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An Analysis Of The Reliability 150 kV High Voltage Air Line Conductors Towards Electric Field Strength

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ABSTRACT

Analysis of conductor reliability on 150 kV high voltage overhead lines (SUTT) against electric field strength is important to ensure the stability and safety of electricity distribution. This study aims to analyze the impact of electric field strength generated by 150 kV SUTT conductors on the operational reliability of the line, including its effect on system performance and the safety of the surrounding environment. Measurements and simulations of electric field strength were carried out at various distances from the conductor to understand the distribution of the electric field generated. The results of the study indicate that high electric fields around the conductor can affect the performance of the insulator, increase the risk of corona, and reduce the operational life of the line components. In addition, the electric field generated can also affect human health if exposure exceeds the limits recommended by safety standards. From the results of this analysis, it is recommended to routinely monitor the electric field strength around the line and implement mitigation measures to ensure long-term operational safety and reliability.

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INTRODUCTION

High voltage overhead lines (SUTT) are vital infrastructure in the electricity transmission system, which plays a role in distributing electricity from power plants to load centers spread across various regions. One of the main challenges in SUTT operations is ensuring the reliability and safety of the conductors used to transmit electricity at high voltages, such as 150 kV. High voltages in SUTTs produce strong electric fields around the conductors, which can affect the performance and long-term reliability of the transmission system.

In an Electric Power System, electrical energy generated from the power plant center is then transmitted to the load control centers through a transmission line, the transmission line can be an overhead line or an underground line, but in general it is an overhead line, PT PLN (Persero) as a company whose business includes providing power plants tends to increase the voltage on the transmission network side. The electric power delivery system with a high-voltage overhead line transmission network has various advantages including: providing smaller power losses, greater electric power delivery, having more adequate system reliability and so on, but on the one hand it also causes an electric field effect for those who live around the high-voltage overhead line.

The main function of a transmission line is to distribute electrical energy from the power plant center to the main substations in the loaded area. To reduce power losses along the transmission line, high voltage is used. The use of this high voltage, in addition to reducing power losses, also produces a high electric field around the conductor wire (Pabla, 1994). An electric field is an area around an electrically charged object that still experiences an electric force. Based on research related to electric fields, if there is another charge inside an electrically charged object, the charge will experience an electric force in the form of repulsion and/or attraction (Pabla, 1994).

The construction of power plants that are sometimes located far from residential areas or loads requires transmission lines to be able to distribute electrical energy. These transmission lines also often pass through residential areas which give rise to complaints from the public about the effects felt under high-voltage transmission lines. Electricity is a necessity that cannot be separated from modern human life today, this is proven that human equipment and needs are inseparable from electricity. Another thing that proves that if the electricity goes out, people feel restless and anxious, especially when the electricity goes out at night, activities at home will be difficult to do. The increasing need for electricity certainly affects the electrical conductor wire itself. An unbalanced electric field will have a bad impact on society.

Electric current can also produce magnetic properties, so when there is an electric current passing through an object that is electrically conductive, it will produce a magnetic field. This understanding underlies the concept that when a compass needle is placed close to a straight section of a current-carrying wire.

Literature Review

Transmission Line

Electrical energy generated by an Electric Power System, is generated from the power plant center and then transmitted to the load control centers through a transmission channel, the transmission line can be an overhead line (Overhead Line) or an underground line (Underground Line) and in general we use the first type of line. Electrical energy distributed through overhead transmission lines generally uses bare wires that rely on air as an insulating medium between the conductor wire and the surrounding environment. The conductor wire is supported by a building construction, namely a tower with a height and distance that is safe for humans and the surrounding environment, between the tower and the conductor wire is separated by an insulator.

Transmission is the process of distributing electrical energy from one place to another with a voltage magnitude divided into Ultra High Voltage (UHV) with a voltage magnitude >500 kV, Extra High Voltage (EHV) with a voltage magnitude of 200 kV to 500 kV, High Voltage (HV) with an operating voltage magnitude between 30 kV to 150 kV, Medium Voltage (MV) of 20 kV, and Low Voltage (LV) which is commonly used in household needs with a voltage magnitude of 220 V to 340 V.

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The electrical energy distribution system is part of the electrical equipment system between large power (bulk power source, BPS) and customer service switches. In addition, a distribution system is usually composed of several equipment and other supporting components such as distribution substations, sub-transmission systems, feeders and distribution transformers, and customer services (Logahan, 2012). In the distribution of the distribution system, it is very important to pay attention to the quality of integrated and adequate services. Factors that can determine the quality of service are such as the ability of the distribution system to distribute electrical energy to customers continuously, with a minimum level of interference frequency.

The continuity of the distribution system is closely related to the network configuration, as well as the medium voltage components installed on the network. In addition, in order for the distribution network function to run well, efforts are needed to overcome disturbances that often occur in the distribution network quickly, efficiently, and in a short time. So these elements can affect the level of reliability of the distribution system in distributing quality electricity. The electric power distribution network system is divided into 2 systems, namely the primary distribution network system (medium voltage distribution network) and the secondary distribution network system (low voltage distribution network).

Part Transmission.

A transmission network consists of several important components/parts in supporting its effectiveness or function, the components of the transmission network construction are:

1. Transmission Tower
   The transmission tower has a tall structure with a height ranging from 18 to 55 meters. Materials other than steel that can be used in transmission towers are concrete and wood.
2. Isolator
   An insulator is a material that holds the conductor so that the voltage does not transfer to a non-conductive structure, the nature of the material that electrically separates two or more adjacent live electrical conductors, so that there is no current leakage, sparks, or sparks. An insulator is a separator between a live area and a non-live area.
3. Conductor
   A conductor is a medium for conducting electric current from a power plant to a substation or from a GI to another GI, which stretches through towers. The conductors on the tension tower are supported by tension clamps, while the conductors on the suspension tower are supported by suspension clamps. Behind the clamps are installed a series of insulators connected to the tower.

Types of Transmission Towers

Transmission towers have many different shapes and materials and can be explained according to their construction form, function, and type. According to their construction form, there are 2 types of transmission towers that are commonly used, namely:

1. Lattice Tower

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Lattice tower is a transmission tower body construction made of steel or aluminum. This type of tower is used for almost all types of electric voltage and is the most common type of tower used for high voltage transmission, especially in Indonesia. Lattice towers are usually made of galvanized steel, but aluminum is also used to reduce the weight of the tower.

Figure 1. Lattice Tower

2. Steel Pole Tower
   This type of pole is made of steel pipe assembled in advance in the factory. Due to its durability and ease of manufacturing and installation, in recent years many transmission lines have preferred to use this type rather than Lattice Tower.

Electric Field

An electric field is an area around an electrically charged object that still experiences electric force. If another charge is in the electric field of an electrically charged object, the charge will experience an electric force in the form of attraction or repulsion (Pabla, 1994). An electric field is an electric force per unit charge. Because electric force follows the principle of superposition vectorially, so does the electric field. This means that the electric field strength of several point charges is the sum of the electric field strength vectors of each point charge. So the electric field strength of several point charges is the sum of the electric field strength vectors of each point charge (Sakinah, 2016).

Based on the Recommendation of SNI 04-6950-2003 of the National Standardization Agency on High Voltage Overhead Lines (SUTT) and Extra High Voltage Overhead Lines (SUTET), the threshold values of electric fields and magnetic fields. That this Standard applies as a guideline for determining the minimum space and free distance on High Voltage Overhead Lines (SUTT) and Extra High Voltage Overhead Lines (SUTET). This standard applies to SUTT with a nominal voltage of 66 kV and 150 kV, as well as SUTET with a nominal voltage of 275 kV and 500 kV in Indonesia, both using steel towers and steel/concrete poles (Sakinah, 2016), are:

Table 1. Threshold Values of Electric Fields and Magnetic Fields

Relation	Clasiffication	Electric Field(KV/M)	Magnetic Field (mT)
With Work	Work All Day	10	0,5
	Short Range	30	5
	only on the arm	-	25
With General Public	up to 24 hours a day	5	0,1
	A few Hours	10	1

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The permissible duration for electric field strength between 10-30 kV/m can be calculated using the formula: t ≤ 80/ E where t = exposure time (hours) and E = Electric field strength (kV/m). The maximum exposure duration/day is 2 hours.

This limitation applies to open spaces where members of the general public can be reasonably expected to spend most of their time during one day, such as recreation areas, fields for meetings and others (Sakinah, 2016). The values of electric field strength and magnetic field strength in forced activities can be exceeded for a duration of several minutes/day provided that precautions are taken to prevent indirect side effects. For the general public, WHO 1990 recommended a maximum exposure level of 5 kV/m for electric fields (Pabla, 1994). Meanwhile, based on the 1990 WHO recommendation, recommendations for the threshold value of electric fields are as follows.

Table 2. Electric Field Threshold Values According to WHO

Electric Field Intensity	Exposure time per 24 hours (kV/m)
(kV/m)	yang diperbolehkan (menit)
5	Unlimited
10	180
15	90
20	10
25	5

Magnetic Field

A magnetic field is an area around the center point of a magnet where certain objects experience magnetic force. Magnetic force can be caused by magnetic objects and also moving electric currents/electric charges. The magnetic field is influenced by the movement of charge transfer, its strength is measured in units of amperes per meter (A/m) but is expressed in the same terms as magnetic induction which is measured in units of tesla (T), milli tesla (mT) or micro tesla (uT).

A magnetic field is formed from the movement of electrons. Given that the electric current that passes through a conductor is a flow of electrons, a magnetic field will be generated around the conductor wire. The magnetic field has a direction, density, and intensity which are described as "flux lines". The magnitude of the magnetic field density is expressed by the number of flux lines that penetrate a certain field brush and has the symbol (B).

Magnetic lines of force always radiate from the north pole to the south pole and never intersect, all lines of force start at the north pole and end at the south pole. Continuous and always forms a curved loop, never cuts, tends to shorten itself, therefore the magnetic lines between different poles cause the poles to be pulled closer. Entry and exit of magnetic material on the right side of the surface. Passing through all materials, magnetic or non-magnetic (Putra, 2013). In addition, there is no insulator for the strength of the magnetic lines.

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Figure 2. Magnetic Field

METHOD

The type of research used by the researcher is descriptive quantitative research, the researcher will describe the comparison of the strength of the electric field with the magnetic field under the high voltage transmission line to the inductor curvature factor. Quantitative methods as research procedures that produce comparative data through calculation results, while descriptive are in the form of written or spoken words from people and observable behavior. Researchers are not required to form certain theories in advance regarding the aspects they are studying, but they can focus their attention on natural events as they are according to the specified data. While the scientific approach of this research is to use a comparative analytical approach through calculations. The main data sources in quantitative research are data, calculations, and actions, the rest are additional data such as documents and others. From the explanation above, the data sources can be divided into 2 (two) parts:

a. Primary data, the primary data source in this study is all data obtained directly from informants as the first source in the form of data on the strength of the electric field and magnetic field under high-voltage lines against the conductor curvature factor and important informants that researchers will later need to obtain data about it.
b. Secondary data, secondary data is supporting data or additional data in this study obtained from written sources such as documents, books, and also statistical data related to this study.

To obtain the data that researchers need in this study, researchers use data collection instruments as used in every field study. Data collection techniques in this study are related to quantitative data collection techniques consisting of observation and drawing conclusions.

While library research, namely analyzing related literature and in which there is data needed for this research concerning the theory and problems of electric field strength and magnetic field under high voltage lines against the inductor curvature factor. Observation, namely conducting direct measurements in the field about the electric field strength and magnetic field under high voltage lines against the inductor curvature factor.

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In order to process the results of this research, of course, using quantitative research procedures, namely by conducting direct measurements or presenting the results of this research with numbers according to the existing data and drawing conclusions using the inductive method. While the data analysis process used is the constant comparative method. It is called the constant comparative method because in data analysis, it constantly compares one data with another.

RESULT

Electric Field Strength

The calculations and measurements in this study were carried out at two different locations. The first location was carried out under the conductor at several random number pole locations of the 150 Kv labuan belwan Bilik transmission line. Calculation and measurement of electric field strength under the high voltage transmission line conductor is done under the lowest andongan at a predetermined point with a measurement height from the ground is fixed at 1.5M. Based on the measurement results that the researcher conducted, the following electric field strength data was obtained:

Table 3. Electric Field Strength of Line 1 Based on Measurement Results

Point	Tower	Ground Clearance(M)	Electric Field Strength (V/M)
1	10-11	17.9	347
2	27-28	17.5	273

Table 4. Electric Field Strength of Line 1 Based on Calculation

Point	Tower	Measurement Distance(M)	Electric Field Strength (V/M)
1	10-11	17.9	1199
2	27-28	17.5	1233
3	78-79	18	1191
4	98-99	17.7	1216

Table 5. Comparison of Electric Field Strength of Line 1 Based on Measurement Results

Point	Tower	Measurement results(V/M)	Calculation Results (V/M)
1	10-11	347	1199
2	27-28	273	1233
3	78-79	377	1191
4	98-99	244	1216

Next, the second measurement location was carried out in Simpang Bahalbatu Village, Pangarsinondi, Simorangkir Julu, Lontung Dolok and Pahae Julu Village. The environmental conditions of the soil are solid and are located in residential areas, plantation areas, and are carried out when the air is clear with the location of the sample points of several transmission tower spans.

Table 6. Electric Field Strength of Line 2 Based on Measurement Results

Point	Tower	Ground Clearance(M)	Electric Field Strength (V/M)
1	115-114	29.7	506
2	134-135	27.3	607
3	170-171	28.5	288
4	201-202	26.6	1.210

Table 7. Electric Field Strength of Line 2 Based on Calculation

Point	Tower	Measurement Distance(M)	Electric Field Strength (V/M)
1	115-114	29.7	1670
2	134-135	27.3	1852
3	170-171	28.5	1756
4	201-202	26.6	1912

Table 8. Comparison of Electric Field Strength of Line 2 Based on Measurement Results and Calculation

Point	Tower	Measurement results (V/M)	Calculation Results (V/M)
1	115-114	506	1670
2	134-135	607	1852
3	170-171	288	1756
4	201-202	1.210	1912

The measurement results show that the electric field strength at all monitoring or measurement locations carried out is still below the threshold value of the electric field strength based on WHO criteria and SNI 04-6950-2003 criteria. The results of the electric field strength measurements that are still below the specified threshold indicate that the electric field strength is still within a very safe range.

Magnetic Field Strength.

A magnetic field is an area around a magnet that still feels the magnetic force. If a magnet is placed in a space, then there will be a change in this space, namely every point in the space will have a magnetic field. The direction of the magnetic field at a point is the direction indicated by the north pole of the compass needle when placed at that point.

The magnetic field around a current-carrying wire is said to be when a needle magnet is brought close to a conductor carrying electricity, the needle magnet will deviate. This symptom will appear if the wire is carrying an electric current. If the wire is not carrying an electric current, the magnetic field does not occur so that the compass needle magnet does not react. This shows that there is a magnetic field around the current-carrying wire.

The calculations and measurements in this study were carried out at two different locations. The first location was carried out under the conductor at several random number pole locations of the 150 Kv Rantau Prapat – Labuhan Bilik transmission line. The second location was carried out at several random number pole locations of the 275 Kv Simangkuk transmission line Sarulla. Calculation and measurement of electric field strength under the high voltage transmission line conductor is carried out under the lowest andongan at a predetermined point with a measurement height from the ground is fixed at 1.5M.

The first measurement location was carried out in Sungai Kasih Village, Sungai Tampang, Perk. Sennah, Kampung Sennah, and Pangkatan Village with a measurement segment/direction from Rantau Prapat to Labuhan Bilik. The environmental conditions of the soil are solid and are in residential areas, plantation areas, and are carried out when the air is clear with sample point locations of several transmission tower spans with the following basic tower specifications.

In order to calculate the magnitude of the magnetic field strength at a point x meters above the ground and in the middle of the transmission line, the transmission tower must be taken as the reference axis. The tower axis becomes the reference source for calculating the magnetic field strength. As shown in the following image.

Table 9. Magnetic Field Strength Line 1

Point	Tower	Ground Clearance (M)	Strong Field Magnet measurement (μT)	Strong Field Magnet calculation (μT)
1	10-11	17.9	0.47	1.55
2	27-28	17.5	0.57	1.59
3	78-79	18	0.28	1.54
4	98-99	17.7	0.35	1.57

Table 10. Magnetic Field Strength of Line 1 Compared to Safe Limits

Point	Tower	Strong Field Magnet Measurement (μT)	Strong Field Magnet calculation (μT)	Safety Limit (mT)
1	10-11	0.47	1.55	0.1
2	27-28	0.57	1.59	0.1
3	78-79	0.28	1.54	0.1
4	98-99	0.35	1.57	0.1

The results of the magnetic field strength measurements which are still below the specified threshold, indicate that the magnetic field strength is still within a very safe range for the surrounding community to carry out activities under the transmission network.

Comparison of Electric Field Strength with Magnetic Field Strength on Conductor Curvature

The difference that occurs between point one and point two is caused by several factors, including the distance between the conductor and other conductors due to the presence of a drag, causing the distance between each conductor along the transmission line to be inconsistent, but in calculating the distance between each conductor along the transmission line is always the same. Another factor is the weather conditions at the time of measurement, indeed when taking measurements the conditions are sunny but sometimes also cloudy so that it is possible for differences to occur when taking measurements during sunny and cloudy times.

The influence of buildings, trees and other objects around the transmission tower also affect the calculation of electric field strength and magnetic field. In addition, the permittivity of the air around the transmission conductor changes, this is caused by the presence of dust and other small particles in the air. Another factor is the lowest point and the middle point of the transmission line which causes a slant, the lowest point of the transmission line is in the middle of the transmission line. Errors in determining the lowest point of the transmission line cause errors in measuring the strength of the electric field and magnetic field. The coordinates of the measurement point are the most important thing in measuring the strength of the electric field and magnetic field. The coordinates of the measurement point are determined before taking measurements.

Based on the results of the research conducted by the researcher, it is confirmed that the comparison of the strength of the electric field with the magnetic field to the curvature factor of the conductor shows that the strength of the magnetic field and the magnitude of the strength of the electric field to the surface are also influenced by the high and low thrust of the conductor itself. Therefore, if there is a leakage current or induction, then in humans there is a pulling force by the magnetic field, then the pull this leads to an electric field. Based on the data obtained by the researcher, the researcher can explain it as follows:

Table 11. Comparison of Electric Field Strength with Magnetic Field Strength

Highest Point	Electric and Magnetic Field Strength	
	Line 1	Line 2
Electric Field	515 V/M	1.210 V/M
Magnetic Field	1.59 μT	0.789 μT

Discussion

The process of distributing electrical energy from the generation source to the substation near the electrical load area is one of the functions of the transmission line. To prevent power losses along the transmission line, a high voltage system is used. The use of this high voltage, in addition to reducing power losses, also produces a high electric field around the conductor wire.

The mechanism of electromagnetic field induction in the current contained in a down conductor, causing the area around the down conductor to experience electromagnetic induction or mutual inductance which induces electrical equipment in the surrounding buildings, the strength of the electric field can have an impact on the community, and the strength of the magnetic field also has an impact on the community under the high voltage transmission line, so it is necessary to conduct a comparative analysis between the strength of the electric field and the magnetic field under high voltage transmission on the environment.

The results of the research conducted by the researcher show that the conductor whose curvature is close to the ground surface will have a greater electric field magnitude than the conductor whose surface is far from the ground surface. This is based on the results of research at two different points, that the curvature of the conductor results in a greater electric field.

Likewise, the strength of the magnetic field under the high voltage transmission line against the curvature of the conductor, that the more curved the conductor, the greater the strength of the magnetic field that occurs against the attractive force that exists near the power transmission line. Therefore, there are limitations to the transmission of electricity to avoid unwanted things, especially for humans and residential buildings around the power transmission line.

CONCLUSION

Based on the results of the research and analysis conducted by the researcher, it can be concluded that: a. The largest electric field value obtained through direct measurement on the first path is 515 V/m, and on the second path is 1,210 V/m, while the largest value obtained by calculation on the first path is 1,233 V/m, and on the second path is 1,910 V/m. The largest magnetic field value obtained through direct measurement on the first path is 0.57 μT, and on the second path is 0.789 μT. while the largest value obtained by calculation on the first path is 1.59 μT, and on the second path is 0.545 μT. The strength of the electric field and magnetic field varies with the curvature of the conductor, whether close to the ground surface or not, but is likely to be greater than a conductor whose surface is far from the ground surface. Based on the results of the research conducted by researchers on the first and second paths, the results of measurements and calculations for the Electric Field and Magnetic Field are still below the specified threshold.

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