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To cite this article: Nur Aqilah Sofiyah Hasni *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **864** 012163

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Effect of Concrete Orientation as an Enhancement Material in Grounding System

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Abstract. To achieve an excellent grounding system, an alternative solution was developed by using enhancement material to modify the soil surrounding the rod. These materials can effectively reduce soil resistivity and grounding resistance for a better grounding system. To achieve this goal, the fundamental part must be taken into account. In this study, the main objective is to analyze different concrete orientations as enhancement material in the grounding system. A 3-D orientation of concrete has been designed using Finite Element Method (FEM) software to analyze the performance of the electric field in the grounding system with different orientation of concrete. Every orientation of concrete had been clarified into four different cases which are full concrete, half concrete, three-quarter concrete, and a quarter concrete. From the result, full concrete is the best orientation of concrete design to be employed at the grounding site as it has a low electric field compared to the other concrete orientation.

1. Introduction

The grounding system must be operated efficiently all the time, during both normal and abnormal phenomena [1]. Two most common abnormal phenomena that may occur which can lead to property damage, injuries or even death are ground fault and lightning strikes. In both of the cases, the overhead transmission or distribution network and the grounding path such as grounding rods, are the parts of the circuit where the fault current or lightning transient flows. Therefore, the grounding system plays an important role to allow the transmission and distribution of the fault current or lightning strikes into the soil to provide safety protection in the electrical installation area [2].

The major aim of the grounding system installation is to dissipate and carry fault current to the ground. This ensures that any individual in the vicinity of the grounding system area is not exposed to critical electrical shocks that may cause death [2]. This is because 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. According to IEE 142-1991, “the intentional connection of a phase or neutral conductor to earth to control the voltage to earth or ground within predictable limits. It also provides for the flow of current that will allow detection of an unwanted connection between system conductors and ground which may instigate operation of automatic devices to remove the source of voltage. The control of voltage also allows reduction of shock hazard to the person who might come in contact with live conductors.” From the statement above, the purpose of grounding is to



limit the potential difference of neutral for system stability, allow for the operation of relays and system protection devices and also for personal safety [3]. To achieve the goals mentioned, the grounding system must be able to provide the lowest impedance path to the ground to make sure fault current or lightning strikes to diverge mainly to the grounding rod into the soil [4].

In order to achieve the lowest impedance path to the ground, the resistivity of the soil must be considered as the main factor in designing any grounding system. It is because the soil resistivity is the parameter that can determine the fault current that flows into the earth's ground. Therefore, it is important to install the best orientation of concrete as an enhancement material to achieve the lowest soil resistivity[4].

According to Lim et al. [5] enhancement 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.

Modifying the soil characteristic by using an enhancement material one of the effective ways to improve the performance of a grounding system [1]. The enhancement material has been classified into two categories which are chemical and natural based. According to IEEE Std [6] Chemical Enhancement Material (CEM) will easily reduce the resistivity of the surrounding soil. However, it can cause pollution to the soil and corrosion may occur to the grounding rod. Also, Gomez et al. [5] state that the usage of CEM is not as cost-effective as they need to be renewed periodically and also will result in unstable resistivity values.

Natural enhancement material (NEM) sometimes comes from the agriculture waste product. This type of material is widely used in the field of grounding systems as they are low in cost production, environmentally friendly and may result in optimum earth resistance for installed grounding systems in high resistivity soil [4]. Concrete one of the NEM that will ensure the grounding system to function effectively. Therefore, in this study, concrete was chosen as enhancement materials to reduce the soil resistivity and improves the grounding system problem statement.

2. Analysis of Previous Works in Shape

Grounding system is a technology to connect the electrical apparatus to the ground. From the previous study, there is two types of shape that had been used in this grounding system field which is a rectangular shape and cylindrical shape. In 2012, an application of a rectangular wood ceramics as a grounding system was investigated. H. Shimizu and N. Watanabe manufactured some wood ceramics plate with dimension 78mm x 64 mm x 7mm to act as an electrode. Then, this rectangular wood ceramic electrode was soldered with a grounding wire and was buried in 200mm depth with about 60mm separation between each electrode [7]. Meanwhile, in 2013 [8] a rectangular shape of steel cages encased in concrete mixed with various proportions of bentonite was designed. In this study, the concrete mixed with the various proportion of bentonite was installed in 8 pits at aside.

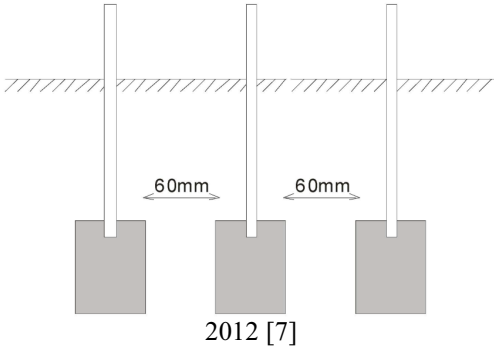
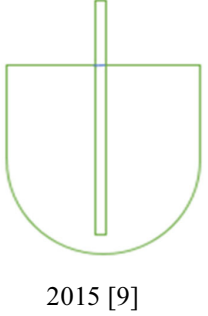
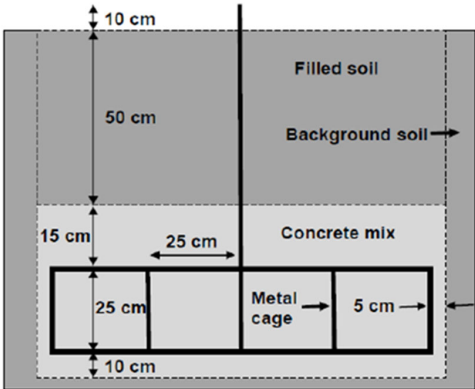
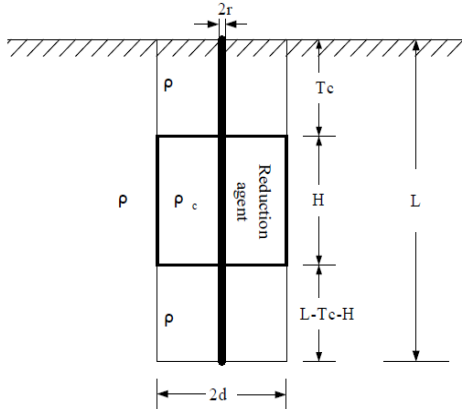
However, as time passed by, a cylindrical shape become dominant compared to a rectangular shape. In 2015, a 2D cylindrical concrete was designed to coat the electrode by using COMSOL Software. This paper investigated the grounding system with additive and without additive material using COMSOL software [9]. In 2016, Chen et al.[10] used coal fly ash as a reducing agent to reduce the resistivity of soil at Kung Shan University of Technology. In this study, the grounding bars No.1 to No.3 were only partially covered with a reduction agent in a cylindrical shape.

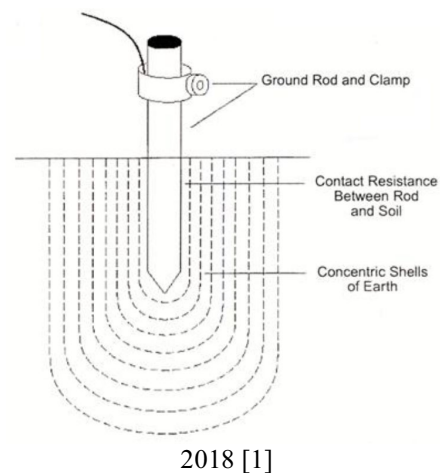
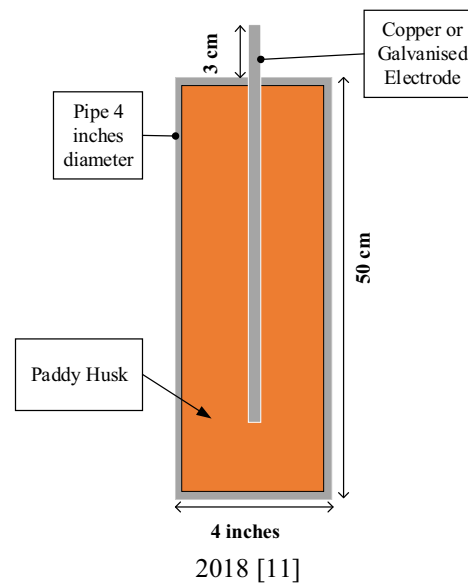
Three years later (2018), a cylindrical shape concrete filled with additive material once again has been used by N.H. Halim to coated the electrodes to investigate the performance of galvanized steel and copper electrode using paddy husk ashes [11, 13, 14]. Also, in the same year (2018), a cylindrical grounding conductor made up of copper with length 1.5m and diameter 0.013m were used to study on bentonite and Kenaf as an additive material in the grounding system [1, 15].

Therefore, as shown in table 1, it can be seen that a previous study from the year 2012 to 2013 tends to use a rectangular shape for the grounding system purposes. However, in recent years study which is from 2015 up until 2018, the trend of designing the grounding system has changed to a

cylindrical shape. Therefore, in this study, a cylindrical shape was chosen rather than a rectangular shape following the previous recent study. Also, this paper aimed to study the different orientations of concrete whether it affects the performance of the grounding system or vice versa.

Table 1. Types of Shape in Grounding System.

Rectangular Shape	Cylindrical Shape
 2012 [7]	 2015 [9]
 2013 [8]	 2016 [10]



3. Designing Grounding System Model

The grounding system is modeled in 3 Dimension (3D) by using the Finite Element Method (FEM) Software. In this grounding system model, it consists of a copper rod, concrete and soil as shown in figure 1. Note that, reference grounding system was installed without any concrete in the vicinity of the soil.

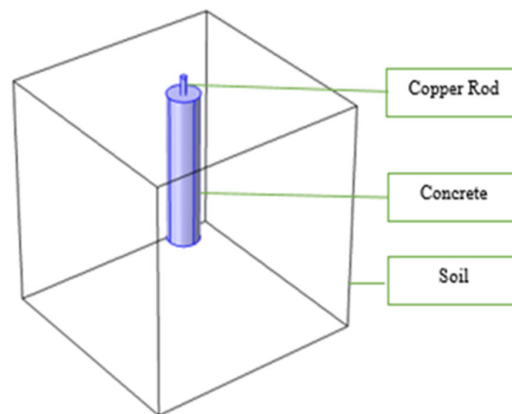


Figure 1. Grounding System Model.

Finite Element Method (FEM) software is used to analyze the best performance of the electric field in the grounding system with different orientation of cylindrical concrete [12]. Every orientation of concrete had been clarified into four different cases as shown in figure 2. Note that, every orientation of concrete got the same volume.

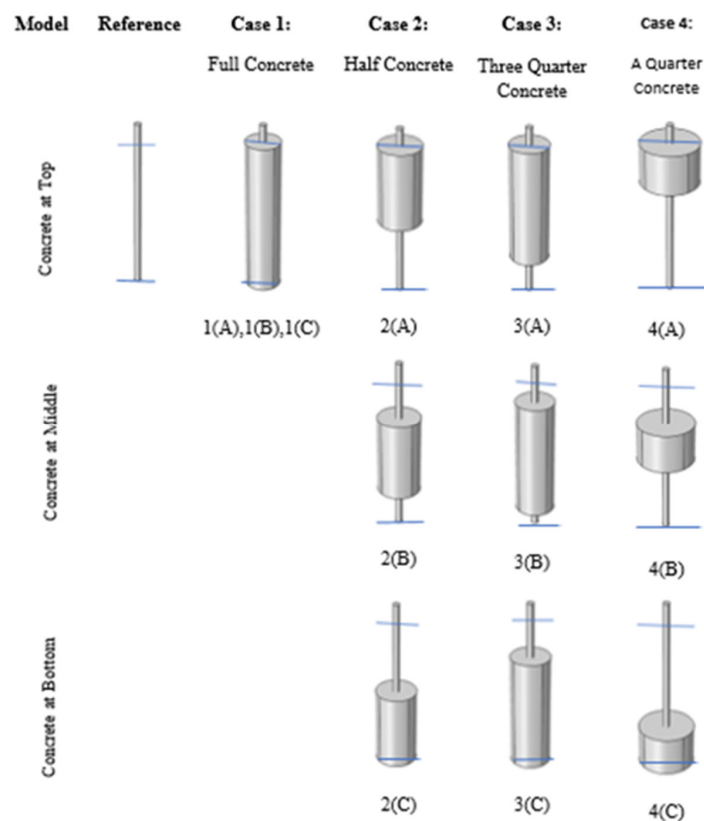


Figure 2. Different Orientation of Concrete.

Next, two 3D Cut Line had been selected to analyses the electric field value at that area. The cut line selected area is at position top and position bottom as shown in figure 3 and figure 4, respectively.

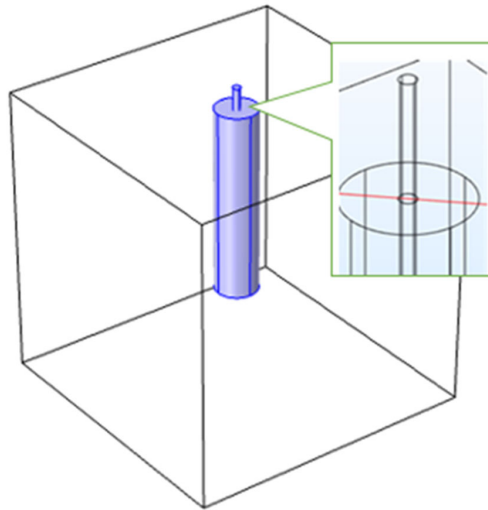


Figure 3. Cut Line at Position Top.

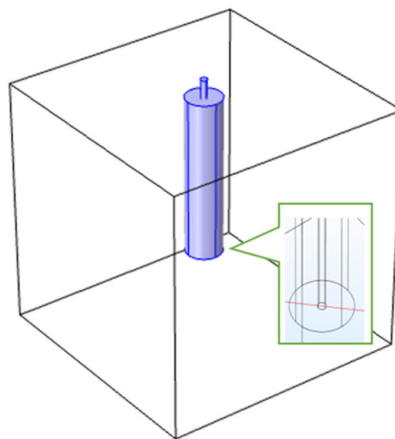


Figure 4. Cut Line at Position Bottom.

4. Results and Discussions

Figure 5, figure 6, figure 7 and figure 8 shows the simulation result obtained for the reference grounding system without any concrete in the vicinity of the soil. Figure 5 and figure 7, shows the intensity of the electric field for position top and bottom respectively. Figure 6 and figure 8 shows the level of the electric field at position top and bottom respectively.

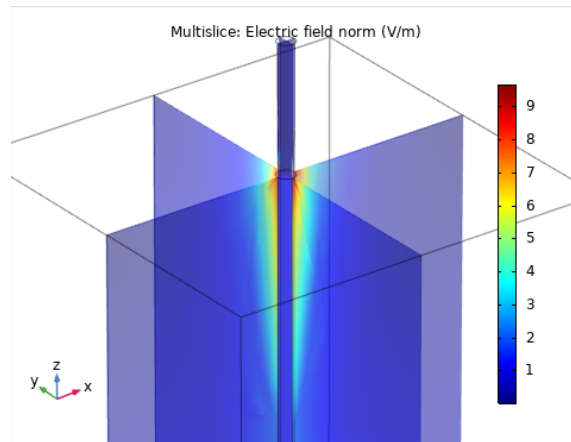


Figure 5. Electric Field at Position Top.

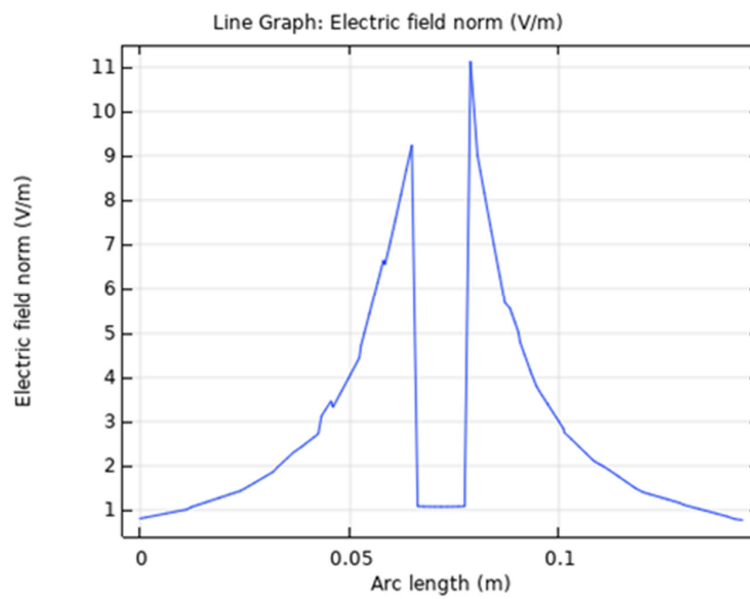


Figure 6. Graph of Electric Field versus Arc Length at Position Top.

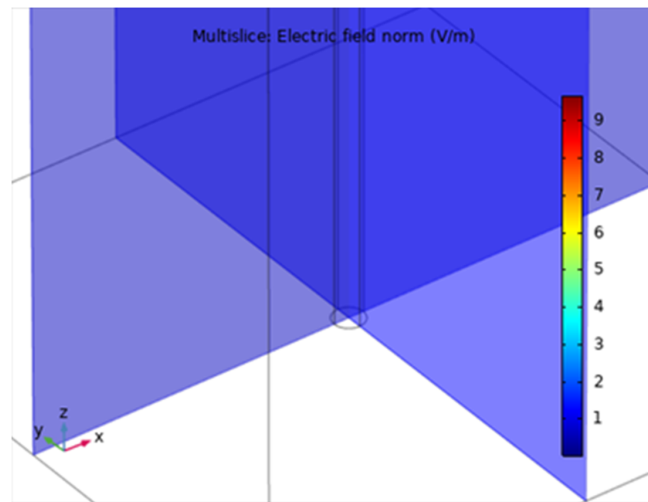


Figure 7. Electric Field at position Bottom.

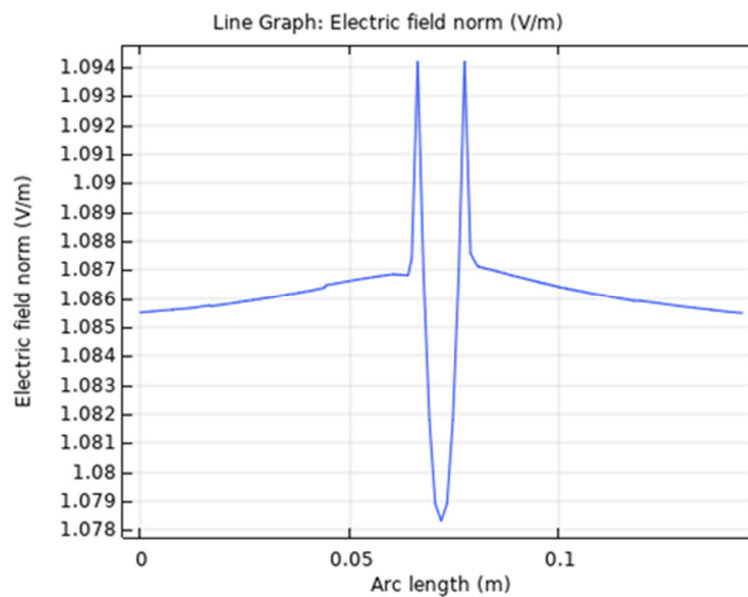


Figure 8. Graph of Electric Field versus Arc Length at Position Bottom.

The highest electric field value obtained from this result for the case 1, case 2, case 3 and case 4 at position top and bottom is recorded and it is tabulated in table 2, table 3, table 4, table 5, table 6 and table 7 according to the model of the concrete which is concrete at the top, middle and bottom. The highest value of the electric field obtained has been compared to the reference grounding system, which is without any concrete in the vicinity of soil.

Table 2. Result for Concrete at Top Position Top.

	Ref.	Case 1	Case 2	Case 3	Case 4
		1(A)	2(A)	3(A)	4(A)
Electric Field (V/m)	11.1134	0.0100	0.0102	0.0106	0.0117
Percentage Error (%)	-	-0.9991	-0.99908	-0.99904	-0.99892

Table 2 shows that case 4 which is a quarter concrete got the highest electric field with 0.017 V/m compared to the other cases, followed by a grounding system case 3, case 2 and case 1 which is three-quarter concrete, half concrete and full concrete respectively. The Reference grounding system showed the highest electric field compared to the other four grounding systems with concrete. Also, the percentage error calculated compared to reference grounding system is -0.99910% for case 1, -0.99908% for case 2, -0.99904 for case 3 and -0.99892% for case 4. All the percentage error value for model concrete at the top in position top obtained are negative, it means that the electric field value to be compared to the reference grounding system is huge. Therefore, it is good.

Table 3. Result for Concrete at Top Position Bottom.

	Ref.	Case 1	Case 2	Case 3	Case 4
		1(A)	2(A)	3(A)	4(A)
Electric Field (V/m)	1.0942	0.0020	1.0942	1.0985	1.0956
Percentage Error (%)	-	-0.99817	0.0	0.00393	0.00128

For table 3, the result shows that the highest electric field value is case 3 with 1.0985 V/m and the lowest electric field value is case 1 with only 0.0020V/m. The percentage value for case 1 is -0.99817%, 0.0% for case 2, 0.00393% for case 3 and 0.00128% for case 4. This shows that case 1 got the best electric field value for concrete at the top in position bottom.

Table 4. Result for Concrete at Middle for Position Top.

	Ref.	Case 1	Case 2	Case 3	Case 4
		1(B)	2(B)	3(B)	4(B)
Electric Field (V/m)	11.1134	0.0100	11.9332	9.1849	11.1345
Percentage Error (%)	-	-0.99910	0.07377	-0.1735	0.00196

Table 4 shows the result for the middle concrete model at the position top. The result shows case 1 grounding system has the lowest in electric field values. This was then followed by case 3, case 4 and case 2. The percentage error calculated compared to the electric field of the reference grounding system is -0.99910% for case 1, 0.07377% for case 2, -0.17353% for case 3 and 0.00196% for case 4.

Table 5. Result for Concrete at Middle for Position Bottom.

	Ref.	Case 1	Case 2	Case 3	Case 4
		1(B)	2(B)	3(B)	4(B)
Electric Field (V/m)	1.0942	0.0020	1.0985	1.1042	1.1043
Percentage Error (%)	-	-0.99817	0.00393	0.00913935	0.00923

Table 5 shows the result for the middle concrete model at position bottom. From the result, the lowest electric field value obtained is 0.0020V/m for case 1 and the highest electric field is case 4 with 1.1043V/m. The percentage error calculated compared to the electric field of the reference grounding system is -0.99817% for case 1, 0.00393% for case 2, 0.009139% for case 3 and 0.00923% for case 4.

Table 6. Result for Concrete at Bottom for Position Top.

	Ref.	Case 1	Case 2	Case 3	Case 4
		1(C)	2(C)	3(C)	4(C)
Electric Field (V/m)	11.1134	0.0100	10.4483	10.4507	10.7375
Percentage Error (%)	-	-0.9991	-0.05985	-0.05963	-0.03382

Table 6 shows the result for model concrete at the bottom for the position top. The table shows that case 1 has shown the lowest electric field values with only 0.0100V/m. This was then followed by case 2, case3 and case 4, with reference grounding system demonstrated the highest electric field value which is 11.1134V/m. The percentage value for case 1 is -0.99910%, -0.05985% for case 2, -0.05963% for case 3 and 0.03382% for case 4.

Table 7. Result for Concrete at Bottom for Position Bottom.

	Ref.	Case 1	Case 2	Case 3	Case 4
		1(C)	2(C)	3(C)	4(C)
Electric Field (V/m)	1.0942	0.0020	0.0013	0.0170	0.0010
Percentage Error (%)	-	-0.99817	-0.9981	-0.99845	-0.99909

Table 7 shows the result for the model concrete at the bottom for position bottom. There are slightly different in value that distinguishing the low and high values for electric fields. The lowest value of the electric field is case 4 with 0.0010V/m while the highest electric field value is case 1 with 0.0020V/m. the electric field value for case 2 and case 3 is 0.0013V/m and 0.0170V/m respectively. Also, the percentage error calculated compared to reference grounding system is -0.99817% for case 1, -0.00393% for case 2, -0.99845% for case 3, and -0.99909% for case 4. All the percentage error value obtained is negative; it means that the electric field value to be compared to the reference grounding system is huge. Therefore, it is good.

5. Conclusions

In this study, four cases of concrete had been designed which are full concrete, half concrete, three-quarter concrete and a quarter concrete with a reference grounding system for comparison purposes in terms of percentage error. The results were analyzed according to the concrete model which is at the top, middle and bottom.

This study only measured the electric field at the position top and position bottom. From the results obtained, it shows that when there is concrete that coated the copper rod, either at position top or position bottom, the electric field value is low compared to the reference grounding system. Moreover, when comparing the electric field value at both position top and bottom, it clearly shows that position bottom have lower electric field value compared to the position top. This is because; depth plays an important role in lowering the electric field. The deeper the depth of rods coated with the concrete into the ground, the lower the electric field.

Therefore, from the result, case 1 which is full concrete is the best orientation of concrete compared to the other cases. This is because full concrete shows the best performance in terms of the lowest electric field in both position top and position bottom.

6. Acknowledgments

Authors wishing to acknowledge assistance or encouragement from colleagues, special work by technical staff or financial support from FRGS (ref. no. RACER/1/2019/TK04/UNIMAP//1).

References

- [1] Wan Ahmad W F H, Hamzah N H, Jasni J, Ab-Kadir M Z A and Gomes C 2018 *34th Int. Conf. Light. Prot. ICLP* (Rzeszow: Poland) p 1
- [2] Jasni J, Siow L K, Kadir M Z A A and Ahmad W F W 2010 *30th Int. Conf. Light. Prot.* (Cagliari, Italy) p 1
- [3] Thottappillil R and Rakov V 2007 *J. Light. Res.* **1** 90
- [4] Lai W L, Ahmad W W, Jasni J and Ab Kadir M Z A 2017 *IEEE 15th Student Conf. on Research and Development (SCORED)* p 338
- [5] Lim S C, Gomes C, Kadir M Z A A, Nourirad G and Malek Z A 2015 *Int. J. Eng. Sci. Technol.* **10** 811
- [6] Ma J, Dawalibi F P and Southey R D 2002 *Proc. Int. Conf. on Power System Technology* **2** 974
- [7] Shimizu H and Watanabe N 2012 *31st Int. Conf. Light. Prot. ICLP 2012* 1
- [8] Lim S C, Gomes C and Ab Kadir M Z A 2013 *Int. J. Electrochem. Sci.* **8** 11429
- [9] Memon A 2015 *Modelling Single Grounding Electrode Using COMSOL* (Doctoral dissertation, Universiti Teknologi Malaysia).p 79
- [10] Der Chen S, Cheng C K, Chen L H and Chen J F 2006 *Int. J. Emerg. Electr. Power Syst.* **7**
- [11] Arshad S N M, Tajudin N S, Halim N H, Abdullah A Z, Wooi C L and Hussin N 2018 *IEEE 7th Int. Conf. Power Energy* (Kuala Lumpur: Malaysia) p 283
- [12] Arshad S N M 2020 *J. Phys. Conf. Ser.* **1432** 1
- [13] Watson J B and G. A. Kimble 2018 *Behaviorism* **1** 42
- [14] Faudzi A H M, Wooi C L, Ahmad N A, Arshad S N M, Afrouzi H N and Rohani M N K 2020 *J. Phys. Conf. Ser.* **1432** 1
- [15] Arshad S N M, Tajudin N S, Halim N H, Abdullah A Z, Wooi C L and Nuriziani Hussin 2018 *IEEE 7th Int. Conf. Power Energy* (Kuala Lumpur: Malaysia) p 209