Grid-Rod Grounding With Gypsum Additive Media In Narrow Rocky Soil Areas

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Abstract: Rocky soil with soil resistivity (ρ) > 200 Ω-meter is very difficult to install a grounding system by obtaining a very small grounding resistance value, so it requires a grounding system with a large area.
The location of the PLN distribution substation has a maximum area of 20 m^2, so a Grid or Grid-rod grounding system with narrow land is needed, so that a decrease in the soil resistivity value is needed. The purpose of this study was to apply gypsum additives to reduce the value of soil resistivity. The results showed that the addition of gypsum additives to limestone soils was very effective in reducing the soil resistivity value from 251.20 ohm-meters to 163.28 ohm-meters or a decrease of 35%. The 35% reduction in the soil resistivity value had an impact on the grounding structure in narrow areas of calcareous soil including: a depth of 2.5 meters, a form of grounding in the form of a grid rod, a reduction in the total length of the mesh conductor from 200 meters to 140 meters (a reduction in the length of the conductor by 30%), reducing the length of the electrode rod from 5000 meters to 2450 meters (reducing the length of the electrode rod by 51%), the size of the grounding system, even in a narrow area of 2 meters x 2 meters, can still be developed for the grounding system.

Keywords : Gypsum, Grid-rod, Narrow land earthing,

I. INTRODUCTION

In areas with rocky soil conditions with soil resistivity > 200 Ω-meter, it is difficult to install an grounding system by getting the smallest earth resistance value. Grid, plate and mesh grounding systems require a large enough land area. In areas that are densely populated, the need for large land areas is very difficult.

The location of the PLN distribution substation generally only has a maximum area of 20 m^2, so a Grid grounding system is needed which can be placed on narrow land.

One step that can be done is by adding additives to the soil. Some common additives are salt, charcoal and bentonite.Several existing studies, such as research on grounding systems in narrow areas of calcareous soil, obtained an optimal mesh system at 0.6472 ohms in dry conditions and 0.4383 ohms in wet conditions, the optimal grid system was 0.6269 ohms in dry conditions and 0. 4314 ohms in wet conditions, and the optimal plate system is 0.9859 ohms in dry conditions and 0.8013 ohms in wet conditions [1].

The study entitled Optimization of Grounding System Planning in the Pecatu 150 kV Gas Insulated Substation Development Plan found that the construction of the Pecatu 150 kV Gas Insulated Substation (GIS) is on a limestone rocky soil type with a soil resistivity of 263.76 ohm meters, so that only grounding systems are allowed. plate grounding, and Multi Grid-Rod grounding systems [2].

These studies show that it is very difficult to obtain a low grounding resistance value on rocky land with a large area of land, especially on narrow land.This research is a reflection of the problems faced in the construction of an grounding system on rocky soil. The aim of this research was to apply gypsum additive to determine the required length of the narrow grid grid-rod system electrodes in limestone soil types when gypsum additive media was added. Based on these problems, the grounding of the grid-rod by adding gypsum additive to rocky soil with narrow land was investigated, so that the results of this study are expected to be used as a reference in planning earthing systems for narrow rocky soil.

II. LITERATURE REVIEW

2.1 Latest Overview

Some references that support this research activity include:

1. The study entitled Optimization of Grounding System Planning in the Pecatu 150 kV Gas Insulated Substation Development Plan found that the construction of the

Pecatu 150 kV Gas Insulated Substation (GIS) is on a limestone rocky soil type with a soil resistivity of 263.76 Ohm Meters, so that only grounding systems are allowed. Plate grounding, and Multi Grid-Rod grounding systems. [2].

2 The research entitled Analysis of Grounding Systems to Secure Electrical Installations in the Electrical Engineering Study Program, Faculty of Engineering, University of Udayana, Jimbaran Bali, found that the recommended grounding system is installed with a grounding resistance value in accordance with the specified conditions, namely a grid-type grounding system with a grounding resistance of 4.79 Ω or plate. with an earth resistance of 4.56Ω.[3].

3. Research on grounding systems in narrow areas of calcareous soil yields results that are optimal mesh systems at 0.6472 ohms in dry conditions and 0.4383 ohms in wet conditions, optimal grid systems 0.6269 ohms in dry conditions and 0.4314 ohms in wet conditions , and the optimal plate system is 0.9859 ohms in dry conditions and 0.8013 ohms in wet conditions [1].

2.2 Grid Grounding System

The Grid grounding system is a combination of mesh and rod grounding systems in order to obtain a standard grounding resistance value. The shape of the Mesh and Rod grounding system or often called the Grid grounding system can be seen in Figure 1.[4].

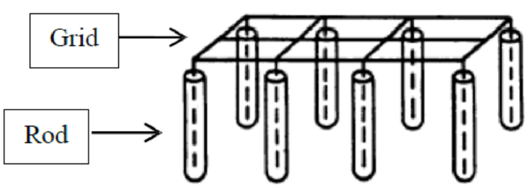

Fig. 1 The form of the grid grounding system.[5].

The Grid grounding system is a combination of mesh and rod grounding systems in order to obtain a standard grounding resistance value.

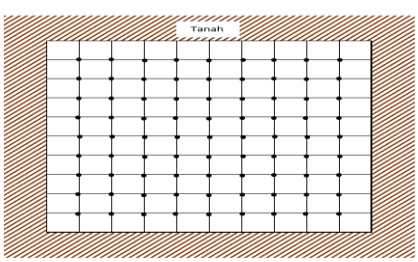

Fig. 2. Grid system gorunding design

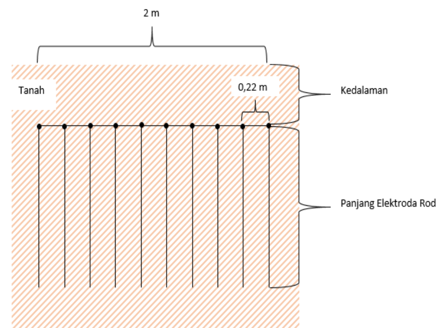

Fig. 3 Grid-rod system design

The value of the grid resistance can be calculated by the following equation:

$$R_G = \frac{R_1 R_2 - R_m^{\ 2}}{R_1 + R_2 - 2R_m} \quad \text{.............................(1)}$$

Calculates the value R_1 as follows:

$$R_1 = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{a^r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2\right] \quad \text{..........(2)}$$

Calculates the value R_2 as follows:

$$R_2 = \frac{\rho}{2\pi n_R L_R}\left[L_n\left(\frac{4L_R}{b}\right) - 1 + \frac{2K_1 L_r}{\sqrt{A}}\left(\sqrt{n_R} - 1\right)^2\right] \quad \text{..........(3)}$$

Calculates the value R_m as follows:

$$R_m = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{L_r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2 + 1\right] \quad \text{..........(4)}$$

Where:

R_G = Grid-Rod earth resistance (Ω)

ρ = soil resistivity (Ω-meter)

A = Grounding area (m²)

h = Grounding system planting depth from ground level (m)

L_c = The total length of the mesh conductor (m)

L_r = The length of the electrode rod (m)

n_r = The number of rod electrodes

L_R = The total length of the electrode rod (m)

$a^r = \sqrt{a.2h}$ The conductor is buried at a depth of h

a = Conductor mesh diameter(m)

b = Conductor rod diameter (m)

$K_1 = 0{,}01$ and $K_2 = 4{,}5$ with a maximum c value, the coefficient that depends on the ratio of length to width.

2.3 Gypsum

Gypsum ($CaSO_4.2H_2O$) is a white stone formed due to the deposition of seawater. Gypsum has the most minerals in the sediment and will be soft when pure. Gypsum contains two molecules consisting of $CaSO_4$ and $2H_2O$. Gypsum can be divided into two, namely anhydrite and dehydrate. Gypsum anhydrite is formed from 32.6% lime (Ca), 20.9% H_2O and 32.6% sulfur (S). Gypsum dehydrate has the same substance content as gypsum anhydrite, the difference is the water molecules. The use of gypsum does not cause pollution in the air and soil, besides that it is relatively cheap, fire resistant, and resistant to deterioration caused by biological factors and resistant to chemical substances. In previous studies it was proven that gypsum can be used to reduce the value of earth resistance, the increase in the weight of gypsum is directly proportional to the decrease in the value of earth resistance [5].

2.4 Soil Classification

The purpose of soil classification is:

1. Organizing (organizing) our knowledge about the soil.
2. To find out the relationship of each individual soil to one another.
3. Makes it easier to remember the characteristics of the soil.
4. Classification of land for more practical purposes such as in terms of:
5. Estimate its characteristics.
   - Determine the best fields.
   - Estimating productivity.

6.Studying new soil relationships and characteristics.

Based on a technical point of view, soil can be classified into the following main types:[6].

1. Gravel
2. Sand .
3. Silt.
4. Clay.

2.5 Measurement of soil resistivity

The value of soil resistivity is influenced by several factors, namely: [7] [8]

1. Type of soil
2. Soil layer
3. Soil moisture
4. Temperature.
5. The soil type resistance can be calculated using the equation:

$$\rho = 2\pi . a . R,$$

where:

ρ =The average type resistance of the soil (ohm-meter)

π = 3,14

a = the distance between the nearest grounding rods (meter)
R = measured resistance value (ohm)

III. RESEARCH METHODS

3.1 Place and Time of Research

The research was conducted in the Bukit Jimbaran Area from June to October 2022

3.2 Research Steps/Flow

The research steps are as follows:

1. The research begins with preparing to collect research materials/equipment such as: gypsum, copper electrodes, other supporting tools.
2. Conduct field surveys to obtain research locations that are suitable for the earthing characteristics of narrow rocky soils
3. Measure soil resistance to obtain soil type resistance in the following way:
4. a. Prepare measurement tools, measurement materials and tools that will be used in the measurement.
   b. Plug 4 electrodes into the ground using a hammer in different places with a distance of 20 meters between the electrodes.
   c. Connection of the cable from the measuring instrument to each end of the electrode located on the ground surface.
   d. The circuit for measuring ground resistance (R) with electrodes to get the ground resistance value can be seen in Figure 4.

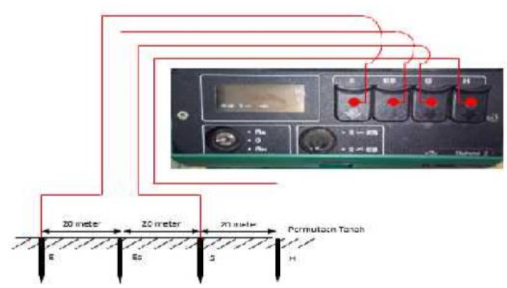

Fig. 4 The circuit for measuring ground resistance (R)

a. Connect the connecting cable to each electrode terminal.
b. If all cables have been connected to the terminals on the measuring instrument. (Elohmi Z (42/35-86-2XP) is correct, so first you can measure ground resistance (R) by opening Switch E with Es.
c. The measurement starts by pressing Switch Re towards the top.
d. Measurement of ground resistance (R) is carried out automatically so that the desired earth resistance value is obtained.
e. Measurement of soil resistance (R) was carried out 3 times at 10.00 WITA, 12.00 WITA and 14.00 WITA every day for 3 weeks.

To determine the value of soil resistivity, it can be calculated according to the Ground Resistance Meter measuring instrument catalog, for example the Elohmi Z model 42/35-86-2 XP with the following equation:

ρ=2.π.α.R……..…………….……………(5)

where :

ρ = Average soil resistivity(Ω-meter)

α = The distance between the closest electrodes

R = The measured ground resistance(Ω)

5. Treat the soil by adding gypsum additives as shown in the figure 5.

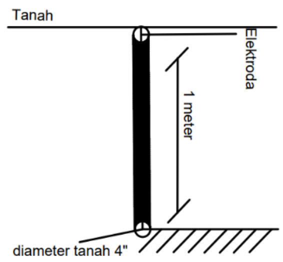

Fig. 5 Earth electrode with Addition of Gypsum Additives

Make a hole with a diameter of 4" (four dim), then plug in a 1 meter long copper electrode filled with gypsum additive, and measure the soil resistance as in the steps below.

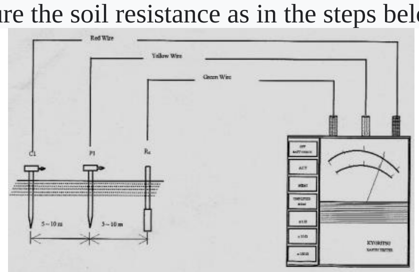

Fig. 6. Earth Resistance Measurement Circuit

where :

R_E = Grounding Electrode (round iron rod coated with copper)

- Connect the connecting wires to the measuring terminals (E, P, C) and to the auxiliary stakes as shown in Figure 6.
- If the cable is fully connected, then take a measurement by pressing the largest measuring limit (scale) button x 1000 first to avoid damaging the measuring instrument then pressing the MEAS button.
- If the pointer moves slightly (small indication price), then change the smaller measurement limit (x 100 , x 10) so that the measurement price can be read clearly.
- During measurement, the indicator light turns on if terminals C and E are connected properly, and if terminals C and E are not properly connected, the indicator light does not light up (turns off).

6. Treatment as step number 4 above, carried out at 5 (five) location points on rocky ground.
7. Perform calculations by taking research resistivity data from measurement results by calculating:

$$R_G = \frac{R_1 R_2 - R_m{}^2}{R_1 + R_2 - 2R_m}$$

Calculate value R_1 as follows:

$$R_1 = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{a^r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2\right]$$

Calculate value R_2 as follows:

$$R_2 = \frac{\rho}{2\pi n_R L_R}\left[L_n\left(\frac{4L_R}{b}\right) - 1 + \frac{2K_1 L_r}{\sqrt{A}}\left(\sqrt{n_R} - 1\right)^2\right]$$

Calculate value R_m as follows:

$$R_m = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{L_r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2 + 1\right]$$

where:

$R_G =$ Grounding resistance *Grid-Rod* (Ω)

$\rho\ =$ soil type resistance (Ω-meter)

$A\ =$ Grounding area (m^2)

$h\ =$ Grounding system planting depth from ground level (m)

$L_c =$ The total length of the mesh conductor (m)

$L_r =$ The length of the electrode rod(m)

$n_r =$ The number of rod electrodes

$L_R =$ The total length of the electrode rod(m)

$a^r = \sqrt{a.2h}$ The conductor is buried at a depth of h

$a\ =$ Conductor mesh diameter (m)

$b\ =$ Conductor rod diameter(m)

$K_1 =$ 0,01 and $K_2 = 4{,}5$ with a maximum c value, the coefficient that depends on the ratio of length to width.

8. Conduct discussions to obtain research results in order to obtain a grid earthing system design on narrow rocky land with the addition of gypsum additives.
9. Make conclusions from research results and make reports and make articles for journals as the output of research.

IV. RESULTS AND DISCUSSION

4.1 Results of Soil Type Resistance Measurement

The results of measuring soil resistance to obtain the value of soil resistivity found that the soil resistivity before being given the treatment of adding gypsum additives obtained a value of 251.20 Ω-meter. After being given adityf gypsum, the soil resistivity value was 163.28 Ω-meter or a decrease of 35%. The graph of decreasing soil resistivity values can be seen in Figure 7.

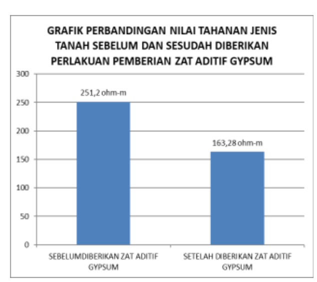

Fig 7. Prisoner Comparison Chart Soil Type Before And After Given Treatment of Giving Gypsum Additives

4.2 Analysis of Grounding Resistance of the Grid-Rod System Before Being Given Gypsum Additive Treatment

The resistivity of rocky soil is 251.20 Ω-meter with an area of 4m^2 and the number of rod electrodes is 11 x 11 rods. The following is the calculation of earth resistance with the grid system as follows:

R_G = Grid resistance *Grid-Rod* (Ω)

ρ = Earthing resistance (251,20 Ω-meter)

A = Grounding area (4 m^2)

h = Grounding system planting depth from ground level (0,5 m)

L_c = The total length of the mesh conductor (44 m)

L_r = The length of the electrode rod (2 m)

n_r = The number of rod electrodes 11 x 11 stem

L_R = The total length of the electrode rod (242 m)

$a^r = \sqrt{a.2h}$ The conductor is buried at a depth of h

a = Conductor mesh diameter (0,02 m)

b = Conductor rod diameter (0,02 m)

K_1 = 0,01 and $K_2 = 4{,}5$ with a maximum c value, the coefficient that depends on the ratio of length to width.

Calculate value R_1

$$R_1 = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{a^r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2\right]$$

$$R_1 = \frac{251x20}{3{,}14x44}\left[L_n\left(\frac{2x44}{0{,}1412}\right) + \frac{0{,}01x44}{\sqrt{4}} - 4{,}5\right]$$

$$R_1 = 1{,}82[6{,}43 + 0{,}22 - 4{,}5]$$

$$R_1 = 3{,}913\ ohm$$

Calculate value R_2

$$R_2 = \frac{\rho}{2\pi n_R L_R}\left[L_n\left(\frac{4L_R}{b}\right) - 1 + \frac{2K_1 L_r}{\sqrt{A}}\left(\sqrt{n_R} - 1\right)^2\right]\ Ohm$$

$$R_2 = \frac{251{,}20}{2.3{,}14.121.242}\left[L_n\left(\frac{4.242}{0{,}02}\right) - 1 + \frac{2.0{,}01.2}{\sqrt{4}}\left(\sqrt{121} - 1\right)^2\right]$$

$$R_2 = 0{,}001[10{,}7872 - 1 + 0{,}02.100]$$

$$R_2 = 0{,}01 \text{ ohm}$$

Calculate value R_m

$$R_m = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{L_r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2 + 1\right]\ Ohm$$

$$R_m = \frac{251{,}20}{3{,}14.44}\left[L_n\left(\frac{2.44}{2}\right) + \frac{0{,}01.44}{\sqrt{4}} - 4{,}5 + 1\right]$$

$$R_m = 1{,}82[1{,}19]$$

$$R_m = 2{,}16 \text{ ohm}$$

Calculate the grid resistance value

$$R_G = \frac{R_1 R_2 - {R_m}^2}{R_1 + R_2 - 2R_m}$$

$$R_G = \frac{3{,}913.0{,}01 - 2{,}16^2}{3{,}913 + 0{,}01 - 2.2{,}16}$$

$$R_G = 11{,}65 \text{ ohm}$$

The value of the earth resistance before being given the addition of gypsum additive treatment where the value of the resistivity value of the limestone soil is 251.20 ohm-meters, with the grid-rod grounding system has a grounding resistance value of 11.65 ohms (> 5 ohms). The desired grounding system resistance value is < 5 ohms for distribution substation system equipment. Considering that the soil type is rocky and it is very difficult to deepen the installation of the grounding system, it can be done by increasing the number of rods.

With the help of exel, calculations can be carried out to obtain a value of earth resistance < 5 ohms. Calculations were made from the number of electrodes 12x12 rods, 13x13 rods, 14x14 rods, 15x15 rods and the last 50 rods have obtained a value of 3 ohms (< 5 ohms). So that the calculation results with the number of rod electrodes 50x50 are as follows:

ρ = Earthing resistance (251,20 Ω-meter)

A = Gounding area (4 m^2)

h = Grounding system planting depth from ground level (0,5 m)

L_c = The total length of the mesh conductor (200 m)

L_r = The length of the electrode rod (2 m)

n_r = The number of rod electrodes 50 x 50 stem

L_R = The total length of the electrode rod (5000 m)

$a^r = \sqrt{a.2h}$ The conductor is buried at a depth of h

a = Conductor mesh diameter (0,02 m)

b = Conductor rod diameter (0,02 m)

K_1 = 0,01 and $K_2 = 4{,}5$ with a maximum c value, the coefficient which depends on the ratio of length and width.

Calculate value R_1

$$R_1 = \frac{251{,}20}{3{,}14.200}\left[L_n\left(\frac{2.200}{0{,}1412}\right) + \frac{0{,}01.200}{\sqrt{4}} - 4{,}5\right]$$

$$R_1 = 0{,}4[7{,}94 + 1 - 4{,}5]$$

R_1 = 1,78 ohm

Calculate value R_2

$$R_2 = \frac{251{,}20}{2.3{,}14.2500.5000}\left[L_n\left(\frac{4.20000}{0{,}02}\right) - 1 + \frac{2.0{,}01.2}{\sqrt{4}}\left(\sqrt{2500} - 1\right)^2\right]$$

$$R_2 = 0{,}0000032[13{,}82 - 1 + 48{,}02]$$

$$R_2 = 0{,}00019 \text{ ohm}$$

Calculate value R_m

$$R_m = \frac{251{,}20}{3{,}14.200}\left[L_n\left(\frac{2.200}{2}\right) + \frac{0{,}01.200}{\sqrt{4}} - 4{,}5 + 1\right]$$

$$R_m = 0{,}4[5{,}298 + 1 - 4{,}5 + 1]$$

$R_m = 1{,}1$ ohm

Calculate the grid resistance value

$$R_G = \frac{R_1 R_2 - {R_m}^2}{R_1 + R_2 - 2R_m}$$

$$R_G = \frac{1{,}78.0{,}00019 - 1{,}1^2}{1{,}78 + 0{,}00019 - 2.1{,}1}$$

$R_G = 3$ ohm

So that for the installation of a distribution substation grounding system on narrow land without the addition of gypsum additives with a land size of 2mx2m which is under the distribution substation on limestone soils, it is installed with a grid-rod system measuring 2mx2m with a planting depth of the grounding system from the ground surface of 0.5 m, the diameter of the conductor mesh is 0.02 m, the diameter of the conductor rod is 0.02 m with the number of rod electrodes of 50 x 50 rods 2 meters long for the grid and 2500 rods with a length of 2 meters for the rod resulting in a value of grounding resistance of 3 ohms (<5 ohms).

The number of rod electrodes is 50 rods x 50 rods for the grid which is very difficult to manufacture because the distance between the electrodes is only 4 cm (very close together).

5.3 Analysis of Grounding Resistance of the Grid-Rod System After Being Given Gypsum Additive Treatment

The calculation of the grid-rod system earth resistance can be calculated as follows:

$$R_G = \frac{R_1 R_2 - {R_m}^2}{R_1 + R_2 - 2R_m}$$

The resistivity of rocky soil is 163.28 Ω-meter with an area of 4m^2. By using the help of Exel to calculate the need for the number of rod electrodes to achieve an earth resistance value of < 5 ohms. Based on the help of Exel, the number of rod electrodes was 35 x 35 rods.

The following is the calculation of earth resistance with the grid - rod system as follows:

R_G = Grounding resistance *Grid-Rod* (Ω)

ρ = Soil type resistance (163,28 Ω-meter)

A = grounding area (4 m^2)

h = Grounding system planting depth from ground level (0,5 m)

L_c = The total length of the mesh conductor (140 m)

L_r = The length of the electrode rod (2 m)

n_r = The number of rod electrodes 35 x 35 stem

L_R = The total length of the electrode rod (2450 m)

$a^r = \sqrt{a.2h}$ The conductor is buried at a depth of h = 0,1412

a = Conductor mesh diameter (0,02 m)

b = Conductor rod diameter (0,02 m)

$K_1 = 0{,}01$ and $K_2 = 4{,}5$ with a maximum c value, the coefficient which depends on the ratio of length and width.

Calculate value R_1

$$R_1 = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{a^r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2\right]$$

$$R_1 = \frac{163{,}28}{3{,}14.140}\left[L_n\left(\frac{2.140}{0{,}1412}\right) + \frac{0{,}01.140}{\sqrt{4}} - 4{,}5\right]$$

$$R_1 = 0{,}37[7{,}59 + 0{,}7 - 4{,}5]$$

R_1 = 1,40 ohm

Calculate value R_2

$$R_2 = \frac{\rho}{2\pi n_R L_R}\left[L_n\left(\frac{4L_R}{b}\right) - 1 + \frac{2K_1 L_r}{\sqrt{A}}\left(\sqrt{n_R} - 1\right)^2\right]$$

$$R_2 = \frac{163{,}28}{2.3{,}14.1225.2450}\left[L_n\left(\frac{4.2450}{0{,}02}\right) - 1 + \frac{2.0{,}01.2}{\sqrt{4}}\left(\sqrt{1225} - 1\right)^2\right]$$

$$R_2 = 0{,}0000086[13{,}1 - 1 + 23{,}12]$$

$R_2 = 0{,}0003$ ohm

Calculate value R_m

$$R_m = \frac{\rho}{\pi L_c}\left[L_n\left(\frac{2L_c}{L_r}\right) + \frac{K_1 L_c}{\sqrt{A}} - K_2 + 1\right]$$

$$R_m = \frac{163{,}28}{3{,}14.140}\left[L_n\left(\frac{2.140}{2}\right) + \frac{0{,}01.140}{\sqrt{4}} - 4{,}5 + 1\right]$$

$$R_m = 0{,}37[4{,}9 + 0{,}7 - 4{,}5 + 1]$$

$R_m = 0{,}77$ ohm

Calculate the grid resistance value

$$R_G = \frac{R_1 R_2 - {R_m}^2}{R_1 + R_2 - 2R_m}$$

$$R_G = \frac{1{,}40.0{,}0003 - 0{,}77^2}{1{,}40 + 0{,}0003 - 2.0{,}77}$$

$R_G = 4{,}2$ ohm(< 5 ohm)

Considering that the installation of a grounding system on limestone soil types is very difficult, both for installation and for obtaining a small value as recommended by a standard, because the soil is hard and also has a high soil resistivity (generally has a soil resistivity value of > 200 ohms) . To obtain a standard low earth resistance value in limestone soil requires extensive earthing systems, because it is very difficult to embed deeper. The distribution substation that lies on the side of the road has very narrow land with an average area of 2 meters x 2 meters, because there are already buildings around it or it is not even possible to expand the grounding area. Based on these problems, this research was carried out by adding gypsum additives and using a grid-rod earthing system. The results of these calculations are to obtain the value of the earthing resistance according to the grounding standard for distribution system equipment according to the SPLN, namely <5 ohm in a narrow area of land size of 2 meters x 2 meters which is under the Distribution Substation and is located on limestone soils with the treatment of gypsum additives. In this treatment, the addition of gypsum additives was very effective in reducing the soil resistivity value from 251.20 ohm-meters to 163.28 ohm-meters or a decrease of 35%.

Decreasing the value of soil resistivity can have an impact on the structure of the earthing system (depth, shape of the earthing system, number of electrode requirements, size of the earthing system).

The results of the research to obtain the value of earthing resistance < 5 ohms using the form of a grid-rod earthing system obtained the characteristics of the earthing system as follows:

a. $\rho =$ Earth resistance 163,28 Ω-meter

b. $A =$ Grounding area 4 m^2

c. $h =$ Grounding system planting depth from ground level (0,5 m)

d. $L_c =$ The total length of the mesh conductor 140 m

e. $L_r =$ The length of the electrode rod 2 m

f. $n_r =$ The number of rod electrodes 35 x 35 stem

g. $L_R =$ The total length of the electrode rod 2450 m

h. $a^r = \sqrt{a.2h}$ The conductor is buried at a depth of h = 0,1412

i. $a =$ Conductor mesh diameter 0,02 m

j. $b =$ Conductor rod diameter 0,02 m

h. $K_1 =$ 0,01 and $K_2 = 4{,}5$ with a maximum c value, the coefficient which depends on the ratio of length and width.

Based on the characteristics of the grid-rod earthing system used above, it is obtained that the grounding system value is 4.2 ohms (< 5 ohms) using a distance between the electrodes of 5.7 cm which is very easy to install between the electrodes.

When compared with the installation of a grounding system without the addition of additives by obtaining a value of earthing resistance < 5 ohms, the number of electrodes needed is 50 rods x 50 rods each 2 meters long for grid needs, and 5000 meters for rod needs, so that it will be difficult for inter-rod installation because it is very close together. Whereas if given the treatment of adding gypsum additive, the need for electrodes for the grid is 35 rods x 35 rods long @ 2 meters for the needs of the grid and 1225 meters for the needs of the rod. The number of electrodes greatly facilitates the installation and manufacture of grid-rods because the distance between the electrodes is 5.7 cm.

V. CONCLUSION

Based on the results of the analysis as answers to research problems and answering the objectives of this study, it can be concluded as follows:

1. The addition of gypsum additives to limestone soils is very effective in reducing the soil resistivity value from 251.20 ohm-meters to 163.28 ohm-meters or a decrease of 35%.
2. Reducing the value of soil resistivity by 35% can have an impact on the structure of the earthing system on narrow limestone land including: installation depth of 2.5 meters, the shape of the earthing system can be in the form of a grid rod, reducing the total required length of the mesh conductor can be reduced from 200 meters to 140 meters (reducing the length of the conductor by 30%), reducing the total length of the electrode rod from 5000 meters to 2450 meters (reducing the length of the electrode rod by 51%), the size of the earthing system even in a narrow area of 2 meters x 2 meters can still be construction of the earthing system was carried out.

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