Analysis of the Effect of Electric Charge Discharge (Corona) on Power Shrinkage on Transmission Lines

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ABSTRACT
This study discusses the analysis of the effect of electric discharge (corona) on power loss in the transmission line between the Glugur Substation and the Paya Geli Substation. Corona occurs when the voltage on the transmission line conductor exceeds the threshold of the air penetration field strength, causing electric discharge into the air and resulting in power losses. This study measures corona power losses throughout 2024 and calculates the efficiency of the transmission line based on power losses caused by the corona phenomenon. Air pressure, temperature, and air density factor data are used to calculate corona losses, with the results showing large variations in each month, ranging from 0.385 kW in January to 24.739 kW in December. The efficiency of the transmission line is calculated at 90.9%, indicating that even though there are power losses due to corona, most of the power transmitted is still received by the receiving substation. Environmental factors such as temperature and air pressure have a significant effect on the magnitude of corona losses, so managing weather conditions and conductor maintenance are important factors in maintaining power transmission efficiency. The results of this study provide important insights to improve the performance of transmission lines in dealing with the corona phenomenon.

Keywords: Electrical Discharge, Corona, Power Losses, Transmission Line, Efficiency, Air Density Factor.

Introduction

Transmission systems are a key element in the electric power infrastructure, playing a vital role in the distribution of energy from power plants to consumers. These systems are designed to bridge the long distance between power plant locations, which are often located in remote areas, and energy consumption areas, which are usually centered in urban areas. As the backbone of energy distribution, transmission lines have a major responsibility in maintaining the reliability, efficiency, and continuity of electric energy supply.

In its operation, high voltage overhead transmission lines have quite significant technical challenges. One of the phenomena that affects the efficiency and performance of this line is the corona phenomenon. This phenomenon begins to be a concern in lines with voltages above 100 kV, where the electric field around the conductor exceeds the air penetration strength. Corona can be defined as the release of electric charge (electrons) from the conductor surface due to ionization of the surrounding air, known internationally as corona discharge.

The impact of the corona phenomenon on transmission lines is quite complex and significant. One of the main impacts is the loss of electrical energy in the form of power losses that directly affect the efficiency of the transmission system. Corona not only causes dissipation of energy that should be used by consumers, but also increases operational costs and has the potential to disrupt the stability of the electricity network as a whole. In addition, this phenomenon produces electromagnetic interference that can affect surrounding telecommunications devices, disturbing noise, and degradation of conductor materials that have an impact on the technical life of the transmission line.

Technically, power loss due to corona depends on various factors, such as operating voltage level, conductor material type, distance between conductors, and environmental conditions such as humidity and air pressure. A thorough knowledge of corona mechanisms is needed to understand how these factors contribute to power loss. With this understanding, effective mitigation strategies can be designed to reduce the negative impacts of corona.

This study aims to analyze the effect of corona on power losses in high voltage transmission lines. This study focuses on measuring power losses due to corona, analyzing factors that influence the phenomenon, and exploring mitigation solutions that can be applied in transmission line operations. The study was conducted through a combination of simulation modeling using advanced software and laboratory-scale experiments to validate the simulation results.

With the increasing demand for electrical energy in line with population growth and industrial development, the efficiency of transmission systems is becoming increasingly important. The results of this study are expected to provide significant contributions to understanding the corona mechanism and its impact on power losses. Furthermore, this study is expected to provide practical recommendations for the development of innovative technologies and mitigation strategies. This will support global efforts to improve energy efficiency and create a more reliable and sustainable power system.

Formulation of the problem:

1) How does Electrical Discharge effect Power Loss in transmission lines?
2) What are the factors that influence the occurrence of Electrical Discharge on transmission lines?
3) How to measure and analyze the level of Power Loss caused by Electrical Discharge?

Literature Review

Definition and Mechanism of Corona

Corona is a phenomenon that occurs in high voltage systems, especially in overhead transmission lines. This phenomenon can be defined as the release of electrical charge in the form of electrons emitted from the conductor surface due to an electric field that exceeds the air penetration strength. This release occurs when the voltage gradient around the surface of the conductor wire reaches a certain threshold, causing ionization of the surrounding air. This ionization produces a purple light emission, accompanied by a hissing sound, and the release of energy in the form of power losses (Manullang, 2020). Corona generally occurs in high voltage transmission lines (more than 100 kV), especially in high voltage (HV) and extra high voltage (EHV) systems. The difference in voltage between phases and between phases and ground is the main factor that triggers corona. This phenomenon is also exacerbated by irregularities in the conductor surface, such as dust particles or dirt that stick to the conductor surface.

Corona Characteristics in AC Systems

In high voltage AC systems, corona occurs in both half cycles of the voltage waveform, both positive and negative. However, experiments show that corona in the negative cycle is more dominant. In the negative half cycle, corona occurs more easily in areas with high electric fields. Factors such as uneven conductor surfaces contribute to the intensity of corona, where short pulses of electric current are concentrated at the peak of the voltage waveform. Increasing the voltage will increase the number of corona pulses, produce a high-frequency hissing sound, and emit violet light. This condition indicates a significant release of electrical energy into the environment, thereby reducing the efficiency of electricity transmission.

Impact of Corona on Transmission Channels

Corona has a significant impact on power loss in high-voltage transmission lines, including: Power Loss: The release of electrical energy in the form of heat, light, and sound causes power losses in the transmission line. This can reduce the efficiency of the transmission system and increase operational costs. Electromagnetic Interference: Current pulsations generated by corona can cause electromagnetic interference to electrical equipment around the transmission line. Material Degradation: Ion release can accelerate corrosion and damage to conductor materials, thereby reducing the technical life of the transmission line. Environmental Impact: The emission of violet light and hissing sound due to corona can cause visual and noise disturbances, especially in residential areas.

Factors Affecting Corona

Some of the main factors that affect the intensity and impact of corona include: Electric Field Strength: The stronger the electric field around a conductor, the more likely corona is to occur. Phase Spacing: Smaller spacing between conductors increases the chances of corona occurring because the electric field becomes more focused. Conductor Surface Irregularities: Irregularities in the conductor surface, such as dust, corrosion, or mechanical defects, can accelerate the discharge of electrical charges. Weather Conditions: Factors such as humidity, temperature, and atmospheric pressure affect the air penetration strength, which determines the threshold for corona to occur.

Corona Impact Mitigation Efforts

Mitigating the impact of corona is important to improve the efficiency and reliability of the electricity transmission system. Some approaches that can be taken include: Optimal Conductor Design: Using large diameter or round conductors to reduce the voltage gradient on the conductor surface. Increasing the Distance Between Phases: Adjusting the distance between conductors to reduce the intensity of the electric field around the line. Routine Maintenance: Cleaning the conductor surface periodically to remove particles that can trigger corona. Use of Spacers: Spacers can be used to maintain the distance between conductors, so that the electric field is more even.

Research Methodology

From the research steps that are analyzed systematically to obtain results that are in accordance with the research objectives. This analysis process includes manual methods and calculations using software, which are summarized in the following seven steps:

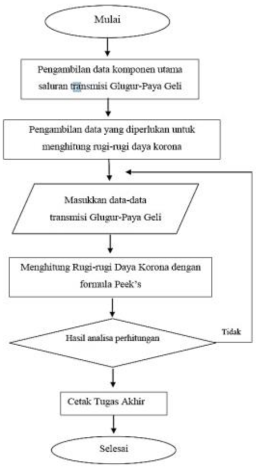

Figure 1. Flowchat Diagram

1. **Technical Data Adjustment**
   a. Calculating air pressure based on the height of the research area (Paya Geli).
   b. Convert air pressure results from cmHg to millibars for data standardization.
   c. Calculate the air density factor by considering air pressure and ambient temperature.
2. **Disruptive Crisis Stress Calculation**
   Determine the disruptive crisis stress based on the following factors:
   a. Air density factor.
   b. Strong air penetrating field.
   c. Conductor surface irregularity factor.
   d. Conductor radius.
   e. Distance between phases.
3. **Manual Calculation of Corona Losses**
   a. Calculating the total corona losses on the transmission line between the Glugur Substation and the Paya Geli Substation.
   b. Taking into account parameters such as:
   c. Air density factor.
   d. Network frequency.
   e. Conductor radius.
   f. Distance between phases.
   g. Receiver side voltage.
   h. Disruptive crisis tension.
4. **Transmission Line Efficiency Analysis**
   a. Calculate the average corona power losses per month.
   b. Evaluate the efficiency of transmission lines based on the results of power loss calculations.
5. **Calculation Using Software**
   a. Entering technical parameter data, such as phase spacing, conductor radius, frequency, voltage, air temperature, air pressure, and air density factor, into Microsoft Excel software.
   b. Conducting simulation calculations of disruptive crisis voltage and corona losses for each month during 2024.
6. **Data Visualization**
   Create curves and graphs to analyze the relationships between key parameters, including:
   a. Air density factor.
   b. Total corona losses.
   c. The relationship between corona losses and disruptive crisis stress.
   d. The relationship between corona losses and rainfall.

Results and Discussion

A. Electrical Discharge Affects Power Loss on transmission lines

Corona discharge in high-voltage transmission lines is a phenomenon that affects the efficiency of electric power transmission. Corona occurs when the electric field around the conductor of the transmission line exceeds the strength of the air-penetrating field, causing air ionization and electric discharge. This process results in power losses, known as corona losses, and has a direct impact on the reduction of power delivered from the sending substation to the receiving substation.

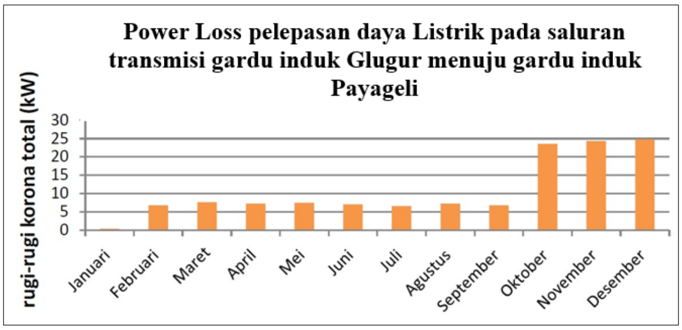

Figure 2. Power loss graph on total electric power release on the substation transmission line in 2024.

1. **Main Causes of Electrical Discharge (Corona)**

Corona discharge on transmission lines is influenced by a number of factors:

a. Electric Field Strength Around Conductors. When the electric field strength around the conductor exceeds the threshold of the air-penetrating field strength, electric charges begin to be released. This phenomenon is influenced by the operating voltage of the transmission line and the configuration of the conductor.
b. Conductor Surface Irregularities. Uneven conductor surfaces due to corrosion, dust particles, or dirt trigger corona discharge at certain points. These irregularities increase the concentration of the electric field, increasing the chance of electric discharge.
c. Environmental Factors. Air pressure, humidity, and ambient temperature affect the density of the air around the conductor, which plays a role in the ionization and corona discharge processes.

2. **Corona's Impact on Power Shrinkage**

Power loss in transmission lines is caused by energy lost in the form of heat, hissing noise, and electromagnetic radiation due to corona discharge. This study shows that:

a. The lowest power loss occurred in January at 0.385 kW, which was likely due to more stable environmental conditions, such as favourable air pressure and humidity.
b. The highest power loss occurred in December at 24,739 kW, possibly influenced by increased humidity due to high rainfall, which increases the chance of air ionization around the conductor.

3. **Corona Loss Mechanism**

Corona losses occur because the electrical energy that should be transmitted to the load is lost due to the air ionization process. Some important aspects of this mechanism are:

a. Energy Lost as Heat. Most of the energy lost in the corona process is released as heat, which increases the temperature of the conductor.
b. Electromagnetic Radiation. Corona discharges emit electromagnetic radiation, which not only reduces the power received by the receiving substation but also has the potential to interfere with nearby electronic devices.

4. **Factors Affecting the Magnitude of Corona Losses**

a. Operating Voltage. The higher the operating voltage, the greater the chance of corona, because the electric field around the conductor also increases.
b. Distance Between Conductors. Smaller distance between conductors can increase the interaction of electric fields between phases, thereby increasing the risk of corona.
c. Conductor Diameter. Smaller diameter conductors tend to have higher electric field concentrations, making them more susceptible to corona discharge.

5. **Impact of Power Loss on Transmission Line Efficiency**

Power loss due to corona discharge has an impact on the overall efficiency of the transmission system:

a. Power Delivery Efficiency Decreased. Corona losses reduce the amount of power received at the receiving substation, thereby decreasing power delivery efficiency.
b. Increased Operational Load. To compensate for the lost power, the system must supply additional energy, which increases operational costs.

6. **Efforts to Minimize Corona Losses**

Several technical steps can be taken to reduce the impact of corona on power loss:

a. Use of Large Diameter Conductors. Larger conductor diameters can reduce the concentration of electric fields at the conductor surface, thereby reducing the possibility of corona discharge.
b. Routine Cleaning of Conductors. Cleaning the conductor surface from dust and dirt particles can reduce surface irregularities, which are one of the main causes of corona.
c. Optimizing Operating Voltage. Keeping the operating voltage within the optimum limits can reduce the risk of corona discharge.

Electrical discharge or corona has a significant effect on power loss on the transmission line between the Glugur Substation and the Paya Geli Substation. The amount of power loss is influenced by technical factors such as operating voltage and distance between conductors, as well as environmental factors such as air pressure and humidity. To minimize its impact, preventive measures and better technical management are needed, such as the use of more efficient conductors and routine cleaning of conductor surfaces. Thus, the efficiency of the transmission system can be improved, reducing power loss that occurs during the process of sending electrical energy.

B. Transmission Line Efficiency Based on Corona Losses and Air Density Factor

The graph of total corona power losses on the transmission line between the Glugur Substation and the Paya Geli Substation shows a significant large variation throughout 2024. The lowest power loss value was recorded in January, at 0.385 kW, while the highest value was recorded in December with 24.739 kW. This variation illustrates how factors such as temperature, humidity, and air pressure can affect the efficiency of power delivery on a transmission line.

1. **Effect of Corona Losses on Transmission Line Efficiency**

Corona losses are energy losses that occur due to the release of electrical charges around the conductors on the transmission line. The efficiency of the transmission line can be calculated by considering the amount of power loss due to corona, using the following formula:

$$\eta = \frac{P_{\text{kirim}} - P_{\text{korona}}}{P_{\text{kirim}}} \times 100$$

Where:

η = Transmission line efficiency

P_{send} = Power sent

P_{corona} = Corona losses

From the calculation, the transmission line efficiency is obtained as 90.9%, which shows that about **9.0008%** of the transmitted power is lost due to corona losses. This shows that even though there is power loss due to corona, the transmission efficiency of this line is still relatively good, with most of the power being received by the receiving substation.

2. **Air Density Factor and Its Effect on Corona**

The corona is greatly influenced by the air density factor, which depends on air pressure and temperature. For the Paya Geli area, which is located at an altitude of 16 meters above sea level, air pressure can be calculated using the formula:

$$b = 76\,\mathrm{cmHg} - \frac{h}{100}$$

With a height value of h=16 m, the air pressure value is 75.84 cmHg, which is then converted into **mbar units**:

$b = 75,84 \times 13,33224\,\mathrm{mbar} = 1011,12\,\mathrm{mbar}$

In addition, the air density factor can be calculated using the formula:

$$\delta = \frac{0,289 \times b}{273 + t}$$

Where:

a. t = air temperature (in degrees Celsius)
b. b = air pressure (in mbar)

With air temperature t=27.2 ∘ C, the air density factor value is 1.106. This value is used to calculate corona losses that occur throughout the year, which are greatly influenced by changes in temperature and air pressure.

3. Variation of Corona Losses Based on Environmental Factors

Changes in temperature and humidity in the Paya Geli area can cause large variations in corona losses throughout the year. In months with high temperatures and high humidity (such as December), conductors are more easily ionized, which causes increased corona losses. Conversely, in January with more stable temperatures and humidity, corona losses tend to be lower. Analysis of corona losses on the transmission line between the Glugur Substation and the Paya Geli Substation shows that despite significant power losses, this transmission line still has a high efficiency of around 90.9%. Variations in corona losses are greatly influenced by environmental factors, especially temperature and air pressure. Therefore, management of transmission lines by paying attention to weather conditions and conductor maintenance is very important to maintain power delivery efficiency.

Conclusion

Based on the results of the analysis conducted on the transmission line between the Glugur Substation and the Paya Geli Substation, it can be concluded that the corona phenomenon has a significant effect on power losses in the transmission line. The highest power losses occurred in December with a value of 24.739 kW, while the lowest power losses were recorded in January at 0.385 kW. The variation in power losses is influenced by factors such as temperature, air pressure, and conductor surface conditions. The efficiency of the transmission line, calculated based on corona losses, reached 90.9%, indicating that even though there are power losses due to corona, most of the power transmitted is still well received by the Paya Geli Substation. Environmental factors, especially air density which depends on air pressure and temperature, also affect the magnitude of corona power losses. Therefore, environmental factor management and transmission line maintenance are important to minimize power losses. Overall, the transmission line between the Glugur Substation and the Paya Geli Substation showed good performance despite the influence of the corona phenomenon. The decrease in efficiency is caused by the release of electrical charges that increase power losses, which in turn affect transmission performance. This study provides a clear picture of the effect of corona on power losses in transmission lines and the importance of considering environmental factors in designing and managing power transmission lines.

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