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Experimental investigation of soil pH Engineering with eco enzyme to improve grounding performance

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ABSTRACT

The reliability of electric power distribution, in mitigating fault and disturbances, is strongly influenced by the effectiveness of grounding systems. A key factor in achieving low grounding resistance an essential requirement per construction and safety standards is soil condition. High grounding resistance is frequently observed in field implementations and is closely linked to soil resistivity, type, stratification, moisture content, and acidity (pH). This quantitative applied research addresses the persistent challenge of high grounding resistance by experimenting with investigating six grounding system models subjected to varying soil acidity levels. The study introduces the use of eco enzyme as a natural additive to modify soil pH and examines its effect on grounding resistance. Findings reveal that eco enzyme application successfully lowers soil pH, with an optimal reduction in grounding resistance observed at pH 3.8 achieving a drop from 40 ohms to 9 ohms. However, further lowering the pH below 3.8 results in a rise in resistance, indicating a threshold where acidic conditions become counterproductive. This research opens opportunities for broader applications of eco enzyme-treated soil in non-rod electrode systems and across diverse soil types, suggesting promising pathways for enhancing grounding systems in various environmental conditions.

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1. INTRODUCTION

The reliability of electric power distribution against internal and external disturbances is strongly supported by the presence of low grounding resistance [1]–[8]. Therefore, during the construction process, technicians always perform grounding resistance testing with an earth tester after completing the grounding installation. The earth tester functions by applying a test voltage to the grounding and test stakes, measuring the resulting current flow, and then displaying the calculated grounding resistance [2], [9].

In the construction of distribution system installations, many grounding resistance issues are found to exceed the requirements specified in construction standards [10]–[12]. Grounding resistance is influenced by several factors, including soil resistivity, soil type, soil layers, soil moisture, and soil acidity. Soil resistivity can be reduced by adding water, replacing the existing soil with lower-resistivity soil, or applying additives [11], [13], [14]. However, most of the currently used additives are derived from industrial processing of mining products, which are often less environmentally friendly.

An interesting finding from previous research is the relationship between low soil acidity and low soil resistivity. Soil acidity is directly proportional to soil resistivity and inversely proportional to electrical conductivity: as acidity decreases, soil resistivity also decreases, leading to increased electrical conductivity [9], [11], [15]–[20]. This insight calls for further research into engineering soil resistivity through acidic solutions with low pH levels.

One such acidic solution is eco enzyme, which can reach pH values as low as 3. The advantage of eco enzyme lies in its natural origin-it is produced by fermenting molasses with organic vegetable or fruit waste [21]–[24]. As a naturally derived material, eco enzyme can be used to adjust soil acidity levels without damaging the natural properties of surrounding soil [13], [14], [23], [25].

This research presents a significant challenge while offering new potential for the added value of eco enzyme. It contributes to promoting zero-waste awareness and provides the additional benefit of enhancing the safety of homes and properties by reducing the risk of installation failure or lightning strikes. Furthermore, if eco enzyme is produced in excess, it can be marketed to improve the quality of grounding installations in power distribution systems.

In this study, soil is treated with eco enzyme at varying acidity levels to observe the corresponding variations in grounding resistance [11], [12], [26]. One common technique to reduce soil resistivity involves chemical treatment within the grounding system [27], [28]. Typically, chemical materials are mixed with natural soil, and the grounding electrode is placed inside a trench filled with this mixture [29], [30], forming an interface between the soil and electrode.

This research also focuses on reconditioning the chemical composition of natural soil to achieve specific acidity levels, thereby increasing electrical conductivity and reducing soil resistivity. The study introduces two key novelties: first, the chemical treatment of natural soil is conducted not in a trench but in a drilled hole; and second, the acidic material used is eco enzyme an environmentally friendly alternative to industrial additives

2. METHOD

This research was conducted through the following three stages: grounding system modeling, grounding resistance measurement and data analysis [31]–[33]. Figure 1 displayed the sample processed in three stages (Figures 1(a)-1(f)).

Stage 1: Grounding system modeling: Six grounding system models were prepared, following these steps: step (1) Testing the acidity level of natural soil: A borehole was made for each model to insert a grounding rod, with a depth of 1.2 meters and a diameter of 0.11 meters, yielding approximately 0.011 cubic meters of natural soil per hole. The excavated soil was collected in a container for treatment. Step (2) Engineering soil acidity using eco enzyme: The natural soil from each borehole was mixed with different ratios of clean water and eco enzyme to create varying pH levels. Lower pH corresponds to higher (H^+), while higher pH corresponds to lower (H^+) [17]: Model 1: 8 liters of clean water (control). Model 2: 6 liters of clean water + 2 liters of eco enzyme. Model 3: 4 liters of clean water + 4 liters of eco enzyme. Model 4: 2 liters of clean water + 6 liters of eco enzyme. Model 5: 8 liters of eco enzyme. The mixtures were thoroughly stirred in containers until homogeneous. Step (3) Soil conditioning and application: The engineered soil mixtures were allowed to stand for at least 1 hour to ensure the eco enzyme fully permeated the soil. Afterward, the soil was re-stirred to ensure homogeneity and suitable consistency for backfilling. The engineered soil was then gradually poured back into the original borehole. During the pouring process, a 22 mm diameter iron pipe was used to pierce the mixture to prevent air pockets. The filled borehole was left to settle for a minimum of 1 hour. A 20 mm diameter grounding copper electrode was then inserted into the center of the compacted engineered soil to ensure optimal contact between the soil and the electrode. As a control, a grounding rod was also installed in natural soil without drilling.

Stage 2: Grounding resistance and soil moisture testing: Grounding resistance and soil moisture near each ground rod were measured weekly for a duration of 8 weeks, at three different times each day: 08:00, 12:00, and 16:00. Grounding resistance was tested using a ground resistance tester with 7 maters distance each electrode and grounding samples, which operates by applying voltage to the electrode and measuring the resulting current flow [27]. The resistance value is indicated directly on the device in ohms [10], [11], [14], [19], [34]. The pH level was measured by the conductivity test with the electrical test method [15], [18].

Stage 3: Soil resistivity analysis: In the final stage, the soil resistivity was analyzed mathematically and statistically using the data obtained from grounding resistance measurements. Soil resistivity was calculated using established (1) [13], [30], [34]-[36]. The findings were then interpreted to draw conclusions regarding the effectiveness of eco enzyme in engineering soil for grounding performance.

(a) (b) (c) (d) (e) (f)

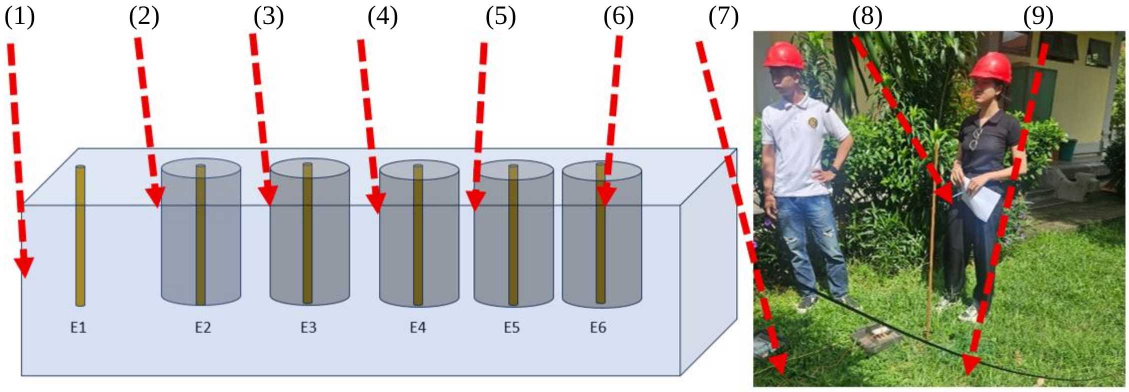
Figure 1. Samples processed, (a) boring and soil container, (b) soil engineering, (c) backfilling, (d) electrode, (e) pH level testing, and (f) Grounding resistance testing

$$Rg = \frac{\rho}{2\pi L}\left\{ ln\left(\frac{4L}{r}\right) - 1 \right\} \qquad (1)$$

Where, Rg is resistance to the ground (ohm), ρ is soil's resistivity (ohmmeter), π =3.14, L is rod length (m), and r is rod radius (m).

3. RESULTS AND DISCUSSION

After completing the modeling process as described in the research methodology above, the following illustrations and photographs present the grounding system models tested in this study. Based on Figure 2, shows that in this study six samples were examined by earth tester, one sample was an electrode inserted into natural soil, the other six samples were electrodes inserted into reconditioned soilshows that in this study six samples were examined, one sample was an electrode inserted into natural soil, the other six samples were electrodes inserted into engineered soil. Figure 2(a) the following can be explained: (1) Natural soil refers to the original, undisturbed soil at the research site, (E1) ground rods inserted directly into natural soil without prior drilling represent sample 1, (E2) ground road sampel 2, (E3) ground road sampel 3, (E4) ground road sampel 4, (E5) ground road sampel 5, (E6) ground road sampel 6, five samples of ground rods embedded at the center of the engineered soil within drilled holes. The soil (2), (3), (4), (5), (6) is engineered soil consists of five variations, each created by mixing natural soil with different doses of eco enzyme. Figure 2(b) can be explained: (7) Earth tester instrument is shown, used for measuring grounding resistance, (8) Photographs of actual ground rods illustrate the physical setup, (9) Vegetation such as grass growing on the natural soil surface is visible. The natural soil at the site is primarily clay, extending to a depth of 1.2 meters. Below this depth, a layer of white solid stone is present.



(a) (b)

Figure 2. Grounding models (a) graphical illustration and (b) installed ground rod

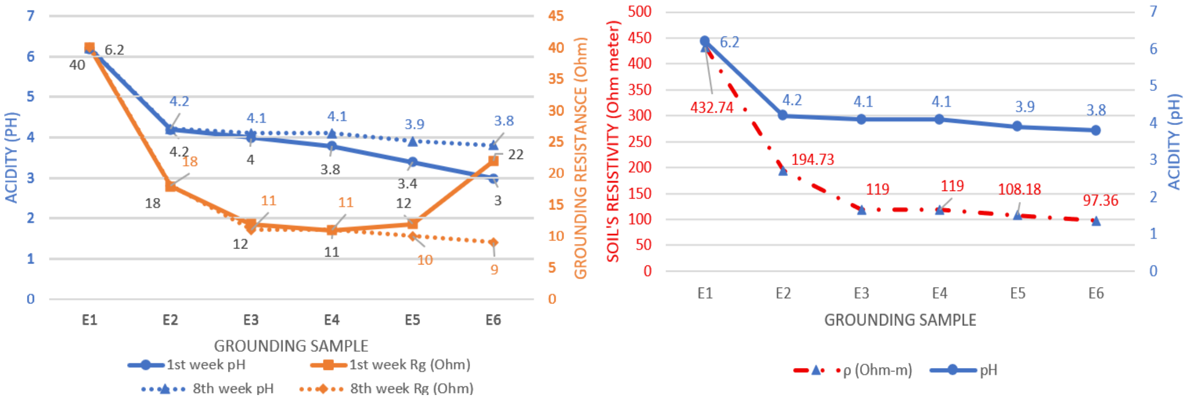
After the grounding models were constructed, tests were conducted to measure soil acidity (pH) and grounding resistance (Rg). These tests were performed weekly until the acidity levels stabilized-observed during the sixth, seventh, and eighth weeks. Using (1), soil resistivity (ρ) was calculated based on known electrode depth (1.2 m) and radius (20 mm). The test results and corresponding analysis are presented in Table 1 and a graph in Figure 3.

Figure 3 presents the results of this study, demonstrating that soil acidity levels significantly affect the resistance of the grounding system. A key novelty of this research lies in the added value of eco enzymes, which influence soil pH and, consequently, grounding performance. As shown in Figure 3(a), soil pH began to stabilize at approximately 3.8 during the sixth week, coinciding with the lowest recorded grounding resistance of 9 ohm a notable reduction from the initial value of 40 ohms.

The corresponding decrease in soil resistivity from 432.74 ohm-meters to 97.36 ohm-meters contributed directly to the reduction in grounding resistance, as indicated by the calculation results in Table 1 and illustrated in Figure 3(b). An important finding from this study, highlighted in Figure 3(a), is that excessively low soil acidity leads to increased grounding resistance. Specifically, when the soil pH dropped to 3.4, the resistance increased from 11 ohms to 12 ohms. A more pronounced rise in resistance from 12 ohms to 22 ohms was observed when the pH dropped further to 3.0. This indicates that while lowering pH can enhance conductivity up to a point, excessive acidity becomes counterproductive for grounding performance.

Table 1. Results of acidity level, grounding resistance and soil resistivity calculations

Week	Variable	E1	E2	E3	E4	E5	E6
1	pH	6.2	4.2	4	3.8	3.4	3
	Rg (Ohm)	40	18	12	11	12	22
	ρ (Ohm-m)	432.74	194.73	129.82	119	173.09	238.01
2	pH	6.2	4.2	4	3.8	3.7	3.2
	Rg (Ohm)	40	19.67	16	11	11.67	22
	ρ (Ohm-m)	432.74	212.8	173.09	119	126.25	238.01
3	pH	6.2	4.2	4.1	3.8	3.7	3.5
	Rg (Ohm)	40	20	14.67	11.67	11	14
	ρ (Ohm-m)	432.74	216.37	158.71	126.25	119	151.46
4	pH	6.2	4.2	4.1	3.8	3.6	3.5
	Rg (Ohm)	40	18.33	13.67	11.33	11.33	14
	ρ (Ohm-m)	432.74	198.3	147.89	122.57	122.57	151.46
5	pH	6.2	4.2	4.1	4	3.8	3.7
	Rg (Ohm)	40	18.33	13.67	11.33	10.33	10.67
	ρ (Ohm-m)	432.74	198.3	147.89	122.57	111.75	115.43
6	pH	6.2	4.2	4.1	4.1	3.9	3.8
	Rg (Ohm)	40	18	11	11	10	9.33
	ρ (Ohm-m)	432.74	194.73	119	119	108.18	100.93
7	pH	6.2	4.2	4.1	4.1	3.9	3.8
	Rg (Ohm)	40	18	11	11	10	9
	ρ (Ohm-m)	432.74	194.73	119	119	108.18	97.36
8	pH	6.2	4.2	4.1	4.1	3.9	3.8
	Rg (Ohm)	40	18	11	11	10	9



(a) (b)

Figure 3. Effect of acidity level on grounding resistance and soil resistivity: (a) the effect of acidity level on grounding resistance in the first and 8th week, (b) the effect of acidity level on soil resistivity in the 8th week

4. CONCLUSION

This research found that mixing eco enzyme to engineer soil acidity significantly impacts the performance of grounding systems. Using a 1.2-meter-deep grounding rod with a radius of 0.1 meters, the grounding resistance was reduced from 40 ohms to as low as 9 ohms. However, careful control of the eco enzyme dosage is essential to achieve an optimal soil pH of 3.8 over time. If the acidity level drops to 3.4 or lower, soil resistivity increases, leading to a corresponding rise in grounding resistance. This study provides a promising foundation for further research, particularly involving different types of electrodes or natural soil variations, to explore the broader applicability of eco-enzymes in improving grounding system performance.

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AUTHOR CONTRIBUTIONS STATEMENT

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Made Sudana	✓						✓						✓	
I Made Purbawa										✓			✓	✓

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 state no conflict of interest.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the first author [Jondra] on request.

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