Statistical Process Control And Analytical Hierarchy Process Methods For Reducing Earth Resistance

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Abstract—Security or protection systems at generators, substations, transmission, and housing and others, especially to overcome lightning disturbances and leakage currents, the earthing system must meet the required standards. For each part of the system, from transmission, substation and residential electricity utilization as well as other parts, the standard of earth resistance is not the same, for example for housing a maximum of 5 Ω, for a small generator system a maximum of 10 Ω, for a large generator a maximum of 20 Ω and so on etc. In areas where the soil type resistance is high, it is necessary to reduce the value of the earth resistance so that it reaches the Indonesian national standard. There are many ways to reduce the value of earth resistance, including lowering soil resistivity, adding electrodes to the soil, changing the type of electrode and its diameter, and so on. The aim of the research was to determine the effect of the value of earthing resistance on the depth of electrode planting and the type of soil that is affected by the water content in the soil and to apply simple statistical tools, namely Statistical Process Control (SPC) and Anlytical Hierarchy Process (AHP).

The measurement method in this research uses a three-point system, namely one point for the test electrode and two points for the auxiliary electrode and the measuring instrument used to measure earth resistance is a digital earth resistance tester type digital model 4105A. This tool is designed according to international electrical commission (IEC) standards. To analyze reducing earth resistance using Statistical Process Control (SPC) and Analytical Hierarchy Process (AHP) methods. The design of this research is to answer the problems and research objectives that have been planned, namely to determine the effect of soil type on earth resistance and to analyze efforts to reduce the value of earth resistance to achieve standards with statistical process control (SPC) and analytical hierarchy process (AHP) methods. To find potential causes, it is done by calculating the analytical hierarchy process (AHP) in order to obtain a sequence of problems to be solved. If the consistency ratio value is more than 10%, then the data judgment must be corrected, but if the consistency ratio is less than or equal to 10% then the calculation results are declared correct or accepted. From the results of the AHP calculation, it is then verified by testing the earth resistance..

Keywords— Earth resistance, Statistical Process Control, Analytical Hierarchy Process

I. INTRODUCTION

The growth and development of industry and the economy in Indonesia will increase the need for energy, especially for electricity, there will also be an increase. The increasing demand for electricity will coincide with the demands of society and customers for electricity services that continue to increase. The construction of electricity generators that continues to be carried out in a sustainable manner in order to meet the growing and developing needs for electrical energy. The service needed by the community is the availability of sufficient and reliable electrical energy and the quality of its continuous distribution. Forms of service on the other hand continue to be developed in order to provide satisfaction to customers, gradually improving the service space in service units. To achieve the things mentioned above, it is necessary to increase the generation and distribution as well as protection equipment.

Protection equipment on the generator side up to the load centers must be properly considered so that the continuity of the distribution of electrical energy remains reliable and continuity is guaranteed. Thus service to the community can be achieved satisfaction. Protection systems at generators, substations, transmission, and housing and others, especially to overcome lightning disturbances and leakage currents, the earthing system must meet the required standards. For each part of the system, from the transmission to the substation and the utilization of residential electricity and other parts, the value of the earth resistance is not the same. The earthing system is an important thing in the electric power system, especially the issue of security and safety for both humans and equipment. To meet the requirements of the earthing system as desired or meet the Indonesian National Standard (SNI), for example for residential buildings below 5 ohms, for areas with high resistivity, the earthing resistance may not be more than 20 ohms, then the land where the earthing system is installed has a value does not meet the requirements must be removed. There are many ways to reduce the value of earth resistance, including lowering soil resistivity, adding electrodes to the soil, changing the type of electrode and its diameter, and so on.

The value of grounding resistance is affected by the depth of planting and the distance of the electrodes. This journal describes how it affects the value of earth resistance. In this study a three-point measurement method was used by injecting a constant AC current between the test electrode and the current electrode which creates a potential difference between the test electrode and the voltage electrode, so that the value of the earth resistance is obtained. The results of the analysis show that the value of the earth resistance will be smaller if the depth of planting is added, the number of electrodes planted, and the distance between the plantings is increased [1].

In the experimental test, the length of each rod conductor = 3.5 meters, the diameter of the rod conductor = 3/4 inch = 0.01905 meters, the radius of the conductor rod = 9.525x10-3

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meters, the average soil type resistance of the first layer = 750 Ohm-m. The depth of implanting the hb electrode = 0.5 meters produces a resistance value of the earth electrode Rd1 = 191.0741 ohm, for one rod the smaller the electrode is planted the farther from the soil surface it becomes Rd1 = 157.4655 ohm and for two electrodes, the distance between the two becomes greater The greater the length of the electrode, the lower the grounding resistance value. The results of the research above show that there are various ways to reduce earthing resistance. One way to reduce the value of earth resistance is to reduce soil type resistance, for example by treating the soil used for earthing. The research that will be carried out is looking for earth resistance data in several types of soil. Problems that can affect earthing resistance and look for dominant problems by using tools or tools [2].

In installing the grounding electrode, it is also necessary to pay attention to how the planting arrangement is. This needs to be done to get a minimum resistance value so that the current flows more easily to the ground. Several types of electrode installation include vertical planting, horizontal planting, radial planting, ring shape, grid shape, and plate shape planting[3] [4].

The value of earthing resistance is influenced by several factors such as: soil type, soil water content, soil temperature, soil moisture, soil electrolyte content and others [5]. The earthing system is an important factor for securing the electric power system in the event of an overcurrent or overvoltage disturbance. When there is a disturbance in the electric power system, with the earthing system the fault current will flow into the ground or be earthed and spread in all directions [6]. The earthing system is a conductor connection system that connects the body of the equipment and electrical installations to the earth so that it can protect humans, equipment or electrical installations from the danger of electric shock or overcurrent and overvoltage [7]. The function of earthing is to channel the fault current into the ground through a grounding electrode that is planted in the ground when a fault occurs, for this reason the resistance value of the earthing system must comply with the specified conditions [8].

Earthing system to unravel the current at the neutral point, and also as a security system for electric power, buildings, electrical equipment and consumers or users. For electrical and electronic equipment the value of resistance (R) from earthing is ideally $\leqslant 1\ \Omega$ but PUIL provides tolerances of up to $\leqslant 5\ \Omega$ [9][15]. Based on the IEEE 80-2000 Standard on distribution substation earthing, it is given less than 1 Ω [10], [11]. From previous research there has been a discussion regarding the harmonics that occur in the transformer on the Tuberose Tube, showing the results of the transformer having a THDi value of more than 8% and resulting in power losses in the transformer [12]. Then another study on the effect of the resistance value for grounding the neutral point, showed results at the neutral point flowing a current of 41.6 A which should be if in a balanced condition there is no current flowing at the neutral point [13]. Another study entitled the analysis of the grounding system on building security equipment at Udayana University on the Denpasar campus concluded that the most effective grounding method is grid type grounding which has the lowest resistance with a value of 2.09 Ω [14].

The research that the author does is to analyze efforts to reduce the value of earth resistance using the statistical process control (SPC) method and the analytical hierarchy process (AHP) to find the causes that occur and to look for the highest criterion value or the main cause by using analytical hierarchy process calculations (AHP). From the dominant problems and known sequence of causes, then it is verified about efforts to reduce the value of earth resistance in certain soils.

II. Methods

The method in this research is as follows :

A. Statistical process control (SPC)

Statistical Process Control (SPC) is a quality control tool for detecting causes of earthing resistance that do not meet the requirements or high earthing resistance in certain soil types. Statistical process control consisting of seven tools, namely: check sheet, stratification, pareto diagram, fishbone diagram or cause and effect diagram, histogram, control chart, scatter diagram (scatter diagrams). Statistical Process Control (SPC) or Statistical Quality Control is made to detect causes that affect the amount of earth resistance. In the SPC method, a cause and effect diagram or fishbone diagram is used to look for potential problems. This tool is to explore the influence of earthing resistance as much as possible and as a basis for analyzing the earthing system.

B. Analytical Hierarchy Process (AHP)

Analythical hierarchy process (AHP) is a tool used to assist in making decisions based on several criteria or alternatives. AHP will produce a priority sequence of several causes that affect earth resistance. By creating a paired matrix that connects the causes that will be used as a basis for calculating priority weights. The process of completing AHP consists of three stages, namely:

1. Determination of the degree of importance of each attribute.

2. Determination of the degree of importance of each alternative to the relationship of each attribute.

3. Determine the overall weight for each criterion or alternative.

Of the three processes, the most important is determining alternative weights which are used as the basis for verifying each type of soil.

III. Results and Discussion

When presenting and discussing results, give in depth analysis, not only reporting the results.

In this AHP calculation, the rod electrodes and for each type of soil are not the same and they are not related to one another.

TABLE 2. RESULTS OF AHP CALCULATIONS ON CLAY TYPES.

No	Root cause	Clay
1	Soil type resistance	0,212
2	Deepness	**0,339**
3	Electrode installation	0,238
4	Electrode diameter	0,158
5	Auxiliary electrode spacing	0,054

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TABLE 3. DATA ON EARTHING RESISTANCE AND WATER CONTENT IN CLAY WITH ONE ROD ELECTRODE

No	Electrode Depth (cm)	Rp Clay (Ω)	Water content (%)	ρ (Ω-cm)
1	25	71,2	28,9	5107,87
2	50	51,9	30,4	4996,43
3	75	36,3	34,7	4507,54
4	100	25,3	36,9	4081,24
5	125	20,4	39,3	3757,16
6	150	15,8	41,7	3199,68
7	175	11,9	44,8	2938,78
8	200	8,1	47,3	2219,53
9	225	4,7	49,8	1412,57

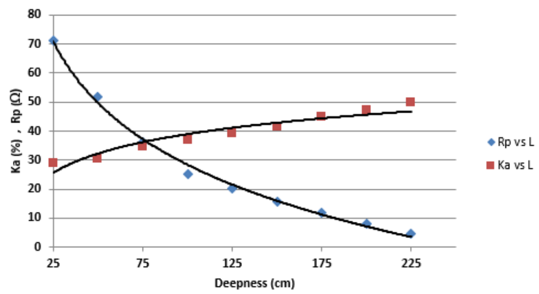

Fig. 1. Relationship between Rp (Ω) and L (cm) and Ka with L (cm) on clay

Figure 1 shows the effect of electrode depth on water content and earthing resistance with rod electrodes. The deeper the electrode is planted, the lower the earthing resistance and the greater the water content in the soil because it is closer to the groundwater source.

The water content is 49.8% at a depth of 225 cm, the grounding resistance has reached the standard for housing (below 5 Ω) and for electrical energy generation systems with a water content of 47.3% with a depth of 200 cm the earthing resistance has reached the standard (below 10 Ω) .

Figure 2 shows the effect of the water content in the soil on the earthing resistance, that the greater the water content in the soil, the smaller the earthing resistance.

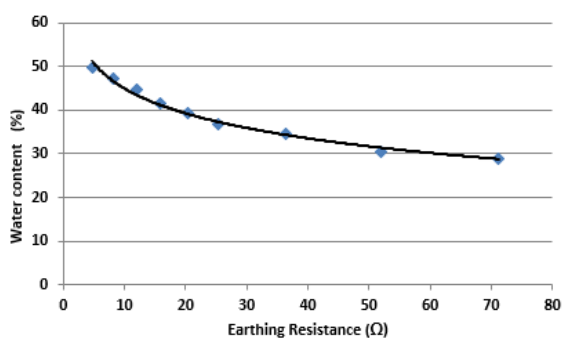

Fig. 2. Graph between earthing resistance (Ω) and water content (%) On clay

Figure 2 shows that the tendency of earth resistance to water content is curved and inversely proportional. Earthing resistance achieved 4.7 Ω at a moisture content of 49.8 %

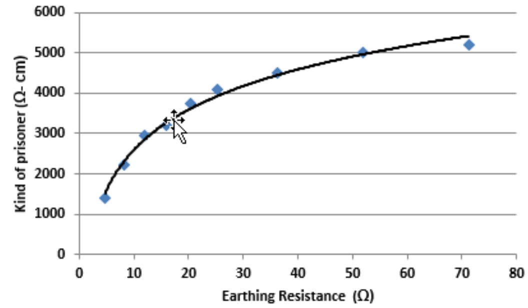

Fig. 3. Graph between earthing resistance (Ω) and soil resistivity on clay

It is shown in Figure 3 that the smaller the soil type resistance, the smaller the earth resistance for earth resistance below 100 ohms. The grounding resistance reaches the standard (below 5 Ω) of the soil type resistance of 1412.57 (Ω-cm).

IV. CONCLUSION

Based on the results it can be concluded that:

1. Two SPC and AHP methods to solve earthing problems in electric power systems at generators and substations and distribution grids in clay-type locations

2. Type of clay to reduce earthing resistance by increasing the depth of the electrode and to reduce earthing resistance in solid soil and dry sand by adding additives or other systems. Earthing resistance in clay reached 4.7 Ω at a depth of 225 cm and a moisture content of 49.8%.

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