# Experimental Study on Lightning Air Terminal Performance based on Material Type

Abdul Syakur, Agung Nugroho, Anastasia Br. Napitupulu

Department of Electrical Engineering, Faculty of Engineering, Diponegoro University
Jln. Prof. Soedarto SH, Tembalang, Semarang, 50275, INDONESIA
e-mail : syakur@undip.ac.id, anastasianapitupulu@gmail.com

***Abstract*—*Lightning air* terminal is a main part of the external lightning protection system in the form of an upright rod conductor which has a construction in the formed side *of lightning air terminal* tapered shape as collector's static electric charge. The main parameters that determine both the deficient performance of a Franklin's *lightning air terminals* seen from the breakdown voltage level. This study discusses *lightning air terminal* based on material types. This research was conducted for 6 times experiments using *lightning air* terminals with 3 different type of material, namely copper, aluminum and galvanized iron (standard IEC 62305). The method used is testing the *Lightning air* terminals (LAT) based on different type of material using a high voltage DC negative polarity by adjusting the gap. Variables that are sought in the form of breakdown voltage and resistance of each *lightning air* terminals. The results from the study showed that the type of material from *lightning air* terminals affect the ability to deliver the lightning current to the *ground* as seen from the breakdown voltage level. The level of breakdown voltage for each material is different with the same gap. At a gap of 1 cm, test uses three types of materials testing of *lightning air* terminals, the probability of the type of material exposed to breakdown voltage on the types of copper by 100% with an average value of 8.23 KV breakdown voltage with 0.06 Ω resistance. Tests with two kinds of materials of *lightning air* terminal, the probability of the type of material exposed to breakdown voltage on the types of aluminum at 100% with an average value of breakdown voltage kV 8.48 with 0.08 Ω resistance. Testing with one type of material of *lightning air* terminal, the probability of the type of material exposed to breakdown voltage on the types of galvanized iron materials by 96.67% with an average value of breakdown voltage of 8.64 KV with 0.10 Ω resistance**

***Keywords—air terminal, lightning protection system, resistivity, conductivity, breakdown voltage.***

## I. Introduction

Lightning is a natural phenomenon which occurs stepping electric charge between the clouds with the earth. If the charge in the cloud grows, the greater the induced charge so that the potential difference between the clouds with the earth become even greater. The incident was followed by the release of the electron charge in the form of tongues of lightning that came down from the clouds and also up from the earth. [1,6]
Indonesia is an area that has the high intensity of a lightning strike. This is supported by the location of Indonesia in the tropical region that have high levels of moisture and high heating [2]. Given the damage that can arise as a result of lightning strikes, it appears efforts to overcome the damage. One of the efforts is to turn on a protection system that will deliver the lightning current to return to the ground, the equipment used is usually a *Lightning air* terminals (LAT), *down conductors* and *grounding*[3].'*ightning air terminal* is part of the external lightning protection system is devoted to capturing lightning strikes, in the form of metal electrodes are mounted vertically or horizontally. The main parameters that determine whether the poor *Lightning air* terminals seen from the breakdown voltage level (after corona) that occurred. According to Schwaiger, breakdown voltage level or levels is influenced by the electric field distribution. [4]

Selection of *Lightning air* terminals (LAT) with the type of material that is not in accordance with the building can not be a good lightning catcher, so that the lightning current can not be supplied to the maximum ground and cause damage to electronic equipment as well as people who live in the building. As according to the General Rules of Installation of Lightning (PUIPP) that the location, shape, and size of the building is very affecting difficult or easy it is to a building struck by lightning [5]

## II. Experimental Setup

### A. Preparation of test samples

The sample used in this study is an aluminum plate that has a diameter of 50 cm and a thickness of 1.5 mm and *Lightning air* terminals with 3 different type of material, namely copper, aluminum and galvanized iron. The third dimension of the *Lightning air* terminals in accordance to IEC 62305. The geometric parameters are shown in Table I. Total sample preparation is numbered 3 pieces, which consist of the types of materials as copper, aluminum and galvanized iron. All three samples were tested with the breakdown voltage variation of the gap distance between measured resistance as well as the calculation of the conductivity of each material.

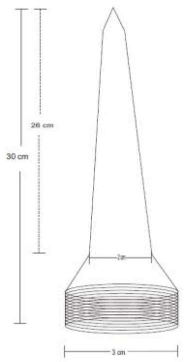


Fig. 1. Dimension of Lightning air terminal

TABLE I. SAMPLE TEST

| | |
|---|---|
| Name Test Materials | *Lightning air* terminals |
| Total height | 30 cm |
| Material | Copper (Cu) |
| | Aluminum (Al) |
| | Galvanized Iron |
| Outside Diameter | 2:54 cm (1 inch) |

### B. *Breakdown Voltage testing*

The parameters for both the poor performance of *Lightning air* terminal seen from its breakdown voltage after (corona) occurs. Breakdown voltage testing is done by using an aluminum plate that is modeled as clouds and 3 pieces *Lightning air* terminals with different material. Then eliminate the type of material of *Lightning air* terminals which has a high probability of most major breakdown voltage. Breakdown voltage testing using the generation of high voltage (DC) negative polarity.

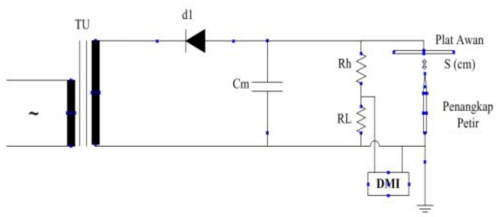


Fig. 2. The test circuit of negatif polarity DC Voltage

Caption:

TU = Transformer Test of three high-voltage winding 220 V / 220 V / 100 kV
d1 = Diodes high voltage
Cm = capacitor measurement of 10000 pF
$R_h$ = Resistor measurement of *high* 280 MΩ
$R_L$ = Resistor measurement of *the low* 15 KΩ
DMI = gauge high voltage DC (kV)

Unidirectional high voltage generation can use the generation of high voltage alternating output associated with a half-wave rectifier circuit (using high voltage diodes). For the rectifier circuit with a capacitor rectifier, providing direct voltage purer than without the capacitor. By enlarging the size of the capacitor grader, frequency and number of phases will reduce defects generated voltage [4]. As breakdown voltage test pictures can be seen in Fig. 2.

According to tables normalization and standardization states that for various tool applies a certain voltage sparks in the standard state. For example, according to Japanese Industrial Standard (JIS) and Japanese Electrotechnical Committee (JEC). Testing in the standard state is:

| | |
|---|---|
| barometer pressure | 760 mmHg |
| temperature around | $20^0$C |
| absolute humidity | 11 g / $m^3$ |

Therefore, sparks circumstances are always influenced by the circumstances of dry air. So to be able to compare the test results with the existing table the necessary normalization formula that can transform these results into the standard state. This is to determine whether the specimens tested are qualified or not.

To correct the test results of the pressures and temperatures used formula:

$$Vs = \frac{Vb}{\delta} \quad \text{.................................. …...............................(1)}$$

Where:

Vs = voltage jump on the state standard (KV )
Vb = voltage jump on the real situation (KV)
δ = air correction *factor*.

$$= \frac{p}{760} x \frac{273+20}{273+\theta} = \frac{0.386p}{273+\theta} \quad \text{.................................. ..... (2)}$$

Whereas p = air pressure at the time of testing (mmHg) and θ = ambient temperature during the test ($^0$C). As a correction to the absolute humidity is used empirical formula:

$$Vb = \frac{\delta Vs}{Kh} \quad \text{.................................. ................................ (3)}$$

Description:

Vs = standard breakdown voltage (KV)
Vb = breakdown voltage measured on the real situation (KV)
Kh = a correction factor dependent on the humidity

### C. *Resistance Measurements*

Measuring resistance intended to determine the magnitude of custody on a material kind of *lightning air terminals.* Meter resistance measurement using mili-Ohm Meter placed at both ends of the *Lightning air* terminals. The greater resistance of a material kind of *lightning air terminals* the ability to carry current gets smaller as for the image using mili-ohm Meter resistance measurement shown in Fig. 3.

Fig. 3. Resistance measurement using mili-ohm meter

## III. Results and Discussion

### A. Breakdown voltage

The average value of breakdown voltage testing of *lightning air terminal* with 3 different type of materials that can be seen in the table 2.

TABLE II. AVERAGE BREAKDOWN VOLTAGE

| Average of breakdown voltage [kV] | Copper | Aluminum | Galvanized Iron |
|---|---|---|---|
| 1 | -8.23 | -8.48 | -8.64 |
| 2 | -11.66 | -13.05 | -13.06 |
| 3 | -15.59 | -18.16 | -18.39 |
| 4 | -18.93 | -21.60 | -21.71 |
| 5 | -21.31 | -24.90 | -25.56 |

It can be seen in table II above the average value of breakdown voltage of each *lightning air terminal* at certain intervals. The average value of breakdown voltage *of lightning air terminal* with copper material at distance of 1 cm intervals for -8.23 kV, on aluminum -8.481 kV, on galvanized iron materials -8.64 kV.

At distance of between 2 cm, breakdown voltage value of *the Lightning air* terminals with the copper material amounting to -11.66 KV, on the kind of aluminum material at -13 05 KV as well as on the type of material galvanized iron for KV -13 06

at distance of between 3 cm, breakdown voltage value of *Lightning air* terminals with the copper material amounted to -15 59 KV, on the kind of aluminum amounted to -18.11 KV as well as on the type of galvanized iron material at -18.39 KV

at distance of between 4 cm, the value of breakdown voltage *Lightning air* terminals with the type of material amounted to -18 931 KV copper, on the kind of aluminum material at -21 598 KV as well as on the type of material of galvanized iron -21 705 KV.

At distance of between 5 cm, the value of breakdown voltage *Lightning air* terminals with the type of material amounted to -21 311 KV copper, on the kind of aluminum material at -24 896 KV as well as the type of materials amounted to -25 561 kV galvanized iron.

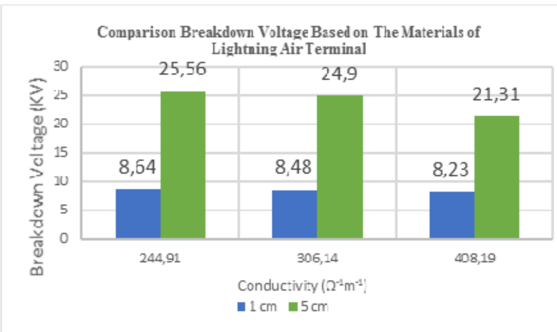


Fig. 4. Comparison breakdown voltage

The probability of exposed material breakdown voltage on any type of material *Lightning air* terminals at certain intervals between the type of copper by 100%, 100% aluminum material types, types of galvanized iron materials by 96.67% on every test with distance of between 1 cm

The parameters good poor performance of *lightning air terminal* can be seen from the breakdown voltage value (after the corona) [4] as in figure 4. the difference in the value of the breakdown voltage *lightning air terminals* with different type of material is influenced by the resistance of each material type of *lightning air terminals.* The greater the custody of a type of material of *Lightning air* terminals the breakdown voltage of the larger types of material. This means that the process of *breakdown* in the longer isolation.

### B. Resistance of material

From the measurements that have been carried out, the resistance value of each test sample can be seen in Table III.

TABLE III. RESISTANCE OF MATERIAL

| No. | Material Type *Lightning air terminal* | resistance (Ω) |
|---|---|---|
| 1 | Copper | 0.06 |
| 2 | Aluminum | 0.08 |
| 3 | Galvanized Iron | 0.10 |

Data resistance measurement result types of materials *of Lightning air* terminals using mili-ohm meter indicates that the sequence resistance *of Lightning air* terminals of the largest to the smallest the type of material galvanized *iron,* aluminum and *copper.*

From the measurement results can be calculated resistance value conductivity, indicated that things that affect the electrical conductivity in a material depends on the internal structure of the conducting material. Copper material has the smallest resistance value of the other materials because it is a metallic material that has number of free electrons are more apart from the nucleus.

After using mili-ohm meter resistance measurement, then the calculation of the conductivity of any material from *the Lightning air* terminals to the equation as below.

$$R = \rho\frac{L}{A} \quad (4)$$

$$\sigma = \frac{1}{\rho} \quad (5)$$

where:

R = resistance (Ω)

ρ = resistivity (Ω.m)

L = length *of lightning air terminals* (m)

A = area ($m^2$)

σ = electrical conductivity ($\Omega^{-1}m^{-1}$)

By using the equation above, the conductivity values of each type of material from *Lightning air* terminals obtained as shown in table IV.

TABLE IV. CONDUCTIVITY OF MATERIAL

| No | Material Type Composer ***Lightning Air Terminal*** | Resistivity (Ω.m) | Conductivity ($Ω^{-1}$m-1) |
|---|---|---|---|
| 1 | Copper | 0.002 | 408 197 |
| 2 | Aluminum | 0.003 | 306 147 |
| 3 | Galvanized Iron | 0004 | 244 918 |

Based on the graphic, conductivity values *lightning air terminal* above obtained the highest conductivity values contained in the copper material types whereas the lowest conductivity values are the type of galvanized iron materials. This is because each material has a different internal structure. The conductivity of a type of material depends on the number of free electrons that are not bound to the nucleus, the process of releasing electrons in the metal into the gas (emission events), the charge density and electron mobility. it has the highest conductivity values of the four other ingredients. Ingredients of *lightning air terminal* which has the highest conductivity values capable of delivering current and voltage induced excess to the *ground.*

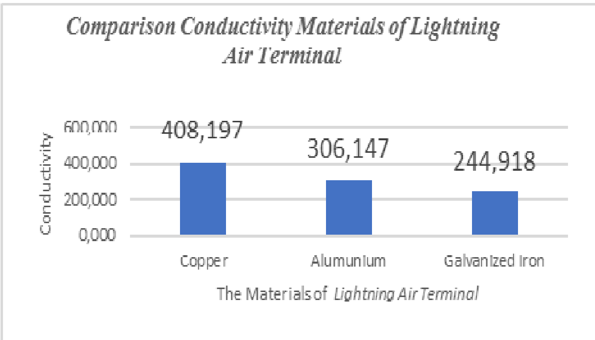


Fig. 5. Comparison conductivity of materials

## IV. CONCLUSION

After considering the breakdown voltage value, the value of resistance measurement, calculation of electrical conductivity in all four types of material from *lightning air terminal* then found that the type of material that has an average breakdown voltage of the largest and has the highest probability of breakdown voltage exposed in testing I that kind of material copper with a probability of 100% and the testing of the second type of material that has the highest probability that the type of the aluminum material as well as the testing of the third type of material that has the highest probability is 96.67% on the kind of material galvanized iron on the distance between particular by eliminating each type of material has a probability highest in earlier tests. The average value of breakdown voltage is different for each type of material caused by the difference in resistance value of each ingredient *lightning air* terminal. Resistance affects the ability of electrical conductivity to the *ground.* The resistance value of the type of materials which have the smallest breakdown voltage that is at 0:06 Ω copper, aluminum resistance value Ω at 0:08 and the types of materials that have an average value of breakdown voltage and the greatest resistance value contained in the type of galvanized iron materials by 0:10 Ω. The resistance value will affect the resistivity and conductivity type of materials of *lightning air terminals.* The conductivity of a material is influenced by the internal structure of the introductory material, the release of electrons from a metal surface into free electrons in the gas (emission), the charge density($\rho_c$) and electron mobility ($\mu_e$).

## REFERENCES

[1] Erico System. "Lightning Protection Solution", Pentair, 2000.

[2] AS / NZS. "Lightning Protection", the Australian / New Zealand Standard, 2007.

[3] IEC 62305-1,*"Protection against* lightning",IEC Publication, 2010.

[4] S. Faufeaix, "Investigation and studies on Lightning Air Terminal shape in relationship with the effeciency of a simple rod ", the International Lightning Protection Association Symposium, 2014.

[5] Richard Chadwick, "The Comparison of Lightning Protection System (LPS) in Accordance with NFPA 780 and IEC 62305-3", 2016

[6] Vernon Cooray, "Lightning Protection" Institution of Engineering and Technology.London, 2010.