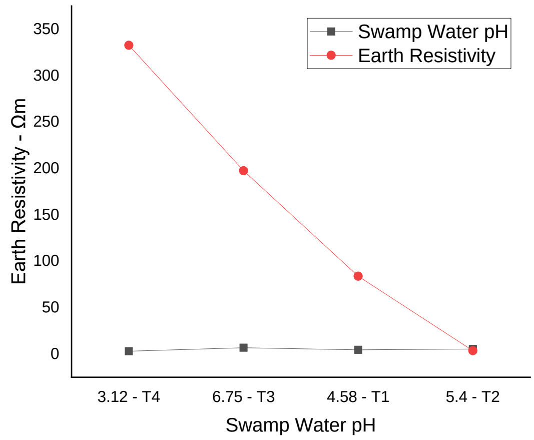


Figure 2. Resistivity graph of swamp soil types

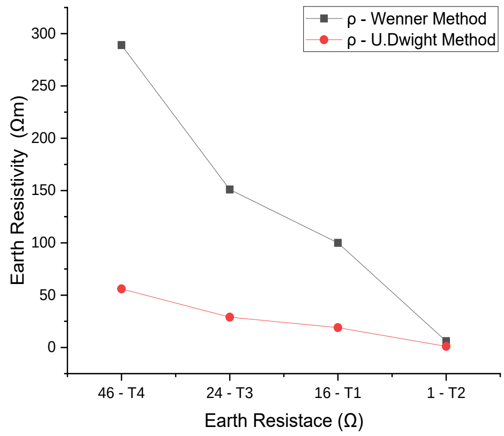
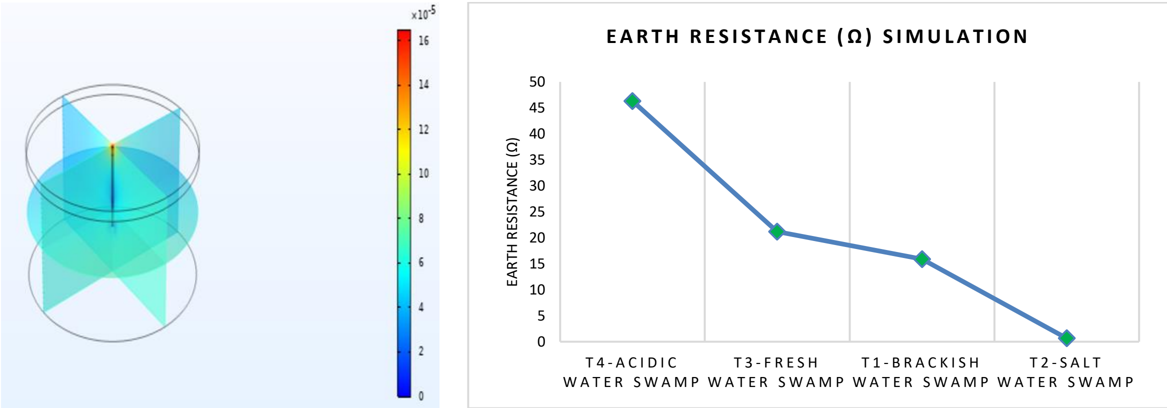


Figure 3. Graph of grounding resistance against swamp soil type resistivity

The simulation in Figure 4(a) shows the grounding contours of the marshland, while the one shown in Figure 4(b) is the simulated grounding resistance value, which is close to the direct measurement results for various types of marshlands based on their water taste. Acidic swamps have a grounding resistance of 46.31 Ω, followed by freshwater swamps with 21.21 Ω, brackish swamps 15.89 Ω, and saltwater swamps 0.66 Ω. Although the resistance values are different, the distribution of hot spots is visible on the surface of the swamp soil. This is because the soil surface has a greater resistance than the tip of the grounding electrode at a depth of 1 meter, with a resistance value still below 100 Ω. From the simulation, it can be concluded that acidic swamps have the highest resistance value, indicating that the soil in this swamp has lower conductivity and higher resistivity than other types of swamps.

In addition, soil resistivity analysis shows that acidic swamps (T4) have high resistivity, reaching 350 Ωm, in contrast to freshwater swamps (T3), which have lower resistivity, around 150 Ωm. This shows that pH variations in each location affect soil resistivity, which can affect the grounding system designed for each type of land. The comparison of Figure 5 with the IEEE 80-2000 and PUIL 2011 standards reveals that the resistivity value of acidic swamp soil significantly surpasses the current standards, highlighting the necessity for updating these standards to account for specific swamp conditions. These findings underline the importance of classifying swamps based on their type of water taste to facilitate grounding system planning.

By putting swamps into groups, professionals and researchers can be more precise when selecting materials and designing grounding systems. This makes electrical installation work in wetland areas safer and more reliable. This research provides new insights that the characteristics of soil resistivity in swamps are not uniform, even though they have high humidity, and require more attention in electrical system planning.



(a) (b)

Figure 4. Simulation results; (a) contour and (b) graphs of grounding resistance

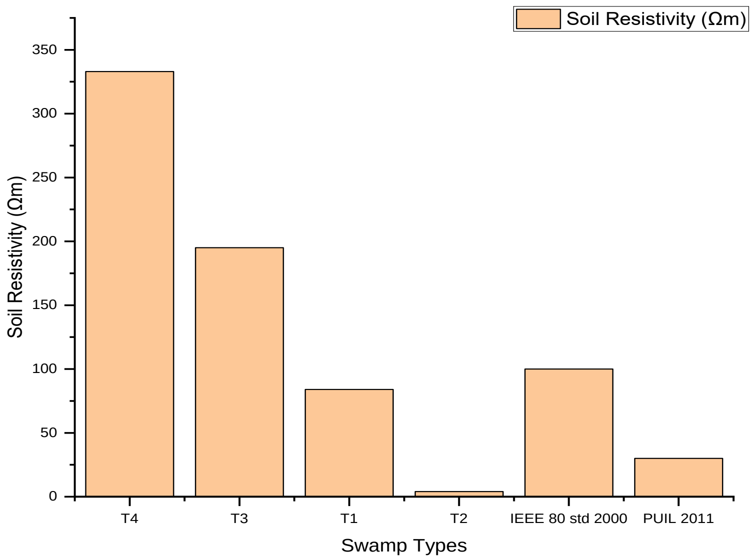


Figure 5. Comparison of swamp soil type resistivity against IEEE std 80-2000 and PUIL 2011

The pH of the swamp water and the resistivity of the soil were measured in the field. The results show that acidic swamp land with a low pH has lower resistivity and grounding resistance values than other types of swamps. This supports the view that groundwater pH affects the electrophysical characteristics of the soil. Variations in measurements show significant differences between swamp types, where acidic swamps have higher resistivity, while saltwater swamps have lower resistivity. These findings highlight that swamps do not have uniform resistivity characteristics, even though they all have high humidity. The resistivity value of acidic swamp soil, which is mostly clay, is much higher than the standards set by PUIL 2011 [25] and IEEE 80-2000 [26]. This indicates the need for standard updates to cover specific swamp conditions. This study emphasizes the importance of classifying swamp land based on water taste types to facilitate grounding system planning. Engineers and academics can better choose the right grounding system materials and designs by grouping swamp land together, either by using rod electrodes with demarcated sizes as required and the required planting depth [27]. This can improve the security, safety, and operational reliability of electrical installations in swamp areas.

4. CONCLUSION

The study on the clustering of swamp land found that acidic water swamps have higher resistivity values and a lower pH than other types of swamps. This study answers the question of how different pH values can affect the resistivity of different types of soil and shows that not all wetlands have low soil resistivity. Where these findings show the difference in soil resistivity values in each type or classification of swamp (freshwater swamps, brackish water swamps, saltwater swamps, and acidic water swamps) so that this study answers the classification of swamp types can affect the design of grounding systems and emphasizes the importance of knowledge of the characteristics and specifications of swamp land types based on water taste. The study also found places where the resistivity value of acidic water swamp soil types is higher than what is listed in IEEE 80-2000 and PUIL 2011. This means that the standard needs to be changed in the future to reflect real-world conditions and answer questions about how relevant and accurate the standards are when planning grounding systems. Because the resistance and resistivity of different types of swamp soil are very different, planners, engineers, and academics need to think about how the swamp land is classified when they are making plans for grounding systems. This will help them come up with the safest and most effective grounding systems for each type of swamp soil.

Ultimately, conducting research on the classification of swamp land can offer scientific understanding of its electrophysical properties, which can then inform the design and implementation of grounding systems. In this study, the researchers didn't look into how the different types of swamp soil are spread out based on how the water tastes. To advance science in the field of grounding systems, specifically the resistivity of swamp soil types, more research needs to be done on grounding resistance, which is affected by the length and diameter of the electrodes used, and at depths of more than one meter using different types of rod electrodes, like copper-coated iron rod electrodes or iron rod electrodes, to compare grounding resistance and soil resistivity. The results of this study may not be applicable to all types of swamps due to its limited scope. Expanding the study to more locations can provide a more comprehensive picture, namely about grounding resistance parameters. To learn more about how water taste affects soil resistivity and pH, and what this means for planning grounding system installations in the future, a comparison study between swamps in different parts of the world needs to be done. At the same time, data on soil resistivity and water pH can help with planning infrastructure. For example, when building facilities for grounding systems in electrical installations, it's important to take into account the unique properties of swamp soil types.

ACKNOWLEDGMENTS

We would like to thank our brother Rahmawan Cs for the tremendous effort he put into the rock in the field.

FUNDING INFORMATION

In this research, the authors declare that no funding is involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dian Eka Putra	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
Muhammad Irfan Jambak		✓				✓		✓	✓	✓	✓	✓		
Zainuddin Nawawi	✓		✓	✓		✓	✓		✓	✓	✓		✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

We hereby inform you that our research does not use humans or animals as research objects.

DATA AVAILABILITY

- The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].
- The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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