Analysis of the Behaviour and Effect of Grounding Filler Materials on Grounding System

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Abstract. The grounding system plays an important role in the electrical system part as it gives protection during fault or lightning occur. The main purpose of the grounding system is to protect humans, electrical appliances and buildings from electrical shock due to lightning or another form of electricity that hazardous. Thus, to install an excellent electrical system and complete its circuit, a grounding system performance must be taken into account. But, in certain cases, due to the geological condition, the soil resistivity is not good enough. Therefore, enhancement filler material has been used to reduce grounding resistance. In this project, it is aimed to elaborate on the usage of Coconut Husk, Paddy Husk, and Bentonite as grounding filler materials to reduce the soil resistivity and improves the grounding system. The result showed that Bentonite showed better performance compared to Coconut Husk and Paddy Husk.

1. Introduction

The grounding system is the connection of electrical equipment or wiring system to the earth ground by a wire or other conductor. The grounding system must be operated efficiently all the time to protect the electrical system, during both normal and abnormal condition [1]. Two most common abnormal phenomena may occur which are ground fault and lightning strikes. Those phenomena can cause severe damage to the affected area. Therefore, grounding system installation is important to minimize the damage from such occurrences [2]. Grounding system is also important to solve electrical power quality problems such as noise, harmonic distortion and electromagnetic compatibility in the electrical power system [3]. An excellent grounding system will ensure that the fault currents to choose the lowest impedance path in the shortest possible time under both normal and abnormal conditions without exceeding any other equipment and operating limit. This is also to assure the person in the vicinity area is not exposed to any risks that may cause death [4].

The performance of the grounding system is depending on two factors that are the type of electrode usage and also on the soil characteristic. Around the world, no soil has the same resistivity value, all of them are different in some form or other. The resistivity of soil all depends on the type of soil. Soil Resistance is the most important factor when determining the design of the grounding system for new installations. Thus, to install an electrical system and complete its circuit, a grounding system performance must be taken into account. But, in certain cases, due to the geological condition, the soil resistivity is not good enough. This causes the grounding system fail to reach the low grounding resistance required by just directly placing the grounding rod into the soil [5]. So, to overcome this
problem, there is a solution that requires increasing the size of a conductor or adding more grounding rod to get a better grounding system. Since it is often too expensive to achieve the desired grounding resistance by using those techniques, the alternative solution was developed by using grounding filler materials to modify the soil surrounding the grounding rod. This material is expected to be able to reduce the soil resistivity and improves the grounding system.

Nowadays, the usage of grounding filler material for the grounding system had been widely investigated by the researcher. Most of the researchers focused on the utilization of the grounding filler material to enhance the performance of the grounding system. In 2012 [6], several compounds were evaluated by Androvitsaneas, Gonos, and Stathopulos. In this experiment, five main grounding rods have been driven into the soil with different grounding enhancing compounds that consist of bentonite, conductive concrete, chemical compound A, chemical compound B and chemical compound C. After investigation, it can be clarified that the performance of the enhancement compounds presents was not consistent throughout the year as it is strongly dependent on soil humidity and rainfall. The final result showed that conductive concrete and bentonite are the most suitable ground enhancing compound in this experiment compared to the materials A, B, and C.

In 2009, George Eduful and Joseph Ekow Cole [7] studied on Palm Kernel Oil Cake (PKOC). This study investigates the derivation of palm kernel nut as a reducing agent after the extraction of oil. To determine the effectiveness of this PKOC as earth resistance reduction, a 100% PKOC was applied in a critical resistance radius of earth electrode at the selected area and the resistance behaviour at the area was monitored over three years. The results showed that PKOC can maintain permanently earth resistance reducing effect without being lost by rainfall. As a result, fluctuation of earth resistance due to rainfall and seasonal changes in climate is substantially negligible.

According to Lim et al. [8] grounding material must possess certain characteristic to further enhance the performance of grounding system itself, such as able to change its surrounding soil to be less resistive, able to create a protective layer to avoid corrosion to the grounding rod and able to retain moisture in the soil. Therefore, it is important to choose suitable grounding filler material for the grounding system purposes. In this experiment, it is aimed to elaborate on the usage of Coconut Husk, Paddy Husk, and Bentonite as grounding filler materials to reduce the soil resistivity and improves the grounding system. This material is expected to be able to reduce the soil resistivity and improves the grounding system.

2. Grounding System Installation

In this experiment, the main materials are 4 copper electrode, Bentonite, Coconut Husk and Paddy Husk ashes. The electrodes used are 50 cm long respectively. The area of the chamber to put the mixture of soil and the grounding filler which are Bentonite, Coconut Husk and Paddy Husk is 4 inches diameter, 50 cm depth and cylindrical type. Figure 1 shows the chamber arrangement.

Figure 1. Copper Electrode in Grounding Filler Chamber.
The grounding system was installed on a field near the School of Electrical Systems Engineering, University Malaysia Perlis. The location was chosen because it is the largest area inside the School of Engineering System. Therefore, it provides a large space for soil resistance measurements. Also, vehicles would not easily pass by the area and disturbing the ongoing experiments. The soil resistance was measured for 73 days using the Three-Pin Arrangement method.

Before installing the grounding electrode and the grounding filler, the field was measured using a measuring tape to identify the site for grounding system installation. A site with dimension 4.65 m x 15.30 m was fenced using raffia string tied on 4 wooden rods located at each corner of the field. The distance between those 4 electrodes was set equally to 3 meters as shown in figure 2. Four grounding systems that were installed are Reference, Bentonite, Coconut Husk and Paddy Husk. Note that, Reference grounding system was installed without any grounding filler in the vicinity of the ground electrode.

![Figure 2. Arrangement of The Grounding Medium.](image)

### 3. Results and Discussions
The grounding resistance is measured daily for 73 days from 1st January until 14th March 2019. The result obtained is shown in figure 3. Besides, daily weather when measuring the grounding resistance was also recorded. Mostly, the grounding resistance measurements are performed in the evening. Therefore, the soil condition in the evening was recorded. The soil condition is recorded as dry if it is a sunny day and when the soil condition is wet, it is recorded as a rainy day. This is because, Malaysia experienced hot, humid and rainy throughout the year.

From the result obtained in figure 3, it shows that there are decreasing in the soil resistance value of all types of grounding fillers used since the first day of the measurement. Also, there is a huge difference in soil resistance value for all grounding electrode with grounding fillers compared to the Reference for the first 20 days. Note that, the effectiveness of the grounding filler depends on its ability to retain moisture. The greater the ability of the grounding filler to retain the soil moisture, the better result of grounding resistance will be obtained. However, there is still a decrease in the soil resistance value from 20th day onwards but not as significant as the first 20 days. This is due to the dispersion of the grounding filler into the soil.
The grounding resistance without any grounding filler is noticed to be not stable at day 14, day 51 and day 69. This is because the result obtained was measured from January until March. Perlis receives less rainfall from January to March. When the temperature is extremely high, the soil condition tends to be drier. Thus, cause the soil resistance value suddenly overshoots to a very high value. Also, from the result, it shows that the soil resistance value drops drastically on day 51 and day 70. This is because there is rain on the morning of day 52 and day 70. So, the soil regains its moisture and all the soil resistances fall back to the stable values. However, the electrode with the grounding filler has lower soil resistance value compared to the Reference grounding electrode. This is because, grounding filler has greater capability to retain soil moisture.

There is another observation from the rise and fall of the soil resistances value, during day 51, it is noticed that the soil resistance value of the Paddy Husk with grounding electrode is extremely high. This is due to the surrounding temperature that is extremely high. Thus, cause the result to suddenly overshoot to a very high value. The soil resistance value of the Paddy Husk is higher than the Reference grounding electrode. This shows an inconsistency in using Paddy Husk as a grounding filler in this project area but further research is needed to analyze its performance for a longer period of time.

Also, the result obtained in figure 2 shows that from day 1 to day 73, the performance of the grounding electrode with Bentonite has the lowest soil resistance values. This is followed by the Coconut Husk and Paddy Husk. The Reference shows the most unstable and has the highest soil resistance value compared to the others.

4. Conclusions
In conclusion, it is showed that the soil resistance is affected by the physical condition of the soil when the measurement is taken. This is because, when the soil condition is wet, the soil resistance tends to be low and when the soil is dry, the soil resistance tends to be high. However, grounding electrode with grounding filler tends to have lower soil resistance value compared to the Reference grounding electrode. This result shows that the grounding fillers successfully maintain the moisture and effectively decrease the grounding resistance of the soil as it have greater capability to retain soil moisture. Also, based on the 73 days measurement data, the results obtained show that the performances of the grounding electrode with Bentonite have been identified as the most effective grounding filler compared to the Coconut Husk and Paddy Husk. The Reference shows the most unstable and has the highest soil resistance value compared to the others.
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