Comparison of Measurement Results in the Breaking System Between Copper Electrodes, Aluminum and Mixed Iron on Solid and Swamp Clay

David Setiawan 1*, Usaha Situmeang 2, & Monice 3

1Universitas Lancang Kuning, Pekanbaru, 28265, Indonesia
Email: dsetia@unilak.ac.id
2Universitas Lancang Kuning, Pekanbaru, 28265, Indonesia
Email: usaha@unilak.ac.id
3Universitas Lancang Kuning, Pekanbaru, 28265, Indonesia
Email: monice@unilak.ac.id

Abstract: The grounding system or so-called grounding system is a security system from a possible electrical surge such as lightning. A good containment system will be influenced by the type of electrode used and the condition of the soil where the electrode is implanted. In this study, the authors compared 3 (three) electrodes, namely copper electrodes, aluminum electrodes and mixed iron electrodes which were implanted in 2 (two) different soil conditions, namely in swamp soil and solid clay. From the measurement results obtained data that the copper electrode is better than the aluminum electrode and the mixed iron in solid clay conditions, whereas in the wetland conditions, the three electrodes received very little measurement results between copper electrode, aluminum electrode and mixed iron electrode. Based on the standard grounding resistance value set in the PUIL where the earthing resistance and the whole grounding system shall be no more than 5 ohms so to obtain the value, the depth of the copper electrode under solid clay conditions shall be implanted deeper than the marshland conditions. From the results of the comparison at a depth of 80cm, the resistance value of the earthing copper electrode on solid clay is 952 ohm and in the swamp soil is 71.07 ohm, the Aluminum Electrode in solid clay is 995.5 ohm and swamp soil is 68.52 ohm and iron the mixture on clay is 1052 ohm and swamp soil 76.55 ohm.

Keywords: Elektroda, Tembaga, Alumunium, Campuran, Pembumian

1. Introduction
Grounding system or commonly referred to as a grounding system is a system of security against equipment - communication and personal equipment to lightning hazard or error in the power system and also can serve as a service on a system. The grounding system used, both for the neutral grounding of a power system, the grounding of lightning arresting and grounding systems for equipment particularly in the field of telecommunications and electronics, needs to be taken seriously, since in principle the ground is the basis for a system of protection. Not infrequently a technician is still lacking in predicting the value of an earthing barrier. The very dominant magnitude to be considered from an earthing system is the resistance of the earth system.
To plan an earth system there are several factors to consider, including Land Resistance, Soil Structure, environmental conditions, cost, size and shape of the system. Usually lower grounding resistance is very effective, but the cost becomes large. For this reason, it is necessary to consider the function and economic effects. Therefore, this study aims to compare three different electrode types namely copper, aluminum and mixed iron with two different soil locations ie swamp and clay soils to be able to plan and make a grounding system that suits their needs.

2. Research Methods
Methods The study was conducted in two stages, namely the determination of the location of the research where the location of the study was conducted in two places namely campus land that is clay and land or land where one of the researchers reside with the condition of swamp land, where the distance between the first and second location approximately 5 km.

Location 1 is on the front page of the Unilak Faculty of Agriculture, Clay including the highlands in Rumbai, Clay including highland in Rumbai, Location 2 is located at Jalan Sembilang Gg. Rumpat Rumbai Coastal, Tanah Swamp close to the river including lowland in Rumbai.

The tools used in this study are among others
1) One unit Earth Tester Brand Hioki, Type FT6031  
2) Artificial Electrode, contained from iron-core Copper Pipe for easy embedded, 10mm diameter,  
3) Aluminum pipe with iron core for easy embedded, 10mm diameter,  
4) Mixed Iron, 10mm diameter Two (2) reference electrode rods The default connecting cable in Earth Tester and additional connecting cables Red with a length of 10 meters Yellow with a length of 7 meters Green with a length of 5 meters. Additional connecting cable with a length of 1.2 meters  
5) Crowbar, hoe, cigarette holder and some equipment to plant and unplug the elekroda.

3. Result and discussion
Measurement results at clay location (area of campus and plateau), measurement done before and after rain (after first measurement then heavy rain so that re-measurement to get comparison.

![Artificial Electrode](image_url)

**Figure 1.** Point and Distance of Swamp Land Electrode

| NO | KEDALAMAN (CM) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA ALUMINIUM (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|-----------------------|------------------------|----------------------------|
| 1  | 20             | >2000                 | >2000                  | >2000                      |
| 2  | 40             | 1708                  | >2000                  | >2000                      |
| 3  | 60             | 1654                  | 1404                   | 1501                       |
| 4  | 80             | 931                   | 993                    | 1059                       |
| 5  | 100            |                       |                        |                            |

**Table 1.** Measures of Ground Ground Before Rain
Table 2. Measuring Ground Earthing after Rain

| NO | KEDALAMAN (CM) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA ALUMUNIUM (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|------------------------|--------------------------|-------------------------------|
| 1  | 20             | >2000                  | >2000                    | >2000                         |
| 2  | 40             | 1778                   | 1922                     | >2000                         |
| 3  | 60             | 1197                   | 1236                     | 1329                          |
| 4  | 80             | 973                    | 998                      | 1045                          |
| 5  | 100            |                        |                          |                               |

Measurements on Swamp Land (close to rivers and lowlands), measurements were made after rain at night, measurements were made at 4 points with a distance of 1 meter square four.

Figure 2. Point and Distance of Swamp Land Electrode

Table 3. Measurement results at point A

| NO | KEDALAMAN (CM) | ELEKTRODA ALUMUNIUM (Ω) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|-------------------------|-----------------------|-----------------------------|
| 1  | 20             | 298                     | 290                   | 276                          |
| 2  | 40             | 152,6                   | 129,1                 | 134,7                        |
| 3  | 60             | 93,5                    | 88,8                  | 94,4                         |
| 4  | 80             | 73,9                    | 70,6                  | 74,9                         |
| 5  | 100            |                         |                       |                              |

Table 4. Measurement results at point B

| NO | KEDALAMAN (CM) | ELEKTRODA ALUMUNIUM (Ω) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|-------------------------|-----------------------|-----------------------------|
| 1  | 20             | 173,2                   | 177,6                 | 223                          |
| 2  | 40             | 108                     | 107,1                 | 120,2                        |
| 3  | 60             | 91,3                    | 93,1                  | 105,5                        |
| 4  | 80             | 82,2                    | 82,1                  | 102,2                        |
| 5  | 100            |                         |                       |                              |
Table 5. Measurement results at point C

| NO | KEDALAMAN (CM) | ELEKTRODA ALUMUNIUM (Ω) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|--------------------------|------------------------|-----------------------------|
| 1  | 20             | 125,3                    | 178,7                  | 226                         |
| 2  | 40             | 88,4                     | 97                     | 222                         |
| 3  | 60             | 77                       | 80,1                   | 114,9                       |
| 4  | 80             | 70,9                     | 69,3                   | 71,4                         |
| 5  | 100            |                          |                        |                             |

If averaged, the result is: The measurement results connect the artificial electrode, the measurement is done by 3 stages ie connecting in series the same kind of material of artificial and combination electrodes, the measurement in parallel with the same artificial electrode material and the combination and the rectangular measurement with the same artificial electrode material and combination.

Table 6. Measurement results at point D

| NO | KEDALAMAN (CM) | ELEKTRODA ALUMUNIUM (Ω) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|--------------------------|------------------------|-----------------------------|
| 1  | 20             | 116,8                    | 183,3                  | 138,4                       |
| 2  | 40             | 73                       | 63,5                   | 74,9                         |
| 3  | 60             | 61,1                     | 57,1                   | 68                           |
| 4  | 80             | 57,3                     | 52,1                   | 57,7                         |
| 5  | 100            |                          |                        |                             |

Figure 3. Figure A Connects Series, Figure B Parallel Hue and Figure C Four Square Hue

The Measurement Results Series is measured by the position of the earth tester jumper with the following results.
Table 7. Measurements Series of jumper positions on Electrode 1

| Electrode 2 | Electrode 1 |
|------------|------------|
| ELEKTRODA TEMBAGA (Ω) | 36,5 | 34,5 |
| ELEKTRODA ALUMINIUM (Ω) | 35,9 | 34,1 |
| ELEKTRODA BESI CAMPURAN (Ω) | 36,8 | 34,8 |

Table 8. Measurements Series of jumper positions on Electrode 2

| Electrode 2 | Electrode 1 |
|------------|------------|
| ELEKTRODA TEMBAGA (Ω) | 36,5 | 34,6 |
| ELEKTRODA ALUMINIUM (Ω) | 35,8 | 34,1 |
| ELEKTRODA BESI CAMPURAN (Ω) | 36,6 | 34,6 |

Parallel Measurement Results, measured by different jumper positions with the following results:

Table 9. Parallel Measurement of jumper positions on Electrode 1

| Electrode 2 | Electrode 1 |
|------------|------------|
| ELEKTRODA TEMBAGA (Ω) | 43,3 | 43,2 | 44,6 |
| ELEKTRODA ALUMINIUM (Ω) | 42 | 42 | 43 |
| ELEKTRODA BESI CAMPURAN (Ω) | 43,7 | 43,7 | 48,7 |
Table 10. Parallel Measurement of jumper positions on Electrode 2

| Electrode 1 | Electrode 2 | Electrode Besi Campuran |
|-------------|-------------|-------------------------|
| Elektroda Tembaga (Ω) | 43,3 | 43,2 | 44 |
| Elektroda Aluminium (Ω) | 42 | 42 | 45 |
| Elektroda Besi Campuran (Ω) | 43,9 | 43,9 | 44 |

For results and discussion, the authors divide into several 4 parts namely:

3.1 Measurement On Clay

From the average between the measurement before and after the rain obtained data as follows.

Table 11. Measurements of single, series, parallel and rectangular electrodes

| NO | Kedalaman (cm) | Elektroda Tembaga (Ω) | Elektroda Aluminium (Ω) | Elektroda Besi Campuran (Ω) |
|----|----------------|-----------------------|-------------------------|-----------------------------|
| 1  | 20             | >2000                 | >2000                   | >2000                        |
| 2  | 40             | 1743                  | 1922                    | >2000                        |
| 3  | 60             | 1425,5                | 1320                    | 1415                         |
| 4  | 80             | 952                   | 995,5                   | 1052                         |
| 5  | 100            |                       |                         |                              |

Figure 4. Graph of Measurement Rod on Clay

The results obtained that:

a. At a depth of 20cm in clay, the measurement values are still above 2000 ohms
b. While into 40cm electrode of a mixed iron over 2000 ohm At 80cm depth have not seen any electrode that close to 100 ohm value
c. The difference between the copper and aluminum electrodes is a maximum of 5% so that the aluminum electrode when it wants to produce the same ground resistance with the copper electrode must increase the depth of the difference.

d. The copper electrode is better than the aluminum electrode, the aluminum electrode is better than the mixed iron electrode.

3.2 Measurements On Swamp Land

For measurements on swampy soil, the author tries to plant at four points so that the measurements obtained can be averaged. From the measurement at point A, point B, point C and point D, the average is as follows:

**Table 12. The mean results of measurements A, B, C and D**

| NO | KEDALAMAN (CM) | ELEKTRODA ALUMINIUM (Ω) | ELEKTRODA TEMBAGA (Ω) | ELEKTRODA BESI CAMPURAN (Ω) |
|----|----------------|--------------------------|------------------------|----------------------------|
| 1  | 20             | 178,325                  | 207,4                  | 215,85                     |
| 2  | 40             | 105,5                    | 99,175                 | 137,95                     |
| 3  | 60             | 80,725                   | 79,775                 | 95,7                       |
| 4  | 80             | 71,075                   | 68,525                 | 76,55                       |
| 5  | 100            |                          |                        |                            |

**Figure 5. Graph of Measuring Results Rod in Swamp**

From the measurement, obtained the result that:

a. At a depth of 20cm, the copper and aluminum electrodes tend to differ slightly, but the thin difference in measurement results can not be said which one is the best.

b. At a depth of 40cm, almost the same as the 20cm measurement, but the copper electrode is better.

c. However, at the measurement of 60cm and above the aluminum electrode can be close to or equal to the copper electrode, as well as the mixed iron electrode.

d. If forwarded to a depth of 100cm, then the three electrodes will be worth less than 50ohm which means it can be used for grounding / grounding housing systems.

3.3 Electrodes Over One / Series Relationships, Parallel And Square Four

To enrich the results of the study, the authors tried to compare between the same electrodes at single, parallel, series and square. Here's the average result.
Table 13. Measurements of single, series, parallel and rectangular electrodes

|                | Elektroda | Elektroda | Elektroda | Elektro Segi |
|----------------|-----------|-----------|-----------|--------------|
| TEMBAGA (Ω)    | 43,3      | 43,2      | 44,6      | 24           |
| ALUMUNIUM (Ω)  | 42        | 42        | 43        | 23,6         |
| BESI CAMPURAN (Ω) | 43,7      | 43,7      | 48,7      | 25           |

Figure 6. Graph of Comparison rods 1, 2 Series, 2 Parallel and 4 Electrodes

From the measurement results obtained data that:

a) In marshy soil conditions, almost all electrodes get good measurements, the difference is not too far so that the measurements between copper and aluminum electrodes are almost the same that they seem to compete with each other.

b) The grounding system uses parallel or series electrodes better than a single electrode

c) The series electrode system is better than parallel

d) And the square electrode results even better, measured under 25 ohms for all electrodes

4 Conclusion

From the description above, the authors can conclude that:

a. Swamp Land is better than clay to be a grounding system / grounding system

b. Copper electrodes are better than aluminum electrodes and mixed iron electrodes in clay conditions

c. Copper, Aluminium and Iron Mixed Electrodes get good measurements on swampy soil conditions, the difference of measurement results is not too far away.

d. The price of aluminum electrode is 60% from the price of copper and iron electrodes 40% from the price of copper electrode

e. If it will use more than one electrode, the serial position is better than parallel
5 References

[1] Blattner C.J., 1982, Study of Driven Ground Rods and Four Point Soil Resistivity Tests, IEEE Trans. On PAS, August, 1982

[2] Gonos, I.F., Antonion, M.K., F.V and Stathopolus I.A., 1998, Behaviour of a Grounding Systems Under Impuls Lightning Current, 6th International Conference and Exhibition on Optimization of Electrical and Electronic, May 1998, Romania

[3] Gonos, I.F., Topolis, F.V. and Stathopolus I.A., 1999, Transient Impedance of Grounding Rods, IEEE High Voltage Engineering Symposium, Conference Publication No 467

[4] Hutauruk, T.S., 1991, Pengetahuan Netral Sistem Tenaga dan Pengetahuan Peralatan, Erlangga, Jakarta

[5] IEEE, 1983, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System, IEEE Std 81

[6] Otero, A.F. and Cidrh, J., Frequency Analysis of Grounding Systems, IEEE Transaction on Power Delivery, Mart, 1998

[7] Otero, A.F., Cidrh, J., and Garrido, C., 2000, Geometrical Considerations in the Frequency Behaviour of Grounding Systems, IEEE Transaction on Power Delivery, June, 2000

[8] Pijpaert, K., 1999, Peraturan Umum untuk Elektrode Bumi dan Pengantar Bumi http://www.elektroindonesia.com Nomor 24, Tahun V, Januari 1999

[9] Rajagukguk, M., 2002, Analisis Transien Perilaku Sistem Pembumian Driven Rod, Seminar nasional dan Workshop Tegangan Tinggi V 2002, Yogyakarta

[10] Sowa, A and Wiater, J., 2004, Decreasing Lightning Shock Hazard at the HV Substation by the Modification of the Grounding System, IEEE Transaction on Power Delivery, January, 2004