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The Corona Losses Detection Analysis at High Voltage

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Abstract— The increasing use and use of electricity in Indonesia causes the potential for greater losses in the transmission and distribution system. This causes many problems that arise, one of which is the corona in the transmission and distribution system. Corona mapping can only be detected through several ways, namely sound, light and distinctive smell. In this thesis, the aim is to detect the corona with the characteristics of a distinctive sense of smell, then the results of the detection are compared with the calculated corona losses. This distinctive odor is the smell of ozone which is produced from ionization at high voltage with the surrounding air, namely oxygen to form ozone molecules that are not permanent. The metal electrode to be tested is the copper tip metal. After testing the voltage of the appearance of the corona occurs at 7kV, high voltage when testing the tip of the copper metal point at a voltage of 21 kV is greater than the corona losses. The greater the voltage, the greater the corona losses generated.

Keyword: Corona discharge, high voltage, ozone.

INTRODUCTION

To meet all electricity needs in Indonesia in 2020 it will reach 1,885 TWh. PLN built a 500 KV SUTET transmission, the total installed air lines in 2020 in Indonesia is 5,227 SU. Which traverses residential areas, fields and rice fields and others. The problem of the electric power system, especially in transmission with extra high voltage, the first is the issue of wire insulation, at extra high voltage the effect of surge circuit is more emphasized on the insulation of the wire used. The second is the issue of equipment isolation, namely the protection of equipment against the danger of surges caused by lightning strikes. then the third problem is the increasing emergence of corona symptoms which result in, among others, radio interference (radio interference), losses on transmission lines (corona losses).

In the corona discharge, which is often called the corona glow discharge plasma, between the two electrodes there are two regions, namely: the ionization region and the drift region. The ionization region is located around the active electrode area while the flow region is a region other than the ionization region between the two electrodes. An active electrode is an electrode that has a high electric field intensity. For the point-to-plane configuration of the plasma, the corona glow discharge occurs at the active electrode, namely the point electrode. The corona glow discharge plasma that occurs can be called a positive corona or a negative corona. This type of corona discharge is determined by the polarity of the voltage applied to the active electrode (Muhammad N, 2011). To produce ozone, one molecule of diatomic oxygen must be separated. The oxygen free radicals are then free to react with other diatomic oxygen to form triatomic ozone molecules. Trying to break the bonds of O-O takes a lot of energy. One of them is the corona discharge method, to initiate the formation of oxygen free radicals, thereby producing ozone (Adi L, 2009).

Corona detection research uses a UV camera as an arc measurement detection when the corona occurs at the stage of the release of purple light seeing from the point where the corona light is visible on the insulator. UV cameras are used for maintenance activities at high voltage. relationship with direct maintenance, when the corona value reaches above 20,000 counts/minute, it is not recommended for the direct maintenance team (PDKB) to do online cleaning because based on experience when maintenance or cleaning is carried out, there are sparks that endanger the safety of the online maintenance team. He concluded that examination using a UV camera is useful for preventing interference caused by pollutants (Rizally, Ahmad. T, & Nurdin, 2020).

The study uses a sound method approach using a microphone sensor that is brought closer to the source of the point of occurrence of the corona by utilizing the hissing noise from the appearance of the corona at a voltage of 20KV to 35KV. Comparison of the sound produced in dB with the voltage, Sound at a sampling frequency of 50, 100, 150, 250, 300, 350 Hz. From the six sampling frequencies, the highest results were obtained at a voltage of 35kV with a loud sound of around -21 dB to -22 dB at a frequency of 50 Hz (Achmad B K 2006). Research with the sense of smell has also been carried out using the measurement method with the ozone monitoring PTFF tube where ozone flows through the PTFF tube. the tested voltage is 7 KV to 9 KV with copper conducting end material (CU). ozone that can be produced is 7KV ozone maximum 11 ppb, 8 KV ozone maximum 17 ppb, 9KV with maximum ozone of 20 ppb. PTFF tube is placed as far as 12 cm from the point of occurrence of corona (Hassan, Kang, & G, 2019).

Therefore, this study tries to experiment using an ozone sensor programmed with an Arduino microcontroller with a distance of 10 cm from the point of occurrence of the corona in the cubicle model, with a voltage range of 6.7 KV to 21 KV. The distance from the electrode to the ground is 3.5 cm. The purpose of this study was to obtain the characteristics of ozone due to air ionization at high voltage and then the results were compared with the calculation of corona losses.

METHOD

To obtain the characteristics of ozone generated by the corona, a test was carried out by generating a high voltage in a miniature cubicle. The use of high voltage causes corona. When the corona is first detected, there will be ozone gas produced from the breakdown of oxygen into ozone. The increased voltage reaches a value of 21 KV and is recorded through excel software. After recording the characteristic data of the ozone produced, it is analyzed. Sensors that detect ozone are programmed through the Arduino IDE software. The corona discharge test starts from the beginning of the purple light, then a hissing sound is heard which is followed by partial discharge and ends with the flashing off.

The placement of the sensor is parallel to the point of occurrence of the corona with a distance of 10 mm and the distance between the electrodes to the plane point is 35 mm, the placement of the schematic in Figure 3.1 is in a miniature cubicle. The test was carried out at the High Voltage Laboratory Electric Power and Energy Studies (EPES) of the Department of Electrical Engineering, University of Indonesia. The following is a figure 1 of the schematic of the position of the end of the conductor that will be tested in this study.

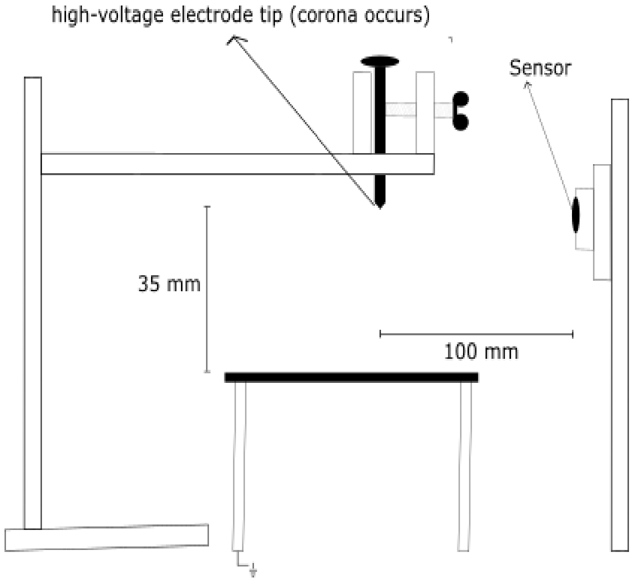

Figure 1. Corona point and sensor position schematic

When alternating current (AC) flows through a conductor from a transmission line with the distance between conductors to other conductors greater than the diameter of the conductor itself, the air around the conductor consisting of ions experiences dielectric stress. When the voltage in the cubicle line is still low, the dielectric stress experienced by the air around the conductor is not sufficient to ionize the air around the conductor. But when the voltage in the cubicle line is increased beyond a threshold value known as the critical disruptive voltage point, the air around the conductor experiences a high enough stress so that ionization occurs against the ions contained in the air. Corona discharge in electrical grids such as cubicles causes:

1) Power losses
2) Noise
3) Electromagnetic interference
4) Smell

$$E_v = M_0 \times g_v \times r \times ln\ \frac{S}{r} \tag{1}$$

$$gv = g_0 \; \delta \; \left(1 + \frac{0{,}301}{\sqrt{\delta \; r}}\right) \qquad (2)$$

Where:
Ev = Corona generation voltage (kV)
Mo = Conductor/electrode roughness constant
gv = Critical visual electric field (kV/cm)
g0 = Destructive electric field (kV/cm)
r = Radius of conductor (cm)
S = Distance between conductor wires (cm)
δ = Density factor or air density factor

g0 is the ability of air to withstand the working voltage, as a reference for the potential gradient, the breakdown voltage can be used to find the visual gradient of the damage. Which is used to find the voltage of the appearance of the corona, where the corona will appear if the working voltage of the system (E) exceeds the voltage of the appearance of the corona (Ev) (Achmad B K 2006). Then you can get the corona losses:

$$P_{loss} = 241\,(f + 25)\sqrt{\frac{r}{S}}\,(E_n - E_v)^2 \times 10^{-5} \qquad (3)$$

Where:
P_loss = Power losses due to corona (kW)
En = Working voltage on the phase to neutral conductor (kV)
Ev = Corona generation voltage (kV)
f = Working frequency on conductor (Hz)

According to the Japanese Industrial Standard (JIS) C 3801 and the Japanese Electrotechnical Committee (JEC) Standard 106, it states that for various types of equipment a certain fire jump voltage applies in standard conditions, the standard conditions are:

1) Barometer pressure = 760 mm Hg (1013 mbar)
2) Surrounding temperature = 20 °C
3) Absolute Humidity = 11 gram/m^3

The air state pressure always affects the dry fire voltage jump, to change the test with standard normalization. So we need equation that can change the test results into standards. This will test whether to be tested according to the standard or not, the equation used in correcting the test for pressure and temperature is:

$$Vs = \frac{Vb}{d} \qquad (4)$$

$$d = \frac{b_B}{760} \times \frac{273 + 20}{273 + t_B} = \frac{0.386\, b_B}{273 + t_B} \qquad (5)$$

Where:
Vs = Standard state voltage (KV)
Vb = Test state voltage (KV)
d = Relative air density
bB = Air pressure at the time of testing (mm Hg)
tB = Temperature at the time of testing (°C)

To find out the bB air pressure when testing can be used the equation:

$$b_B = \left(Pu - \frac{h}{100}\right) cm\; Hg \qquad (6)$$

Where:
Pu = Atmospheric pressure above sea level (76 cm Hg)
h = Height of test site (m)*
bB = Test air pressure (cm Hg)

* Labs. High Voltage Universitas Indonesia (EPES) 90 m altitude (Source: GPS Tools app)

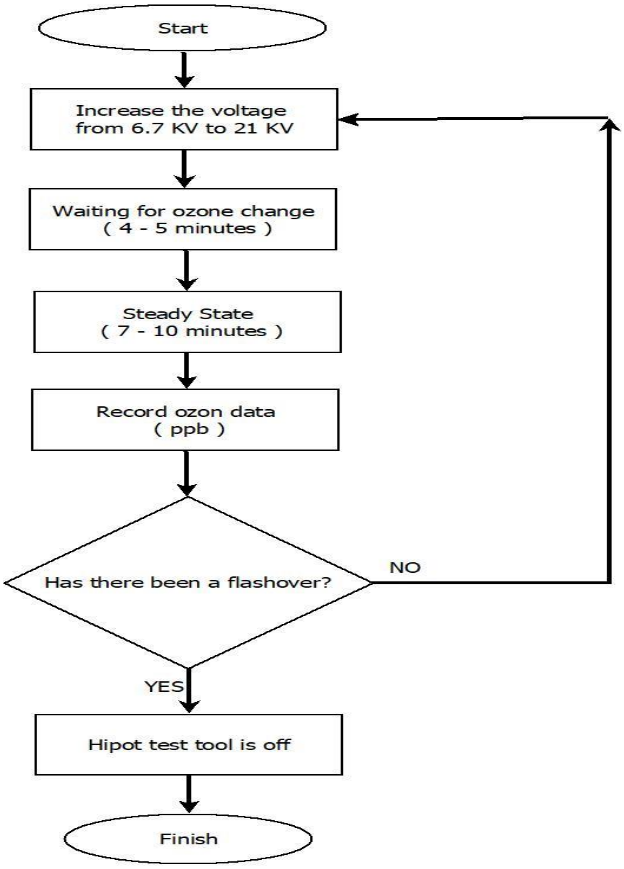

Figure 2. Data colletion process

Figur 2 The data collection process starts from the operation of the Hipot test, the voltage is increased by 6.7 KV to 21 KV slowly until there is a change in sensor readings, then the voltage is selected to be 6.7 KV; 7.5 KV; 9.5 KV; 10.5 KV; 11.4 KV; 12.7 KV; 13.5 KV; 14.6 KV; 15.6 KV; 16.4 KV; 17.7 KV; 18.4 KV; 19.4 KV; 20.1 KV; 21.3 KV. The voltage is increased slowly, until the ozone concentration changes with a waiting time of about 4-5 minutes. Then, the reading time is in steady state 7-10 minutes, then recorded with the highest concentration value in PPB units. After being noted, if there is no flash over, the voltage is increased according to the selected voltage and is repeated until the voltage flashes, i.e. the voltage jumps to the iron plate area or to ground which causes the hipot test tool to off.

In research testing equipment, several tools and materials are used to support research. This research starts from testing the corona discharge in the cubicle until a flashover occurs. Tools and materials are generally divided into two parts, namely hardware and software for data retrieval and data processing. Research tools and materials used are as follows:

1) Hipot Test 100 KV
2) High Voltage Transformator 200 V/100 KV
3) Digital meter Hipot Test
4) Connecting rod
5) Miniature cubicle
6) Copper electrode
7) Voltage transformer
8) Ozon sensor
9) Personal Computer with software Arduino IDE dan Microsoft Office

RESULT

Research testing uses a copper conductor by providing a gradual voltage and then the sensor output is taken from the highest value produced, with sensor readings every 3 seconds. If there is a voltage difference with the previous experimental test, which is ± 0.1 KV, the following is the result of the highest value generated.

In Figure 3 the highest value of ozone concentration is at the highest voltage, this is also because the high voltage produces a large amount of energy to be able to break down oxygen. Choose a copper conductor because it is the most widely used conductor in electrical conductors. This first experiment with a distance of 35 mm from ground flash over occurred about 4-5 minutes after the voltage was increased to 21.3 KV. This causes the ozone concentration to decrease, the ozone decomposes again into oxygen in the air. The negative corona effect has a very clear hissing sound at 13 KV, but initially there is a very low hissing sound at 7 KV.

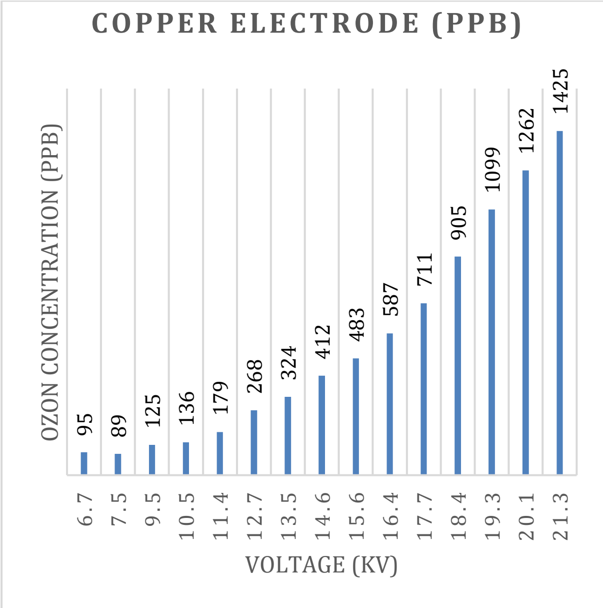

Figure 3. Graphic copper electrode concentration ozon maximum

Great energy and large relative mass of atoms result in a high flashover voltage with the same distance and the same conductor diameter. The flashover voltage forms a plasma that will ionize the oxygen around the plasma, this plasma is like an electrical conductor that can separate oxygen to produce ozone. This ionization property of ozone is only temporary, because if it is not given a voltage or a large electric charge, the oxygen that forms ozone will return to oxygen again.

From the corona symptoms that occur there are losses due to the corona, therefore they can be analyzed and calculated. Air pressure Testing & relative air density factor Equation (4) and (5):

$$b_B = \left(76 - \frac{90}{100}\right) cm\ Hg$$

= 75.1 cm Hg = 751 mm Hg

$$d = \frac{0.386 \quad 751}{273 + \ 27}$$

= 0.966

Then from the test by increasing the voltage gradually a distance of 3.5 cm from the ground electrode and the diameter of the conductor is 3 mm. In this test, symptoms of corona appear (Ev) with a hissing sound at 7 KV, the value of Ev = 7 KV. In this case δ = d, because it is a factor of air density. Then the corona losses obtained from this test using equation (3) obtained the corona losses graphic equation:

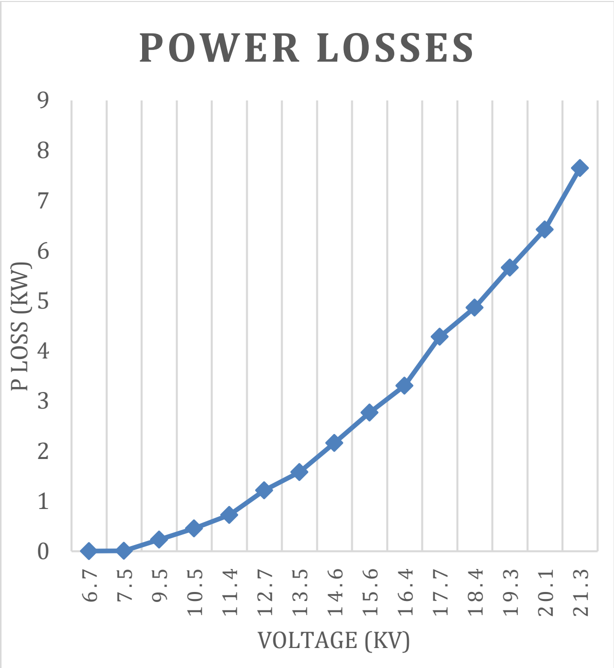

Figure 4. Corona losses

Figure 4 is the Corona losses with the corona emergence voltage at 7 KV the higher the phase-to-neutral voltage is increased, the higher the corona losses generated. From a voltage of 6.7 – 7.5 KV there is no big corona loss. When the voltage is increased and there is a high hissing sound accompanied by a purple light of corona plasma at a voltage of 13.5 KV, the hissing sound gets higher up to 21.3 KV. In this test the losses from the corona are exponential. In losses due to the hissing effect corona with a high tone sound intensity in a closed room or cubicle model this hissing effect is directly proportional to the losses caused.

DISCUSSION

The increasing development of detection technology is carried out on the basis of the impact of the resulting losses. Various approaches have been carried out by technology researchers with the aim of simplifying the lives of many people. The development of smart network technology has transformed progress in real-time monitored networks. This research can be further developed using the basis of the Internet of Things (IoT) for application to smart grid.

Performance This detection sensor uses the working principle of amperometry. Amperometry is a voltammetric method by applying a constant voltage to the working electrode, and the current is measured as a function of time. Literally, amperometry is the measurement of current. In electroanalytical chemistry, the concentration of the analyte determines the value of the current. This method is carried out based on the complete electrolysis of the analyte. In this method, the analyte is oxidized and reduced completely on the surface of the working electrode or reacts completely with the reagent produced by the working electrode. The sensor is surrounded by a measuring substance, which consists of a gas or a liquid solution. Furthermore, the sensor is encapsulated by a combination of membrane material and an outdoor surface around the electrolyte. A constant voltage between the working and reference electrodes is applied over time. Ozone penetrates through the membrane and causes a reduction reaction at the working electrode. The resulting current is measured at the working electrode. From the measured current value, the concentration is calculated. Between the working electrode and the reference electrode, a constant voltage is supplied. The current, measured at the working electrode, changes when ozone is present in the measuring substance (Lisa Farmer et al, 2020).

Differences in sensor readings may be affected by ambient air condition factors such as humidity and temperature which may vary. So the readings will continue to be dynamic, which means that each reading will not have to be the same as the previous condition. Research is 10 cm away from the occurrence, Figure 5 is another study that is 12 cm from the point of occurrence of the corona with the PTFF Tube sensor method. This research allows a much more accurate approach. The following is a picture of another research using PTFF Tube and the results of the research.

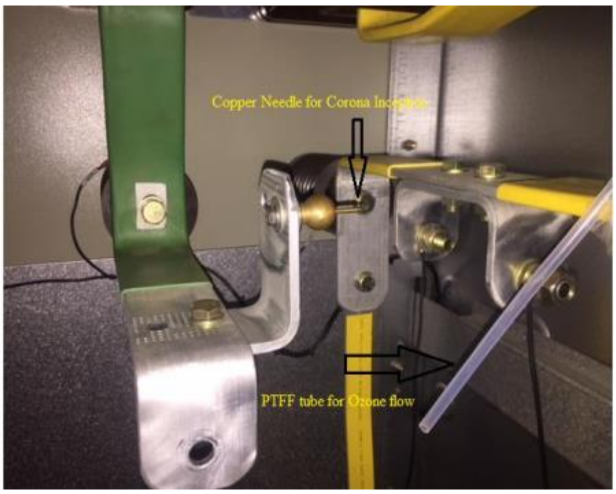

Figure 5. Detection Corona with PTFF tube monitor ozone

Table 1. Measurement results of copper conductor with PTFF tube sensor (Javed Hassan et al, 2019)

Material	*Applied Voltage (KV)*	*Average ozone (ppb)*	*Max. Ozone (ppb)*
Copper (CU)	7	9.8	11
	8	14	17
	9	16	20

CONCLUSION

The amount of corona losses can be detected with an ozone sensor but cannot be a reference in determining how big the value is because ozone ionization affects air conditions. The maximum ozone level at 21 KV is 1425 ppb or if the calculation results are matched with corona losses, it is 7.65 KW. While the lowest after the corona was obtained from testing at a voltage of 9.5 KV with a maximum ozone of 125 pbb and the results of the calculation of corona losses at a voltage of 9.5 KV of 0.233 KW. The results of the measurement and calculation graph modeling show exponential properties, meaning that if the voltage is increased continuously, there will be even greater corona losses. Ozone ionization occurs because of the high voltage that ionizes the surrounding air. If the high voltage disappears then the ozone will return to oxygen. In this study, at first there was a loud noise at 7 KV with a small sound, then purple light occurred at 13.5 KV.

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