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Understanding the Phenomenon of Corona Discharge near Power Lines

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Abstract: The phenomenon of ionisation of air surrounding the conductor resulting in luminous glow with hissing noise is known as the corona effect. Electrical engineering finds it challenging to reduce this effect and control its undesired energy loss. In the literature there are plenty of papers on corona, in order to advance the research on this subject we needs up to date information on the current situation. As such is lacking at present, A current literature review of this phenomenon is reffered for more detail.

Keywords: Corona phenomena, discharge, luminous glow.

1. INTRODUCTION

Corona is an electrostatic discharge phenomenon which occurs when the electric field exceeds a certain critical value causing the surrounding air ionize (1)

This phenomenon occurs when the electrostatic field across the transmission line conductors produces the condition of potential gradient. when the potential gradient at the conductor surface reaches the value of 30kV/cm at normal pressure and temperature The air gets ionized (2).

Air acts as a dielectric medium between the transmission lines. Meaning that, it is an insulator between the current carrying conductors (3).

If the voltage induces between the conductor is of alternating nature then the charging current flows between the conductors. And this charging conductor increases the voltage of the transmission line. The electric field intensity also increases because of the charging current. If the intensity of the electric field is less than 30kV, the current induces between the conductor is neglected. But if the voltage rise beyond the 30kv then the air between the conductors becomes charge and they start conducting. The sparking occurs between the conductors till the complete breakdown of the insulation properties of conductors takes place (4).

2. CORONA FORMATION THEORY

The air contains many free electrons and ions. these ions and free electrons experience forced upon them when an electric field intensity establishes between the conductors,. Due to this effect, the ions and free electrons get accelerated and moved in the opposite direction (2). The mechanism of recombination of ionized oxygen atoms, resulting from the discharge process, and oxygen molecules in the air is exploited for the production of ozone (O3) on a utility-scale through ozone generators operated by corona technology (4). which need to trigger efficient discharges in a controlled environment in order to optimize ozone production.

The charged particles during their movement crash with one another and with the very slow moving uncharged molecules as well. Therefore, the number of charged particles promptly increase. This increase the air conductivity between the conductors and a breakdown occurs. Thus, the arc establishes between the conductors (5).

3. CALCULATION OF LOSSES

The percentage of power loss in corona depends on the voltage of the system. According to previous published research proposed an equation for corona (6), from which equation [1] is derived for the total amount of power loss in a wire due to corona effect

$$P = \frac{k_0}{k_d}(f + 25)\sqrt{\frac{r}{d}}[V_0 - g_0 k_i r k_d \ln\left(\frac{d}{r}\right)]^2 \times 10^{-5}\, {kW}/{km}$$

Equation [1]

Where r is conductor radius, d is conductor spacing, k_0 is fixed constant, k_{d} is normalized air density factor, f is frequency V_0 is line voltage to neutral, Ki is wire irregularity factor and g_0 is disruptive gradient in air.

The research reported in (7) shows how to calculate corona loss as mentioned in equation [2] that corona loss is dependent on the frequency.

$$p = 241 \times 10^{-5} \frac{(f+25)}{\delta} \sqrt{\frac{r}{d}(U_p - U_0)^2}\ \ {kW}/{km}$$

Equation [2]

Where is f frequency supply (Hz), U_0 is critical disruptive voltage, r is conductor radius, d is conductor spacing,U_P is operating voltage and δ is the correction factor of air density.

4. FACTORS AFFECTING CORONA

5.1 Effect of supply voltage, If the supply voltage is high corona loss is higher in the lines. In low-voltage transmission lines, the corona is negligible, due to the insufficient electric field to maintain ionization.

5.2 The condition of conductor surface, If the conductor is smooth, the electric field will be more uniform as compared to the rough surface. The roughness of conductor is caused by the deposition of dirt, dust and by scratching. Thus, rough line decreases the corona loss in the transmission lines.

5.3 Air Density Factor, The corona loss in inversely proportional to air density factor, which mean that corona loss, increase with the decrease in density of air (6).

5.4 Effect of system voltage, Electric field intensity in the space around the conductors depends on the potential difference between the conductors. If the potential difference is high, electric field intensity is also very high, and hence corona is also high. Corona loss, increase with the increase in the voltage.

5.5 The spacing between conductors, as the spacee between two conductors is much more as compared to the diameter of the conductor than the corona loss occurs in the conductor. If the distance between them is more than certain limits, the dielectric medium between them get decreases and the corona loss also reduces(8).

corona discharge has undesirable effects such as the glow appear across the conductor which shows the power loss occur on it, the audio noise occurs because of the corona effect which causes the power loss on the conductor, the vibration of conductor occurs because of corona effect. the corona effect result in ozone generation which the cause corrosive of the conductor, the corona power loss reduces the efficency of the line (9).

5. CORONA PREVENTION TECHNICS

Corona decreases the efficiency of transmission lines. therefore, it is mandatory to decrease corona effect. Methods developed during the last decades to minimize corona effects, have their own limitations. This study discusses in detail these methods with the view of providing information to develop new methodologies to avoid the drawbacks of present corona prevention techniques.

It has been seen that intense **corona effects** are observed at a working voltage of 33 kV or above. Therefore, careful design should be made to avoid corona on the sub-stations or bus-bars rated for 33kV and higher voltages otherwise highly ionised air may cause flash-over in the insulators or between the phases, resulting in considerable damage to the equipment.

Corona can be prevented or minimized by the increasing of critical extinction voltage. The rate of critical voltage should be 150% of the maximum circuit voltage. The voltage of the line – Voltage of transmission lines is fixed by economic considerations (10). To increase the disruptive voltage the spacing of the conductors should be increased, If the space between conductors increases, then the voltage drops between them also increases due to increase in inductive reactance (11). However, spacing cannot be increased too much otherwise the cost of supporting structure such as bigger cross arms and supports may increase to a considerable extent.

The conductor diameter is increased by bundled conductors so that the corona loss is decreased. One more method is to reduce the electric field strength for a given voltage difference, that can be achieved by the increasing of the conductor diameter. Hollow conductors would tackle the problem in EHV lines. Increasing of the space between the conductors of a transmission line is also a method to prevent corona, however there is a limitations to this method due to restriction of space in the tower and cost. Sharp protrusions, edges and cuts in the conductors should be avoided as in such case the localized electric fields can suddenly be increased so that corona generation at lower inception voltages is promoted (12).

Increasing the number of conductors in a bundle reduces the effects of corona discharge because its reduces the electric field strength near the conductors. Conductor bundling also reduces the high voltage gradient on the conductor for extra high voltage range above 230kV (13). Some of bundled conductors advantages are reduced line reactance, reduced Radio Interference, However, the technique has its limitations on the system. Bundling increases ice and wind loading and also needs greater clearance with nearby structures. Charging kVA is another characteristic that is increased by bundling and it would be a drawback at light loads. To implement the bundling, spacers also must be used in order to separate the conductors from each other. There is a rotational part inside these spacers that can be blocked during the cold weather.

Metallic rings are fixed at the end of bushings and insulator strings. The metallic ring distributes the charge across a wider area due to its smooth round shape which significantly reduce the potential gradient at the surface of the conductor below **critical disruptive voltage** and thus prevents corona discharge (14).

Wherever the conductor curvature is sharp, the intensity of the electric field is high at the point. Therefore, sharp points, are the areas where corona discharge occurs first. Corona Rings are employed at the terminals of very high voltage equipment to attenuate electric fields (15).

Many methods have been used to reduce corona losses under various conditions. However, many of these techniques, which have reasonable effectiveness in suppressing corona, on the other hand give rise to some undesired effects to the systems for which they have been employed.

6. CONCLUSION

Understanding corona generation and effects of corona on other systems, requires a remote sensing of corona.

The physics and chemistry nature of corona should clearly be understood to improve the techniques of reducing corona and this can be done by developing more accurate and sensitive corona detecting and monitoring techniques. Having a good knowledge of corona discharge will be the key for engineers to develop proper techniques to mitigate adverse effects of such (13).

Corona is an important factor in power electric systems to ensure both reduction in energy losses and increment in system safety. Corona may also cause nuisance in signal systems and have threat to the signal integrity of data communication. There are several techniques to decrease the phenomenon to some extent. Bundling, increasing the conductor diameter, using hollow conductors and increasing the space between transmission line conductors are some of present day methods. All these techniques have the goal to minimize the effects of corona..

Although, the techniques of corona reduction and prevention are reasonably good at present, it may be not adequate for the future due the rapid increment of power demand. Also, there are some drawbacks of these applied methods that have to be overcome in the future. To solve the problem, designers should have a good understanding of the nature and other properties of corona.

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