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A High Voltage Generation And Measurement Techniques Of Alternating Current

Kristovel Ritonga[1], Muhammad Habib Agil[2], Roy Putra Andika Ambarita[3], Viktorman Waruwu[4], Solly Aryza[5]
Universitas Pembangunan Panca Budi, Medan, North Sumatera, Indonesia

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ABSTRACT
Isolation is the most important and inseparable thing in high voltage equipment. This isolation serves to separate two or more electrical conductors that are under voltage, so that there will be no electric jump or spark between the conductors. Air in normal conditions (air pressure 1013 mBar and temperature 20oC) has a certain breakdown voltage against high alternating voltage. Gas insulating materials, especially air, are insulating materials that are widely used in high voltage equipment because air in ideal conditions is a perfect insulator and is also the most widely used because it is easy, cheap and simple. In this test, room temperature conditions, conditions above and below room temperature are applied to ball-plane electrodes and needle-plane electrodes with different gap distances, to see how much influence the shape of the electrode, temperature, gap distance and voltage polarity have on the dielectric breakdown strength of air. Based on the measurement results at different gap distances, the characteristics of the increase in air breakdown voltage are obtained due to the influence of the gap distance between the two electrodes. The measurement results at different polarities show that the rougher, smaller and sharper electrodes with positive polarity will more easily release electrons. Keywords: insulation, air conditions, high voltage.

Corresponding Author:
Kristovel Ritonga
Universitas Pembangunan Panca Budi, Medan, North Sumatera, Indonesia
sollyaryzalubis@gmail.com

INTRODUCTION

Increasing growth and infrastructure development will increase the need for electrical energy. Electrical energy is an important part of everyday life. Electrical energy is energy that is currently widely used to support the needs of the community (Siti, 2023). In the distribution of high-voltage electrical energy, reliable equipment is needed. The electrical power distribution system is supported by adequate distribution equipment. Under normal conditions, the electrical power distribution system is distributed by current and working voltage that affects the performance of existing equipment. Electrical power distribution equipment is equipment that functions to distribute current and working voltage to the entire electrical network (Rudiansyah, 2024).

A common problem in the distribution of electrical energy is insulation failure, especially liquid and air insulation. Insulation is needed to separate two or more electrical conductors that are under voltage so that there is no electrical jump between the

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conductors. If an electric field exceeds its capacity, the insulation will experience a breakdown voltage event and damage to electrical equipment so that the continuity of the system's work is disrupted. This is caused by two factors, namely overvoltage and thermal heating due to the heat energy generated by the electrical conductor. The heat generated by the conductor can cause the insulation temperature to increase above its working temperature. If this heating continues, the insulation will deteriorate and can also cause insulation failure which can cause breakdown voltage, this is because the insulation is no longer able to withstand the high voltage passing through it. In order to avoid insulation failure, it is necessary to know in advance the working capacity of the insulation used (Dwi Harinata, 2019).

Various studies have been conducted to see or determine the characteristics of the breakdown voltage of liquid insulation and air insulation with various methods or treatments. However, no one has tested using several changes in temperature and electrode diameter. Therefore, the author wants to test the characteristics of the breakdown voltage of liquid insulation and air insulation at several changes in temperature and electrode diameter. Failure of air insulation in general, failure of electrical equipment when in use is caused by the failure of insulation in carrying out its function as a high voltage insulator. Insulation failure is caused by several factors, including the insulation has been used for a long time, mechanical damage, reduced dielectric strength, and due to overvoltage. Air is the most widely used insulating medium in high voltage engineering. Some common high voltage phenomena or symptoms include skin effect, corona, spark over and flash over. The physical phenomena of symptoms or failure of high voltage are influenced by the shape of the electrode used (Dwi Harinata, 2019).

The generation and measurement of high-voltage alternating current (AC) are essential aspects of electrical power systems, particularly in testing high-voltage equipment such as transformers, insulation cables, circuit breakers, and transmission network components. In modern power systems, the use of high voltage aims to reduce power losses during transmission and improve the efficiency of electricity distribution.

High-voltage measurement is crucial to ensure the reliability and safety of electrical equipment, complying with industry standards and operational safety regulations. As technology advances and the demand for more reliable electrical systems increases, innovations in high-voltage generation and measurement techniques continue to develop. These techniques play a vital role in the power industry, directly influencing operational safety and equipment efficiency.

Literature Review

High Voltage Alternating Current Generation Techniques.

AC power can produce voltage and current with magnitude and polarity that change cyclically over time. The direction of the electromotive force generated in the conductor between the magnetic field varies following changes in the direction of the magnetic lines of force and the movement of the conductor (Syahru, 2018). The source of AC power is an AC generator. This alternator consists of a square coil that rotates in a magnetic field. AC distinguishes between alternating current with a sinusoidal function or profile and non-

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sinusoidal alternating current. Sine waves are used as a power supply for PLN. Non-sine waves are usually used in inverters (Abdillah, 2023).

Test Transformer Characteristics.

A transformer is a tool or machine that functions to transfer power or electrical energy from high voltage to low voltage or vice versa. Power disturbances often occur in power sources, so a protective device is needed to protect against these disturbances. One of the safety systems that can be used on transformers is a differential relay. A differential relay is a very important protection device for transformers that work at high speeds without coordination with other relays. A differential relay works when the vector difference between two or more electrical quantities exceeds a predetermined value, and a differential relay cannot be used as backup protection (Ariyanto, 2024).

The equipment used to generate high AC voltage is by using a transformer. The transformer that is usually used is a test transformer. The test transformer used for high voltage generation has a low power rating (kVA) but has a high voltage rating and the one that is generally used is a single-phase transformer because high voltage testing is carried out phase by phase. The insulation for the test transformer only takes into account the insulation against the maximum test voltage and the construction of the windings and its insulation must achieve the voltage gradient (dv/dt) which is uniform./dt) which is uniform (Electrical Engineering UI, 2024).

The design of the test transformer is generally similar to the potential transformer used for voltage and power measurements in the power system. The overall impedance of the test transformer must be less than 5% and must be able to carry a short-circuit current for one minute or more (depending on the design). In addition, the flux density selected must be low, so as not to draw a large magnetizing current that will not saturate the core and produce higher harmonics (Electrical Engineering UI, 2024).

Air Insulation Breakdown Voltage Measurement

The purpose of measuring the breakdown voltage is to observe the characteristics of the dielectric breakdown voltage of air at various temperatures and different gap distances using ball-plane electrodes and needle-plane electrodes. The measurement is carried out with the steps as described in the following flowchart (Sasmito, 2011):

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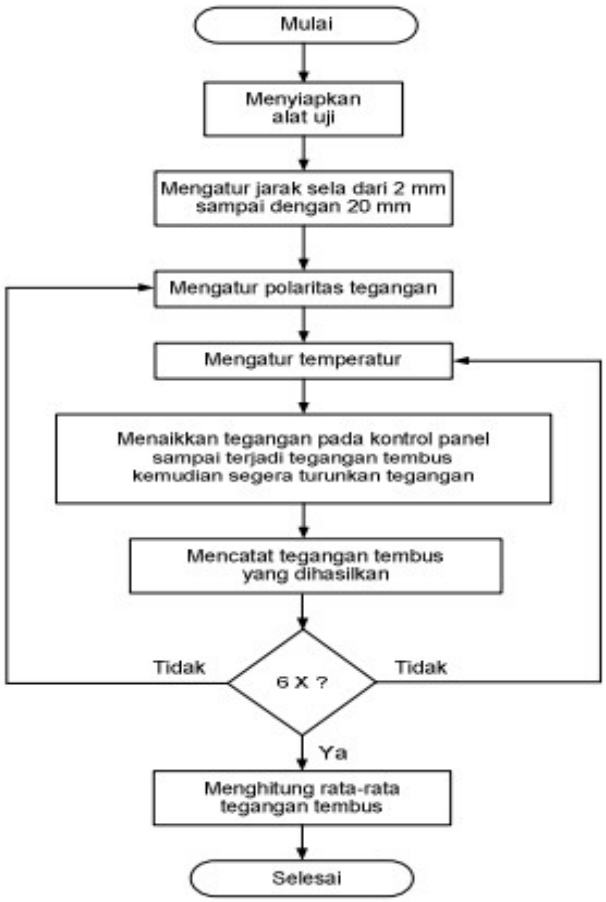

Figure 1. Flowchart System

The measurement method for High Voltage Alternating Current is by using a capacitor divider, namely by connecting the capacitor to a voltmeter, so that the high voltage to be measured is not measured directly by the voltmeter.

METHOD

This study employs a quantitative approach to analyze the generation and measurement of high-voltage alternating current (AC). The methodology includes data collection, experimental setup, measurement techniques, and result validation to ensure accuracy and reliability in high-voltage applications. The research follows an experimental and analytical approach, focusing on:

1. High-voltage AC generation techniques, including transformer-based methods and resonant circuits.
2. Measurement methods used in high-voltage applications, such as voltage dividers and electrostatic techniques.
3. Error analysis and calibration to ensure the accuracy of high-voltage measurements.

The study investigates different high-voltage AC generation techniques, including:

1. Transformer-Based Generation

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a. Cascade transformers: Used to step up the voltage in stages to achieve high-voltage levels.
b. Testing transformers: Specifically designed for insulation testing and high-voltage applications.

2. Resonance Methods
   a. Series resonance: Utilizes a resonant circuit to generate high voltages efficiently.
   b. Parallel resonance: Used in specific applications to maintain voltage stability.
3. High-Voltage Generators
   a. Electrostatic generators: Generates high voltages based on charge accumulation.
   b. Impulse voltage generators: Produces transient high-voltage pulses for testing insulation strength.

Each method is analyzed based on efficiency, reliability, and application scope in high-voltage testing environments.

a. 1 unit Control Unit (CU)
b. 1 unit HV Test Transformer (TT)
c. 1 unit of Current Limiting Resistance (CLR)
d. 1 unit RC Divider (RCD)
e. 1 unit High Voltage Divider (HVD)
f. 1 unit Floor Pedestal (FP)
g. 1 unit Connecting Line (CL)
h. 1 set Earth Cable (EC)
i. 1 unit Space Ball CurrentLimiting Resistor (SB-CLR)
j. 1 unit Manual Discharge Space Ball (SB)
k. 2 units Support Insulator (SI)

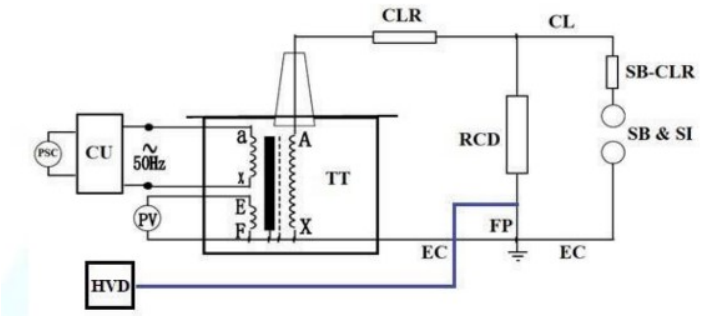

Figure 1. wiring instalation

RESULT

Result Potential Energy

Voltage is the amount of potential energy available (work to be done) per unit charge, to move the charge through a conductor. Voltage is the current of charge that has electricity. There are objects that have a negative electric charge, then channel it from a lower voltage to a place with a high amount of voltage, From this explanation it can be concluded that it

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has several types of voltage, from extra low, medium, extra high, or low and high. And there is also the definition of alternating current.

Alternating current is a current whose direction and magnitude change at any time. Alternating current is widely used in the world of electricity. Alternating current always has a peak value of the upper wave and a peak value of the lower wave. Power Plant Engineering or Power Plant Engineering (TPTL) is a branch of the field of energy engineering, and is defined as the engineering and technology needed for the production of central power stations. Electrical measurement is any change in the measured variable displayed in a form other than electricity, for example this measuring instrument is an analog ammeter, voltage meter, analog ohmmeter. Usually the output results are displayed on the LCD layer on the measuring instrument. This module explains that high voltage alternating current is divided into two types, namely high voltage alternating current with low frequency and high voltage alternating current with high frequency. The test transformer used has a larger ratio of the number of turns compared to the Power Transformer and its kVA capacity is small compared to the capacity of the Power Transformer. Usually a single-phase transformer is used, because testing is carried out phase by phase.

Electrical equipment failures generally occur due to insulation failure. Insulation failure is caused by aging insulation, mechanical damage, decreased dielectric strength, usage time and exposure to overvoltage. The definition of overvoltage is the magnitude of the voltage in the electrical network exceeding its normal voltage. High voltage that occurs in the system can be divided into two, namely normal high voltage and high overvoltage (disturbance). Normal high voltage is the voltage that can be withstood by the system for an unlimited time while high overvoltage (disturbance) can only be withstood by the system for a limited time. Based on its form, high voltage can be divided into two, namely periodic and aperiodic.

For periodic, the wave is usually sinusoidal where the wave has time and has a pattern. When aperiodic, the wave is in the form of an impulse wave and for example, a lightning strike occurs because the lightning strike occurs suddenly so that the voltage rises to a maximum and then decreases. Based on its nature, high voltage testing is divided into destructive and non-destructive testing. For destructive testing, for example, withstand test, discharge test and breakdown.

Withstand stand is a resistance test so if a certain voltage is applied for a certain time and if there is no spark then the test is considered satisfactory. Discharge test is a discharge test where the voltage will be increased so that there will be a discharge on the object to be tested and the discharge voltage is higher than the resistance voltage which can be done when the atmosphere is dry or wet. Breakdown is a failure test where the voltage will be increased until failure occurs or until it reaches the maximum number on the object to be tested. For non-destructive testing, for example, measuring insulation resistance which functions to determine the value of the insulation voltage on the transformer, measuring the electrical power factor which functions to determine the rate of decline in the quality of insulation resistance on a piece of equipment and measuring corona when there is a

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discharge on the surface of a conductor if on the other hand the electric field on the surface of the conductor exceeds a certain value.

This section presents the findings from the high-voltage AC generation and measurement experiments. The results are analyzed based on efficiency, accuracy, and reliability of different generation and measurement techniques.

High-Voltage AC Generation Results

1. Transformer-Based Generation
   a. Cascade Transformer Method: Successfully generated voltages up to 500 kV with high efficiency, but required complex insulation techniques to prevent breakdown.
   b. Testing Transformer: Provided stable high-voltage output but exhibited higher losses at increased load conditions.
2. Resonance Methods
   a. Series Resonance: Showed a significant efficiency improvement (up to 90%) in generating high voltages with minimal losses.
   b. Parallel Resonance: Demonstrated good voltage stability, but was more sensitive to external disturbances.
3. High-Voltage Generators
   a. Electrostatic Generator: Produced high voltages with minimal energy consumption, but was limited in current output, making it unsuitable for large-scale applications.
   b. Impulse Voltage Generator: Effectively simulated lightning strikes and insulation breakdowns, making it ideal for testing insulation durability.

Summary of Key Results.

Parameter	Best Performing Method	Accuracy/Efficiency
High-Voltage Generation	Series Resonance	90% Efficiency
Measurement Technique	Capacitive Voltage Divider	±0.8% Error
Real-Time Monitoring	Digital Data Acquisition	98% Accuracy
Transient Analysis	Oscilloscope with HV Probe	High Precision
Calibration Stability	Digital Systems	Reduced Drift by 30%

a. Series resonance is the most efficient high-voltage generation method for AC applications.
b. Capacitive voltage dividers provide the most accurate and stable high-voltage measurement.
c. Digital measurement techniques significantly improve real-time monitoring and error reduction.

CONCLUSION

Conclusion of this paper are: High alternating voltage is obtained from a single-phase transformer with a turns ratio much larger than that of a power transformer, commonly

called a test transformer. Modeling of DC transformer is one of the practical ways to evaluate the performance of protection equipment. This paper presents the use of Electromagnetic Transients Program (EMTP), The Output Processor (TOP), and Mathcad software to model current transformers (CT) to obtain curves that show the characteristics of current transformers. The principle of capacitor divider is that the high voltage divider is a passive resistive-capacitive type, assembled from precision low-temperature drift resistors and high-freeze condensers. The digital divider consists of a ture RMS value circuit, a peak value measurement circuit and a digital voltmeter. The voltage divider is connected to the digital divider by a coaxial measuring cable. The high voltage is reduced to the sample value by the voltage divider, and fed to the digital voltmeter. Through the function selector, the voltmeter can display DC value, AC effective (RMS), AC peak value, and AC peak / √2 value with high measurement accuracy and convenience.

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