Distribution Pattern of ELF Field Exposure Electricity Distribution Substation Portal Pole Type 20 kV Medium Voltage Network

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Received: 2nd May 2024; **Accepted**: 17th May 2024; **Published**: 2nd June 2024
DOI: https://dx.doi.org/10.29303/jpft.v10i1.6783

Abstract *- The electricity distribution substation is one of the components of the electricity distribution system. Electrical distribution substations, especially portal pole-type electrical distribution substations, can emit ELF fields. However, people need to be aware of the health risks of ELF fields and continue to carry out various activities near electricity distribution substations. This research aims to create a distribution pattern for ELF Field and determine its safety level based on WHO thresholds. The research was conducted in the Jember Regency, particularly in Sumbersari District. This research uses a portal pole-type electricity distribution substations. The substation criteria studied were a portal pole distribution substation on a 20 kV transmission line with a transformer capacity of 160 kVA. The measurement points are 0 m below the transformer, 0.7 m, 1.4 m, 2.1 m, 2.8 m, 3.5 m, 4.1 m, and 4.9 m from the distribution substation building at a height of 1.5 m from the ground for three days at 21.00 WIB and 30 measurements were taken. The distances of these points to the transformer are 4.256 m, 4.313 m, 4.480 m, 4.745 m, 5.094 m, 5.510 m, 5.979 m and 6.490 m respectively. The type of research used is quantitative research with survey data collection techniques. The research design used was cross sectional study. Cross sectional study is a type of observational research design that collects data at one specific point in time from a sample which represents the population studied. ELF field measurements show a spherical distribution pattern with an average magnetic field intensity between 0.0358 µT and 2.91 µT and an average electric field intensity between 2.35 V/m and 16.42 V/m. The magnitude of the magnetic field and electric field measured gets smaller as the distance from the measurement point increases. According to WHO, these results are below the threshold for the general group. This research concludes that the portal pole-type distribution substation in the medium voltage network produces a safe ELF field with a spherical distribution pattern that is inversely proportional to the distance.*

Keywords*: Electrical Distribution Substations; Electrical Networks; ELF Field; Distribution Patterns*

INTRODUCTION

The distribution substation is a component of the electric power distribution system, which is responsible for the distribution of electric power. Before reaching the end user, electric power must pass through an electricity distribution substation to match the customer's voltage requirements. A distribution substation is an electrical facility that includes multiple electrical elements, such as disconnection devices, connecting devices, safety measures, and transformers. The main objective of building a distribution substation is to make electrical power transmission more effective in accordance with consumer voltage requirements (Pratama et al., 2023). The main role of distribution substations, as stated by Marniati (2022), is to facilitate the distribution of electrical energy from medium voltage to consumers who require low voltage. This entails converting medium voltage to low voltage, then distributing it to low-voltage consumers.

At the distribution substation, there are various components, including transformers. A transformer is an electrical device that is capable of changing quite large voltages, namely from high voltage to low voltage

(Subaga *et al*., 2019). A transformer's operation is based on the fundamental principle of electromagnetic induction. The transformer uses a coil of wire, which, when supplied with alternating current, will produce electromagnetic induction (Setijasa *et al*., 2023). Variable alternating current (AC) produces a flux that continually fluctuates (Nurhayati & Maisura, 2021). The alternating flux has the potential to impact the secondary coil, giving rise to an electromotive force and electric current.

Electromagnetic waves refer to the transmission of electric and magnetic fields without the need for an intermediary medium (Amineh, 2020). Maxwell asserts that perpendicular electric and magnetic fields interact to form electromagnetic waves (Michaud, 2020). We can categorize electromagnetic waves into many classes based on their frequency. Extremely low-frequency (ELF) waves are a specific category of electromagnetic waves.

ELF waves have special characteristics, such as a frequency spectrum that ranges from 0 to 300 Hz and consists of an ELF magnetic field and an ELF electric field (Sinaga *et al*., 2023). The State Electricity Company (PLN) facilitates the distribution of electric power to consumers in Indonesia, operating at a frequency of 50 Hz and a voltage of 220 V. Tritakis *et al* (2023) categorize this frequency as very low, making it one of the smallest in the frequency range. According to the Biot-Savart Law, a magnetic field will be detected when an electric current flows through a conductor wire. In the framework of the energy distribution system, electric power distribution substations are equipped with conducting cables that make it easier to distribute electric current. Maxwell's theory states that changes in the magnetic field can cause changes in the electric field and vice versa (Muhibbullah, 2021).

At the electricity distribution substation, there is a transformer. Alternating current flowing in the primary coil can produce a magnetic field. According to Maxwell's equation, which discusses the Ampere-Maxwell law, if there is a current density (J) and an electric displacement field (D) that changes with time and penetrates a plane surrounded by a closed path, a magnetic field (H) will be produced whose direction corresponds to a closed track (Mart, 2023). Based on this, there are indications that the electricity distribution substation emits ELF electric and magnetic fields. However, public understanding of the existence of electric field radiation and Extremely Low-Frequency (ELF) magnetic fields originating from electric power distribution substations is still lacking.

The World Health Organization states that the ELF field does not have a significant impact on the risk of health problems if it is below safe limits. However, prolonged exposure to radiation exceeding the threshold value can cause negative effects on health. The World Health Organization has determined that the safe limits for ELF electric fields and ELF magnetic fields are 5 kV/m and 100 μT for general groups and 10 kV/m and 500 μT for workers (WHO, 2007). Carpenter's (2019) research provides support for the idea that prolonged exposure to ELF fields exceeding established thresholds may increase the risk of cancer. Schuermann and Mevissen (2021) found that electromagnetic radiation exceeding a certain threshold can increase oxidative stress caused by the interaction between the field and the chemical bonds of biomolecules, thereby increasing the possibility of cancer.

Based on previous research conducted by Setiyanto *et al* (2017), it is stated that a 20 kV electricity distribution network can increase the ELF magnetic field significantly when compared to the natural ELF magnetic field. The strength of the magnetic field will become greater as the distance to the conducting wire gets closer, and the strength of the magnetic field will become weaker as it moves away from the conducting wire. According to research by Septiani *et al* (2016), electricity consumption can influence the size of the magnetic field at the substation. It was noted that nighttime (18.00–22.00) is the peak of electricity consumption, so the magnetic field detected at night is the highest.

The explanation above reveals that electricity distribution substations, particularly those of the portal pole type, exhibit signs of emitting Extremely low-frequency field radiation (ELF). In addition, portal pole-type electrical distribution substations have the potential to cause health hazards due to exposure to very low-frequency field radiation (ELF). Therefore, it is necessary to research the distribution pattern of the ELF field at electricity distribution substations to determine its distribution and assess its level of safety.

RESEARCH METHODS

This study employs a quantitative research approach with a cross-sectional design. A cross-sectional study is an observational research design that involves collecting data from a sample at a certain time to ensure the representativeness of the population being studied. The variables examined in this research consist of an independent variable, namely the distance measured at the electricity distribution substation. The dependent variable in this research is the magnitude of the ELF electric field and the ELF magnetic field emitted by the electricity distribution substation. The control variable in this study is the measurement height, namely 1.5 m from the ground surface. The control area designated for this research was the field at the University of Jember.

This research's data collection process entails collecting primary data. We obtain primary data by taking direct measurements at a predetermined location. The specified location is a substation located in the Jember Regency. The criteria for the distribution substation studied is a portal pole-type substation on a 20 kV transmission line with a maximum transformer capacity of 160 kVA. The sample used in this research consisted of one electricity distribution substations. An EMF tester is used to take data. Data measurements will be carried out at several locations, namely at distances of 0 m below the transformer, 0.7 m, 1.4 m, 2.1 m, 2.8 m, 3.5 m, 4.1 m, and 4.9 m. The distances of these points to the transformer are 4.256 m, 4.313 m, 4.480 m, 4.745 m, 5.094 m, 5.510 m, 5.979 m and 6.490 m respectively. These measuring points will be placed on the front, back, right, and left sides of the electricity distribution substation. Measurements were carried out for three days at 21.00 WIB with 30 repeated measurements. The reason for choosing the time to conduct the research is because the highest level of electricity use characterizes the evening period (18.00–22.00).

The analysis test in this research used the one-way ANOVA test. The purpose of using this test is to determine the difference in the average ELF field at each measurement point. The Surfer application is used to create ELF field distribution patterns. After the ELF field data and distribution patterns are obtained, the data will then be analyzed to determine the health impacts, potential biological effects, and level of safety from exposure to the ELF field.

RESULTS AND DISCUSSION

Results

This research was conducted at a portal pole-type distribution substation on a 20 kV transmission line in the Jember Regency. This research obtained large amounts of data on the ELF field intensity detected around the portal pole type distribution substation. ELF electromagnetic waves are composed of an ELF magnetic field and an ELF electric field, so the dependent variables in this research are the intensity of the ELF magnetic field and the intensity of the ELF electric field. This research data was obtained by taking measurements using a tool, namely the ETS-Lindgren ELF Survey Meter. Measurements were carried out at 21.00 WIB with repetition 30 times at each measurement point.

ELF field measurements were carried out in the control area located at Jember University Field. Measurements were carried out at the same point with repetitions 30 times at a height of 1.5 m above ground level. The average natural ELF field is shown in Table 1.

Table 1. Average Natural ELF Field Intensity

Time (WIB)	ELF Magnetic Field Intensity (μT)	ELF Electric Field Intensity (V/m)
21.00	0.01286	1.413

Table 1 shows the average value of natural ELF field intensity measurements of magnetic and natural electric fields in the Jember University field at 21.00 WIB. The table above shows that the average values of the natural magnetic field and electric field can change at a certain time, even though they are not significantly different. Natural ELF field data in Table 1 is used as a control variable in this study.

Measurements of the ELF magnetic field and ELF electric field were carried out at lateral distances starting at 0 m below the transformer, 0.7 m, 1.4 m, 2.1 m, 2.8 m, 3.5 m, 4.1 m, and 4.9 m from the portal pole type distribution substation on the 20 kV network building with measuring points encompassing the front, back, right and left of the substation. The distances of these points to the transformer are 4.256 m, 4.313 m, 4.480 m, 4.745 m, 5.094 m, 5.510 m, 5.979 m and 6.490 m respectively. Measurements were repeated 30 times at 21.00 WIB. The following is the average value of the ELF magnetic field intensity measurement at the portal pole type distribution substation on the 20 kV network (Table 2):

Table 2. ELF Magnetic Field Intensity at 21.00 WIB

Measurement Point (m)			ELF Magnetic Field Intensity (μT)
X	y	z	
0	0	4.256	2.914
0	0.7	4.313	0.9162
0	1.4	4.48	0.7793
0	2.1	4.745	0.7505
0	2.8	5.094	0.4995
0	3.5	5.51	0.0999
0	4.2	5.979	0.0661
0	4.9	6.49	0.0396
0	-0.7	4.313	0.9101

Measurement Point (m)			ELF Magnetic Field Intensity (µT)
X	y	z	
0	-1.4	4.48	0.9106
0	-2.1	4.745	0.7535
0	-2.8	5.094	0.4659
0	-3.5	5.51	0.0919
0	-4.2	5.979	0.0527
0	-4.9	6.49	0.0384
0.7	0	4.313	1.0264
1.4	0	4.48	0.7796
2.1	0	4.745	0.7416
2.8	0	5.094	0.4709
3.5	0	5.51	0.0652
4.2	0	5.979	0.0632
4.9	0	6.49	0.0385
-0.7	0	4.313	0.9113
-1.4	0	4.48	0.7771
-2.1	0	4.745	0.7480
-2.8	0	5.094	0.3323
-3.5	0	5.51	0.0653
-4.2	0	5.979	0.0669
-4.9	0	6.49	0.0358

Based on Table 2, the ELF magnetic field intensity at the portal pole type distribution substation on a 20 kV network, which has a maximum transformer capacity of 160 kVA from one substation that have the same specifications at a 0 m below the transformer, 0.7 m, 1.4 m, 2.1 m, 2.8 m, 3.5 m, 4.1 m, and 4.9 m, with measuring points encompassing front, back, right and left of the substation and the distances to the transformer being 4.256 m, 4.313 m, 4.480 m, 4.745 m, 5.094 m, 5.510 m, 5.979 m and 6.490 m respectively are between 0.0358 µT and 2.91 µT. Based on Table 2, a graph of the average ELF magnetic field can be made. This graph is shown in Figure 1 below.

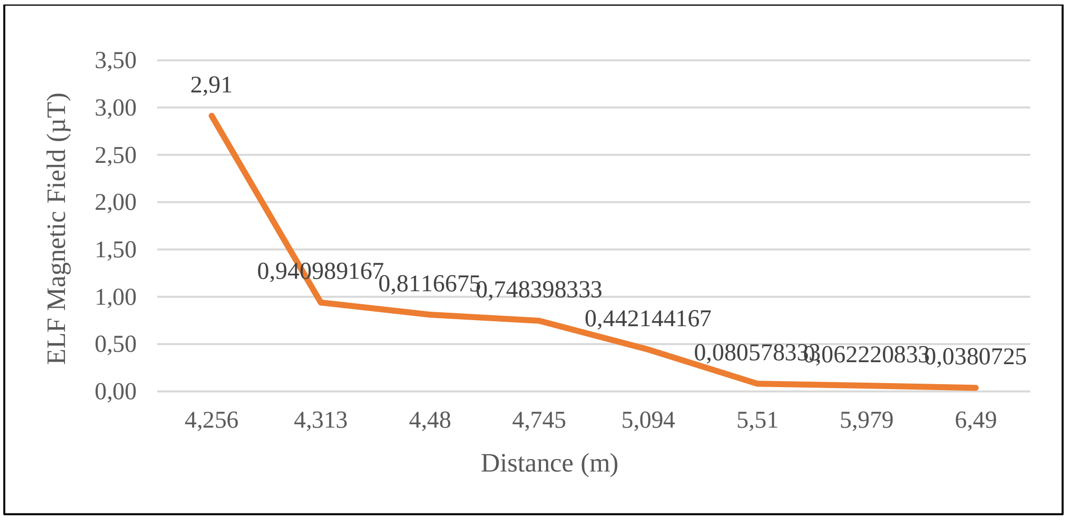

Figure 1. ELF Magnetic Field at Each Measurement Point

The results of the ELF magnetic field measurements were carried out by the One Way Anova test to determine the difference in the average ELF Magnetic field at each distance. After carrying out the One Way Anova test, a Post Hoc Test was then carried out by carrying out the least significant difference (LSD) test by comparing the average ELF magnetic field with the natural ELF magnetic field. The One Way Anova test on the ELF magnetic field at a distance of 21.00 WIB obtained the results as presented in Table 3 below.

Table 3. Results of One Way Anova Test Analysis of ELF Magnetic Field Data at 21.00 WIB

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	285.815	29	9.856	1499.965	0.000
Within Groups	5.716	870	.007		
Total	291.531	899			

Table 3 shows that the One Way Anova test have a significance of 0.000 (< 0.05). When the data has a significance of <0.05, it can be interpreted that in the data, there is a significant difference in the average ELF magnetic field at each distance. We will then conduct a further test, the Least Significance Different (LSD) test, and present the results in Table 4 below.

Table 4. Results of Least Significant Difference (LSD) Test Analysis of ELF Magnetic Field Data at 21.00 WIB Against Distance

I	J	Mean Difference (I-J)	Std. Error	Sig.
Natural ELF Magnetic Field	Point 4.256 m	-2.8329600*	.0209294	.000
	Point 4.313 m on the right side of the substation	-1.0135200*	.0209294	.000
	Point 4.313 m on the left of the substation	-.8984167*	.0209294	.000
	Point 4.313 m in front of the substation	-.9033233*	.0209294	.000
	Point 4.313 m behind the substation	-.8972033*	.0209294	.000
	Point 4.48 m on the right side of the substation	-.7667600*	.0209294	.000
	Point 4.48 m on the left of the substation	-.7642067*	.0209294	.000
	Point 4.48 m in front of the substation	-.7664733*	.0209294	.000
	Point 4.48 m behind the substation	-.8977367*	.0209294	.000
	Point 4.745 m on the right side of the substation	-.7286900*	.0209294	.000
	Point 4.745 m on the left of the substation	-.7351400*	.0209294	.000
	Point 4.745 m in front of the substation	-.7375967*	.0209294	.000
	Point 4.745 m behind the substation	-.7406733*	.0209294	.000
	Point 5.094 m on the right side of the substation	-.4579767*	.0209294	.000
	Point 5.094 m on the left of the substation	-.3194133*	.0209294	.000
	Point 5.094 m in front of the substation	-.4866633*	.0209294	.000
	Point 5.094 m behind the substation	-.4530300*	.0209294	.000
	Point 5.51 m on the right side of the substation	-.0523000*	.0209294	.013
	Point 5.51 m on the left of the substation	-.0524633*	.0209294	.012
	Point 5.51 m in front of the substation	-.0870633*	.0209294	.000
	Point 5.51 m behind the substation	-.0789933*	.0209294	.000
	Point 5.979 m on the right side of the substation	-.0503000*	.0209294	.016
	Point 5.979 m in front of the substation	-.0532033*	.0209294	.011
	Point 5.979 m behind the substation	-.0398400	.0209294	.017
	Point 6.49 m on the right side of the substation	-.0256400	.0209294	.221
Natural ELF Magnetic Field	Point 6.49 m on the left of the substation	-.0229367	.0209294	.273
	Point 6.49 m in front of the substation	-.0266833	.0209294	.203
	Point 6.49 m behind the substation	-.0255367	.0209294	.223

Based on Table 4, it is known that at 21.00 WIB the ELF magnetic field at the portal pole type distribution substation did not have a significant difference from the natural ELF magnetic field at a distance of 6.49 m. This is proven by the results of the smallest real difference (LSD) test carried out. At a distance of 6.49 m it has a significance of 0.221, 0.273, 0.203 and 0.223 (>0.05), respectively. If the data has a significance of >0.05, it can be interpreted that the average ELF magnetic field at a distance of 6.49 m from the portal pole type distribution substation does not have a significant difference in the average data compared to the natural ELF magnetic field. The distribution pattern of the ELF magnetic field emitted by the portal pole type distribution substation at 21.00 WIB is presented in Figure 2 below.

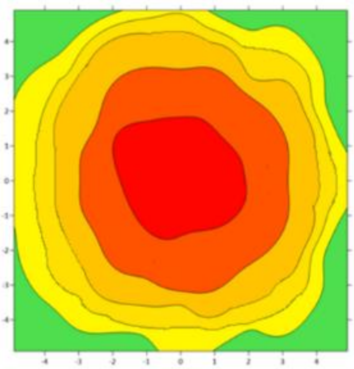

Figure 2. ELF Magnetic Field Distribution Pattern at 21.00 WIB

Based on Figure 2, it is known that at a distance of 6.49 m from the substation, the distribution of the detected ELF magnetic field is close to the natural ELF field. This is shown in green in Figure 2. At a distance of 4.256 m to 4.745 m from the distribution substation you can see red, which means that the ELF magnetic field at that distance on average is above 0.5 μT. At a distance of 5.094 m to 5.979 m from the distribution substation, it shows orange to yellow, which means that the ELF magnetic field at that distance is on average below 0.5 μT but is not yet close to the natural ELF field value.

Based on the ELF electric field measurement results, the ELF electric field intensity measurement values at the portal pole type distribution substation on the 20 kV network are presented in Table 5 below.

Table 5. Average ELF Electric Field Intensity at 21.00 WIB

Measurement Point (m)			ELF Electric Field Intensity (μT)
x	y	z	
0	0	4.256	16.42
0	0.7	4.313	8.84
0	1.4	4.48	6.67
0	2.1	4.745	4.02
0	2.8	5.094	4.37
0	3.5	5.51	3.13
0	4.2	5.979	2.96
0	4.9	6.49	2.64
0	-0.7	4.313	11.01
0	-1.4	4.48	6.50
0	-2.1	4.745	4.99
0	-2.8	5.094	4.06
0	-3.5	5.51	2.93
0	-4.2	5.979	3.32
0	-4.9	6.49	2.35
0.7	0	4.313	9.93
1.4	0	4.48	6.98
2.1	0	4.745	4.89
2.8	0	5.094	4.96
3.5	0	5.51	3.45
4.2	0	5.979	2.85
4.9	0	6.49	2.44
-0.7	0	4.313	11.74
-1.4	0	4.48	7.09
-2.1	0	4.745	5.22
-2.8	0	5.094	4.28
-3.5	0	5.51	4.43
-4.2	0	5.979	2.93
-4.9	0	6.49	2.82

Based on Table 5, the ELF electric field intensity at the portal pole type distribution substation on a 20 kV network, which has a maximum transformer capacity of 160 kVA from one substation that have the same specifications at a 0 m below the transformer, 0.7 m, 1.4 m, 2.1 m, 2.8 m, 3.5 m, 4.1 m, and 4.9 m, with measuring points encompassing front, back, right and left of the substation and the distances to the transformer being 4.256 m, 4.313 m, 4.480 m, 4.745 m, 5.094 m, 5.510 m, 5.979 m and 6.490 m respectively are between 2.35 V/m and 16.42 V/m. Based on Table 5, a graph of the average ELF electric field can be made. This graph is shown in Figure 3 below.

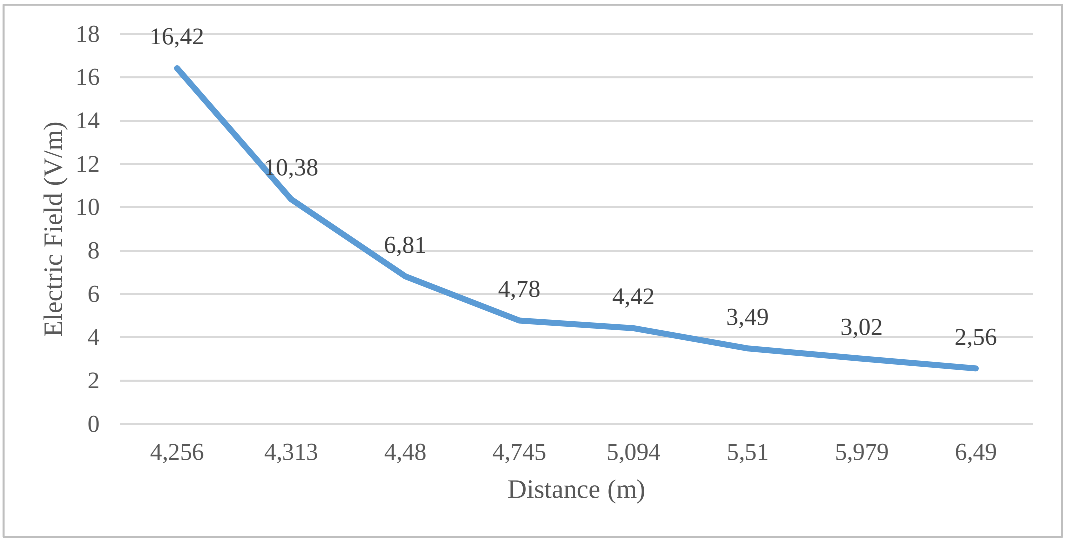

Figure 3. ELF Electric Field at Each Measurement Point

The results of the ELF electric field measurements were carried out using the One Way Anova test to determine the difference in the average ELF electric field at each distance. After carrying out the One Way Anova test, a Post Hoc Test was then carried out by carrying out the least significant difference (LSD) test by comparing the average ELF electric field with the natural ELF electric field. The One Way Anova test on the ELF electric field field at a distance of 21.00 WIB obtained the results as presented in Table 6 below.

Table 6. Results of One Way Anova Test Analysis of ELF Electric Field Data at 21.00 WIB

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9717.326	29	335.080	3853.282	0.000
Within Groups	75.655	870	.087		
Total	9792.981	899			

Table 6 shows that the One Way Anova test have a significance of 0.000 (< 0.05). When the data has a significance of <0.05, it can be interpreted that in the data, there is a significant difference in the average ELF electric field at each distance. We will then conduct a further test, the Least Significance Different (LSD) test, and present the results in Table 7 below.

Table 7. Results of Least Significant Difference (LSD) Test Analysis of ELF Electric Field Data at 21.00 WIB Against Distance

I	J	Mean Difference (I-J)	Std. Error	Sig.
Natural ELF Electric Field	Point 4.256 m	-15.02100*	.07614	.000
	Point 4.313 m on the right side of the substation	-9.02333*	.07614	.000
	Point 4.313 m on the left of the substation	-9.04900*	.07614	.000
	Point 4.313 m in front of the substation	-8.04533*	.07614	.000
	Point 4.313 m behind the substation	-10.10167*	.07614	.000
	Point 4.48 m on the right side of the substation	-5.41600*	.07614	.000
	Point 4.48 m on the left of the substation	-5.45333*	.07614	.000
	Point 4.48 m in front of the substation	-5.46400*	.07614	.000
	Point 4.48 m behind the substation	-5.55200*	.07614	.000
I	**J**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**
Natural ELF Electric Field	Point 4.745 m on the right side of the substation	-3.34067*	.07614	.000
	Point 4.745 m on the left of the substation	-3.74900*	.07614	.000
	Point 4.745 m in front of the substation	-2.74100*	.07614	.000
	Point 4.745 m behind the substation	-3.30167*	.07614	.000
	Point 5.094 m on the right side of the substation	-3.17400*	.07614	.000
	Point 5.094 m on the left of the substation	-2.54667*	.07614	.000
	Point 5.094 m in front of the substation	-2.63000*	.07614	.000
	Point 5.094 m behind the substation	-3.12800*	.07614	.000
	Point 5.51 m on the right side of the substation	-2.53167*	.07614	.000
	Point 5.51 m on the left of the substation	-3.05067*	.07614	.000
	Point 5.51 m in front of the substation	-1.99400*	.07614	.000
	Point 5.51 m behind the substation	-1.91467*	.07614	.000
	Point 5.979 m on the right side of the substation	-1.66333*	.07614	.000
	Point 5.979 m on the left of the substation	-1.47567*	.07614	.000
	Point 5.979 m in front of the substation	-1.49033*	.07614	.000
	Point 5.979 m behind the substation	-1.75767*	.07614	.000
	Point 6.49 m on the right side of the substation	-1.45533*	.07614	.000
	Point 6.49 m on the left of the substation	-1.07000*	.07614	.000
	Point 6.49 m in front of the substation	-1.12567*	.07614	.000
	Point 6.49 m behind the substation	-1.23967*	.07614	.000

Based on Table 7, it is known that at 21.00 WIB, all ELF electric field data at the portal pole type distribution substation had significant differences from the natural ELF electric field. This is proven by the results of the Least Significance Different (LSD) test, which showed that all the data had a significance of 0.000 (<0.05). When the data has a significance of <0.05, it can be interpreted that all average ELF electric fields have a significant difference in the average data from the natural ELF electric field. The distribution pattern of the ELF electric field emitted by the portal pole type distribution substation at 21.00 WIB is presented in Figure 4 below.

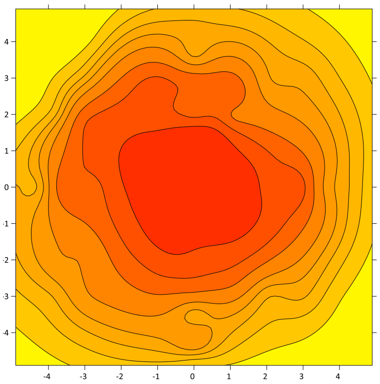

Figure 4. ELF Electric Field Distribution Pattern at 21.00 WIB

Based on Figure 4, it is known that at a distance of 4.256 m to 4.745 m from the distribution substation, it is shown in red, which means that the ELF electric field at that distance has an average of above 5 V/m. At a distance of 5.094 m to 6.49 m from the distribution substation, it shows orange to yellow, which means that the ELF electric field at that distance is on average below 5 V/m but is not yet close to the natural ELF field value.

Discussion

Figure 1 shows a graph of the ELF magnetic field at each distance. At a distance of 4.256 m from the transformer, it was detected that the ELF magnetic field was at its highest point compared to other distances. This is caused by the distance factor, which gets closer to the power source. According to the Biot-Savart law, the magnitude of the magnetic field will be influenced by distance in an inverse relationship (Sianaga et al., 2020). This means that the farther the measurement point is, the smaller the ELF magnetic field detected.

Table 3 shows the results of the One Way Anova test. According to it, the ELF magnetic field at 21.00 WIB have a significance of 0.000, which means that there is a significant difference in the average ELF magnetic field at each distance. Table 4 contains the Least Significance Difference (LSD) test carried out on ELF magnetic field data at 21.00 WIB by comparing it with natural ELF magnetic field data. Based on Table 4, it can be seen that the ELF magnetic field at a distance of 6.49 m from the electricity distribution substation has an average ELF magnetic field that is not significantly different from the natural ELF magnetic field. The significance at a distance of 6.49 m from the right, left, front and rear transformers of the distribution substation is at 0.221, 0.273, 0.203 and 0.223, confirming this. This significance value is more than 0.05 (>0.05), which means that the average ELF magnetic field at a distance of 6.49 m from the portal pole type electricity distribution substation does not have a significant difference in the average data regarding the natural ELF magnetic field.

Based on Figure 2, it can be seen that at a distance of 6.49 m from the distribution substation, it has a green colour, which indicates that at a distance of 6.49 m from the electrical distribution substation, the detected ELF magnetic field does not have a significant average difference with the natural magnetic field. These results are inversely proportional to the magnetic field value at a distance 4.256 m from the electrical distribution substation. Figure 2 shows that at a distance 4.256 m, it has a deep red colour because the average magnetic field measured is far above the natural ELF magnetic field. At a distance of 4.313 m to 5.979 m, it can be seen that the colour of the distribution pattern gradually changes from red to to yellow. This can mean that the magnitude of the magnetic field at a distance of 4.313 m to a distance of 5.979 m is gradually decreasing, even though it is not yet close to the natural ELF field value. Based on the distribution pattern shown in Figure 2, it can be seen that the magnitude of the ELF magnetic field decreases as the measurement point increases at the electrical distribution substation. The results of the ELF magnetic field distribution pattern in Figure 2 also strengthen the results of the Least Significance Different (LSD) test that has been carried out previously, which states that at a distance of 6.49 m from the electricity distribution substation, the average ELF magnetic field is not significantly different from the average natural ELF magnetic field.

Based on the discussion above, it can be concluded that the portal pole-type electrical distribution substation on a 20 kV distribution network with a maximum transformer capacity of 160 kV can increase the environmental ELF magnetic field. This is supported by previous research conducted by Setiyanto et al (2017), which stated that there was a significant increase in the intensity of the Extremely Low Frequency (ELF) magnetic field around the PLN 20 kV distribution network compared to the intensity of the natural magnetic field. In addition, the ELF magnetic field is inversely proportional to distance, so the greater the distance, the smaller the ELF magnetic field detected. This result is in accordance with the results of research conducted by Dermawan (2018), who conducted research on a 500 kV extra high overhead line (SUTET) in Pasuruan Regency, which showed that the further away the measuring point, the smaller the magnetic field detected. Apart from that, other research conducted by Suhatin et al (2017) also supports these results, stating that the magnitude of the ELF magnetic field weakens the further it is from the source. Another thing that we can conclude is that at a distance of 6.49 m from the electrical distribution substation transformer, there is an average ELF magnetic field that is not significantly different from the natural ELF magnetic field. This distance of 6.49 m can be a recommended safe distance from exposure to ELF magnetic field radiation emitted by electrical distribution substations.

Figure 3 shows a graph of the ELF electric field at each distance. At a distance of 4.256 m, it was detected that the ELF electric field was at the highest point compared to other distances. This is caused by the distance factor, which gets closer to the power source. According to the Biot-Savart law, the magnitude of the magnetic field will be influenced by distance in an inversely proportional relationship (Sianaga et al., 2020). This causes the farther the measurement point is, the smaller the ELF magnetic field detected. According to Faraday's law, if a magnetic field (B) changes with time and penetrates a plane surrounded by a closed path, it will produce an electric field (E) (Langer et al., 2019:62). Based on this, it can be seen that the ELF electric field is directly proportional to the ELF magnetic field so that the greater the magnetic field, the greater the electric field value will be. This also indicates that the electric field is inversely proportional to distance.

Table 6 shows that the results of the One Way Anova test for the ELF electric field at 21.00 WIB have a significance of 0.000, which means that there is a significant difference in the average ELF electric field at each distance. Table 7 contains the Least Significance Difference (LSD) test carried out on ELF electric field data at 21.00 WIB by comparing it with Natural ELF electric field data. Based on the test results, it can be seen that the significance value is 0.000 at each measurement point. This significance value is less than 0.00 (<0.05), which means that the average ELF electric field at a distance of 6.49 m from the portal pole type distribution substation has a significant difference in the average data compared to the natural ELF electric field.

Figure 2 shows that for a distance of 4.256 m to 6.49 m from the electricity distribution substation transformer, no ELF electric field was detected, which was close to normal. This is shown by the results of the distribution pattern that is formed where the colour of the visible distribution pattern is red, which then changes to yellow as the distance increases. This indicates that at 21.00 WIB, the electric field from a distance of 4.256 m to 6.49 m was not yet close to the

ELF electric field value. The results of the ELF electric field distribution pattern in Figure 2 also strengthen the results of the Least Significance Difference (LSD) test, which was carried out previously. Here, the test stated that at 21.00 WIB, there was no significant difference in the average electric field between the distance of 4.256 m to 6.49 m with a natural ELF electric field.

Based on the discussion above, it can be concluded that a portal pole type electricity distribution substation on a 20 kV distribution network with a maximum transformer capacity of 160 kV can increase the environmental ELF electric field. This is supported by relevant previous research conducted by Marniati (2022) on the 150 kV high voltage overhead line (SUTT) on the Mataram GI - Mataram GI switching route, Lombok, which shows that SUTT can increase the environmental electric field even though it is still below the specified safety threshold that has been established. In addition, the ELF electric field is inversely proportional to distance, so the greater the distance, the smaller the ELF electric field detected. This research is also in line with research conducted by Jahrudin et al (2022), which states that the electric and magnetic field strengths from SUTT exposure are still far below the safe threshold set by WHO.

The ELF field is composed of two components, namely, the ELF magnetic field and the ELF electric field. Based on table 2, the average intensity of the ELF magnetic field at 21.00 WIB at a distance of 4.256 m to 6.49 m from the portal pole type distribution substation transformer is in the range of 0.0358 µT to 2.91 µT. WHO (2007) revealed that the ELF magnetic field threshold for the general group with a frequency of 50 Hz is 100 µT. The data in Table 2 shows that the intensity of the ELF magnetic field detected at the portal pole type electricity distribution substation is below 100 µT (<100 µT). If the average ELF magnetic field intensity in Table 2 is compared with the ELF magnetic field threshold issued by WHO, it can be seen that the ELF magnetic field emitted by distribution substations is included within the safe category.

Based on Table 5, the average ELF electric field intensity at 21.00 at a distance of 4.256 m to 6.49 m from the portal pole type distribution substation transformer is in the range of 2.35 V/m to 16.42 V/m. WHO (2007) sets the threshold for the ELF electric field for the general group, which has a frequency of 50 Hz and is 5 kV/m. The data in Table 9 shows that the intensity of the ELF electric field detected at the portal pole type electricity distribution substation is below 5 kV/m (<5 kV/m). If the average ELF electric field intensity in Table 2 is compared with the ELF electric field threshold issued by WHO, it can be seen that the ELF electric field emitted by distribution substations is included within the safe category. Based on the discussion above, it can be concluded that the ELF field emitted by a portal pole type electricity distribution substation on a 20 kV distribution network with a maximum transformer capacity of 160 kVA is classified as safe for the health of the surrounding community.

CONCLUSION

Based on the results of the analysis of the data obtained, it can be concluded that the distribution pattern of extreme low frequency (ELF) field exposure at the portal pole type electricity distribution substation on the 20 kV medium voltage distribution network shows a spherical pattern that is inversely proportional to the distance. The average maximum distance of ELF field radiation emitted by a portal pole type electrical distribution substation on a 20 kV medium voltage distribution network is

6.49 m from the portal pole type distribution substation transformer. However, at 21.00 WIB, the ELF electric field still does not have the same value as the natural ELF field. The detected ELF field radiation is still below the threshold set by WHO and a distance of 6.49 m from the portal pole type distribution substation transformer is a safe recommended distance.

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