Study on Negative Effects of Corona & its Consequences on Polymer Insulators and Remedial Action

Prepared by Mr. Pankaj Kakoti (Manager-Products)
& Mr. Naushad Ansari (Sr. Product Engineer)
Taurus Powertronics, Bangalore

Abstract

In early 1960's, first modern non-ceramic insulator (NCI) was introduced. They are often also called polymeric insulators, with advantages over traditional counterparts of low weight, vandalism resistance, hydrophobic surface properties, etc., showing a steadily increasing share of the insulator market.

In the struggle on the way of polymeric insulators becoming broadly accepted on the market as an alternative solution to the traditional porcelain and glass counterparts, an adequate standard has not existed until now. As a result, CIGRE working group concentrated during recent years on defining the physical parameters important for the use of polymeric materials in outdoor insulation and on checking if relevant test methods are available today. Twelve properties have been identified, among which the resistance to corona and ozone was listed as being of great importance.

In this paper we will discuss about the negative effects of Corona, its Consequences on Polymer/Composite Insulators & methodology to detect Corona & remedial actions to arrest the problems on the Insulators.

Introduction

What is Composite/Polymer Insulator?

Composite insulators are designed in such that they offer a very high surface leakage resistance. This structure has a fiber reinforced rod as the main strength member, which is covered on outside by a polymeric rubber. The whole structure is then fitted with two end fittings to make a complete insulator in one assembly. This is the reason they are called composite insulators since the complete insulator is one unit as shown in Fig .1

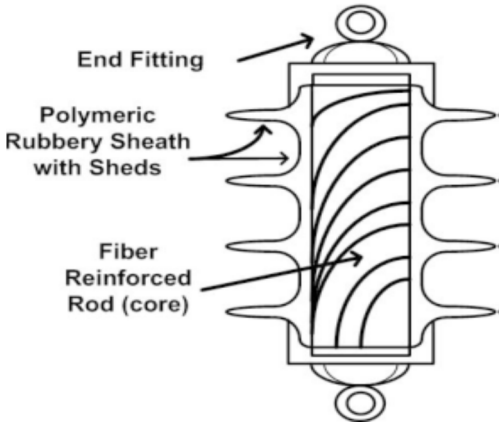


Fig. 1. Polymeric insulator with rubber sheds

The rubber covering the rod is not straight but moulded to give a shape of what is called a weather shed. Many types of polymeric rubber have been used by different manufacturers of polymeric insulators. But since all them belong to rubber family, so they have good leakage current suppression ability. The beautiful feature of these insulators is their uniform distribution of electric field and, hence, the stress over their surface. This is due to the fact that all insulator surface from energized end to dead end is of same material and moulded in one cast.

Most commonly used polymeric materials for the housings in outdoor environments are nowadays silicone rubber (SIR), ethylene-propylene-diene monomer (EPDM) based rubber, ethylene vinyl acetate (EVA) elastomeric materials and epoxies (EP). End-fittings are made of metal and the most common materials are cast, forged or machined Aluminium and forged iron or steel

The properties that make the use of polymeric materials in high voltage outdoor environments advantageous over traditional glass and porcelain are:

- High surface and bulk resistivity,
- Fracture toughness over a wide temperature range,
- Hydrophobicity (water repellence) and the ability of its recovery (mainly for SIR).
- Better insulating properties (improved AC and lightning impulse (LI) strength, hydrophobic surface, less leakage currents),

- Need for less maintenance (no cleaning required) thanks to the improved contamination resistance, and
- Non-brittle construction providing improved resistance to vandalism, and lower risk for shipping or handling damages.

What is Corona?
The corona is a weak luminous discharge that usually takes place in a strongly non-homogeneous electric field at/or near atmospheric pressure due to air ionization. This process is accompanied by excitation of Nitrogen molecules and by chemical reactions, leading to:

- Production of corrosive chemicals like: Ozone and Nitrogen Oxides. At high humidity the oxides will create Nitric acid – a very corrosive material.
- Radio interference, Audio noise, Emission of UV radiation

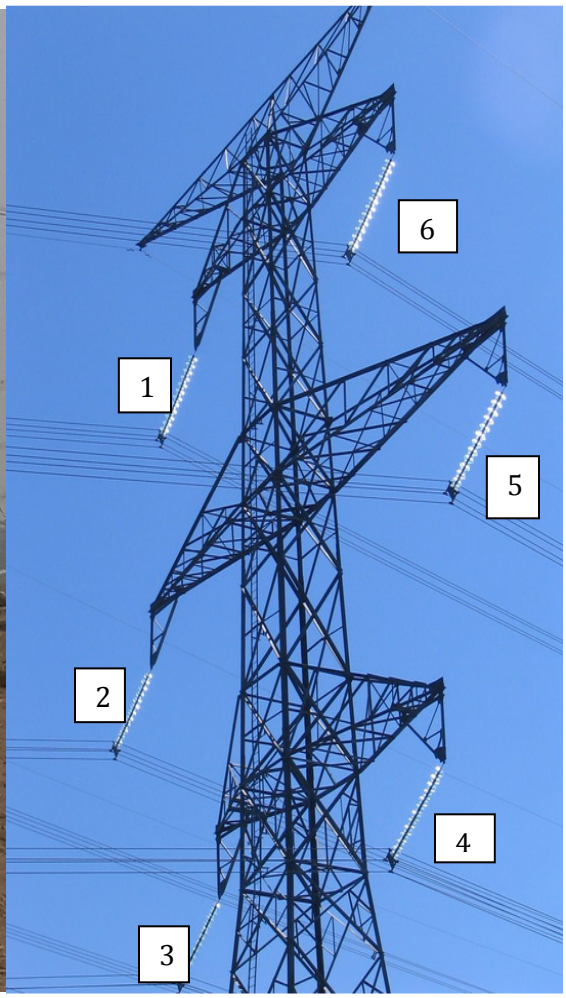
Negative Effects of Corona discharges on polymeric insulators

Under the action of corona, surfaces of insulator housings are simultaneously subjected to a mixture of energetic and reactive species as well as radiations, e.g. electrons, ions, ozone, UV and high temperature. Diverse chemical reactions take place during the exposure. The most important ones include
(i) An increase of the oxygen content at the surface by formation of silanol and hydroxyl groups
(ii) Oxidative cross-linking, and
(iii) Degradation of the polymer network structure resulting in the formation of low molecular mass compounds.
All these, by modifying material surface, yield changes of mechanical and electrical properties of the housing.

Corona discharge as an ageing factor to polymeric insulators has long been recognized. Generally, there exist two main sources of corona discharges on the surface of composite polymeric insulators in the field

i) Poorly designed insulator hardware (including corona rings): This source acts locally and may promote ageing of insulator housing, even at dry conditions. However, proper hardware design of field grading devices allows avoiding it effectively
ii) Presence of water droplets on insulator housing surface: Here unavoidable presence of water droplets on insulator surfaces acts as a discrete and distributed source of corona that yields ageing at different insulator parts. Discoloration, erosion, and sheath/shed cutting were reported among the effects. Such damages can be attributed to the action of energetic ions and reactive gases from the discharge, ozone and nitrogen oxides, and possibly UV radiation.

Testing Methodology with OFIL Daycor Corona Camera



1. Point the camera to the upper pole insulator (1)
2. Scan the insulator from the “hot end” to the “cold end”
3. Scan the insulators from 1 to 6, 2 to 5 & 3 to 4
4. If you find corona, record a video clip
5. Then, scan spacers, connectors and conductors

Video Recording

Follow the operation steps below:

1. Start recording
2. Add voice: location, electrical & environmental conditions etc.
3. Record each component in a separate video clip
4. Decrease the gain to the value that presents clearly the corona source
5. Run the counter at an optimal window size for about 10 sec.
6. Zoom in (visible mode) to see faults clearly
7. End recording

Lab Experiment done by TAURUS at High Voltage Laboratory with OFIL- Corona Camera (Model: Daycor Superb)

Corona scanning activity on composite Insulator was carried out at High Voltage Testing Lab using OFIL-make Corona Camera to observe the different parameters which lead to the formation of Corona on Polymer Insulator.

Setup I: Composite Insulator test without Moisture and with Moisture addition to pollution.

a) Test conducted on Polluted Polymer insulator containing without moisture.

Finding: Corona found at 140 KV near 1st Shed, no corona at string. Attached photo.

b) Test conducted on Polluted Polymer insulator containing with moisture

Under wetting conditions, patches of surface water form in regions of lower hydrophobicity and are separated by dry regions or 'bands' Localized arcs are form, bridging gaps between water patches further stressing the rubber

Findings- Insulator Containing Pollution and Moist was found with High Corona accumulated on sheds of Insulator.

Remarks- Corona over Insulator shed creates a tracking path for discharge that's leads to ageing of the insulators. This is loss of physical properties over time, reducing their dielectric and mechanical withstand. This continuing exposure to corona resulted in cracks in the rubber sheath and degradation of the end fitting seal. Once a seal is compromised, moisture can come into contact with the fiberglass rod, leading to brittle fracture. Brittle fracture is a mechanical failure of the rod due to acid attack and where the fracture exhibits one or more smooth planar surfaces – mainly perpendicular to the axis of the rod and giving the appearance of the rod being cut.

Setup-II: Evaluated for Proper Installation of Grading Ring- Test Conducted with Proper Grading Ring and Missing Grading Ring.

a) Good Insulator with Grading Ring

The Grading ring changes the shape of the electric field, spreading it out in a sense, so that it is no longer strong enough at any point to ionize the air. The role of the Grading ring is to distribute the electric field gradient and lower its maximum values below the corona threshold, preventing the corona discharge.

Finding: Insulator with proper Grading was observed with No corona on insulators with applied Voltage of 150 kV corona found only at the ring.

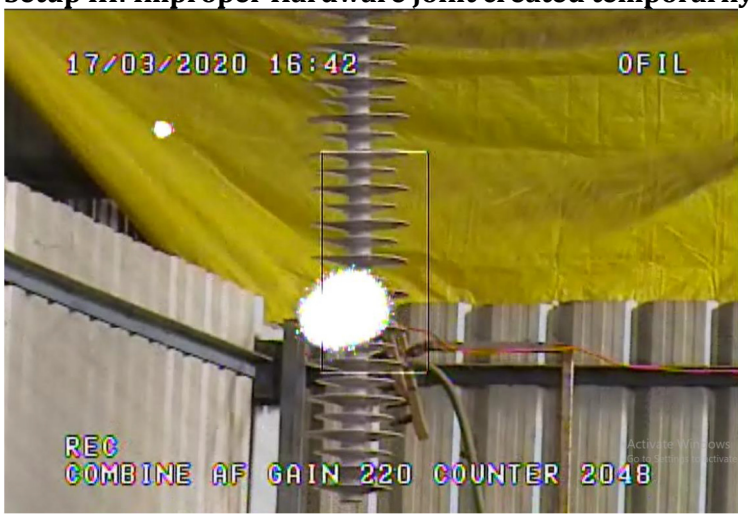
Remarks-If Grading ring is not installed Properly or installed in correct place or uniformly connected all possible corona generated will be on the insulator disc and makes the insulator failure in Long run.

b) Good Insulator tested without Grading Ring:

Finding-Insulator without grading ring was observed with corona at First shed of Insulators with Applied Voltage of 140 kV.

Remarks-In High voltage Transmission Line above 220 kV, Proper Installation of Grading Ring helps to minimize the effect of Corona and Improve the life of Insulators, Improper Installation or Missing of Grading ring could be a major reason for harming the healthiness of Insulator and Transmission Line.

Setup III: Improper Hardware joint created temporarily on Polymer insulator.



In High voltages Transmission line i.e., 220 kV and above if Hardware joints of Insulators are loose, partial discharge will occur due to ionization of air hence followed by electrical arcing. This will make insulator get fail early due to deposition of nitric acid.

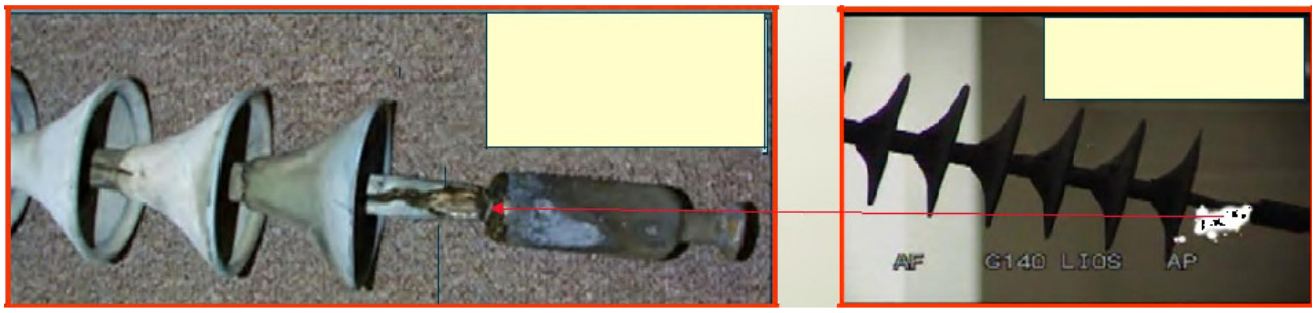
Finding- Corona was found on the Insulators Joint due to improper Hardware Joint Connection.
Remarks –High Corona discharge were observed at 70 kV applied Voltage, with increase in applied voltage Corona intensity will increase resulting breakdown of the Line.

Setup-IV: Test Conducted with Improper Conductor

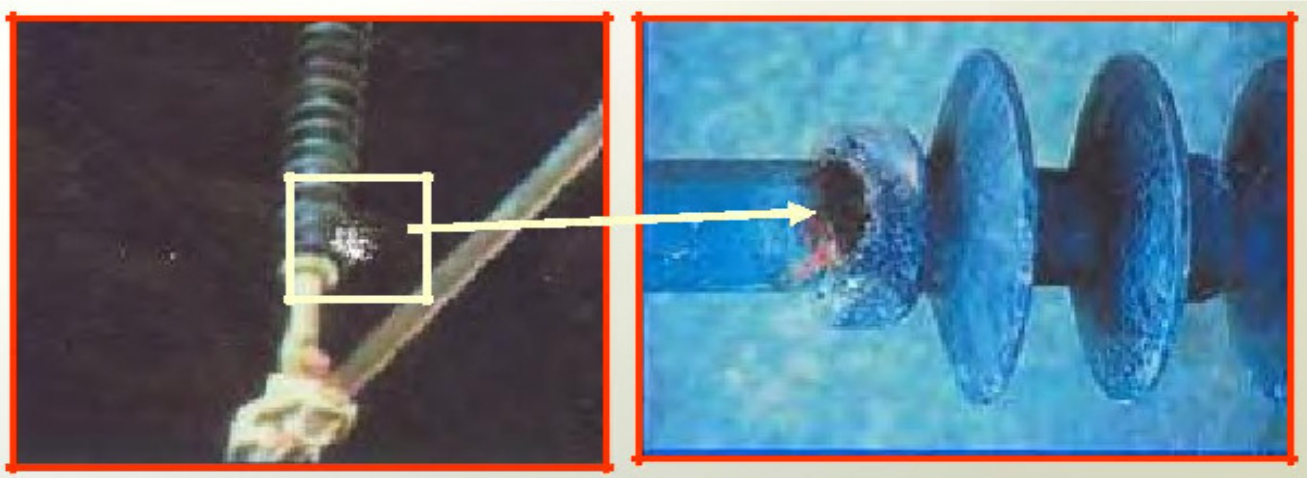
Improper Conductor or Open Conductor strands ionize the air particles leads to create a virtual conductor promoting the power lose, it also enhances the deposition of Nitric acid on conductor.

Findings-High intensity of Corona was found on Conductor with hissing Noise.
Remarks- Bad Conductor or Conductor with open strand promote Corona Discharge, increases loss of physical properties over time, reducing their dielectric and mechanical withstand.

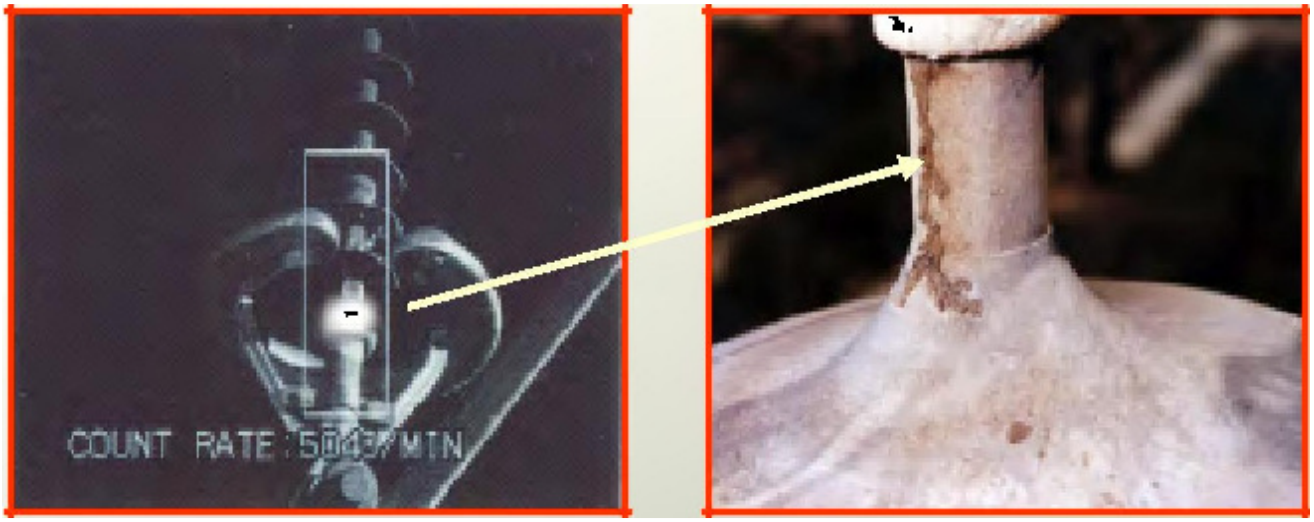
Few Photos from the field: Degradation of Polymer Insulators due to negative effects of Corona:



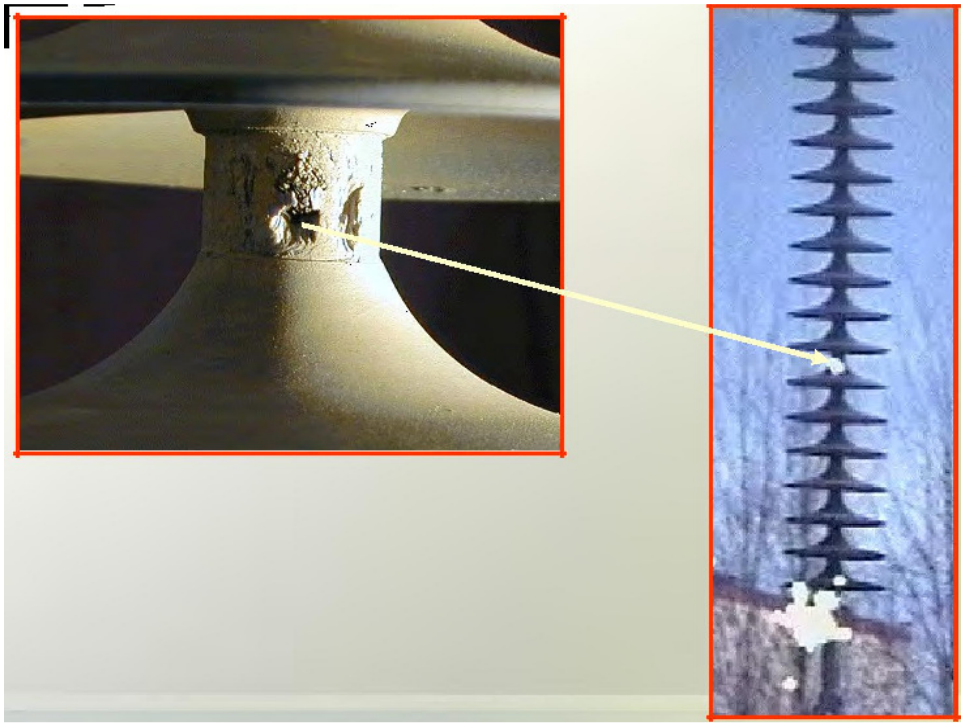
To get to that point is to waste your time & money
Detect this failure in advance to take the right action on time



Failing end fitting Seal



Surface Tracking



Erosion of material on the surface

Recommendations:

To reduce the negative effects of corona following precautions are recommended

1. To reduce corona due to sharp edges, we need to make edges smooth by polishing and applying paint. Also by using metallic caps.
2. To reduce corona due to loose connections and hardware fittings, we need to tighten loose connections and fittings. We need to do periodical check with Corona Camera to avoid Catastrophic Failure of the Transmission Line.
3. To reduce corona on Insulators and insulator hardware, we need to do periodic hot line washing after inspection with **Corona Camera typically with TAURUS OFIL**
4. Regular inspection of line and substation with corona camera is suggested as predictive method to reduce the Corona effects, which may causes damage to the insulators & result into flash over

Conclusion:

From the above experiments & study, we concluded that many phenomena leading to degradation of the electrical and mechanical integrity of polymer insulators, which can be detected by UV inspection for corona and arcing. The Taurus OFIL Corona Camera will detect and locate the source of corona and arcing and indicate the severity of the fault leading to the discharge. The inspection can be carried out by foot patrol, patrol with a camera mounted on a van or airborne patrol to assess the Corona effects on the Insulators & accordingly prioritize the remedial actions to prevent the Catastrophic Failure of the Line.