Corona and its Effects

Evan Mayerhoff
High Voltage Connection, Inc.

Corona is a phenomenon that has the capability for degrading insulators, and causing systems to fail. In this discussion, formulas are provided to calculate the voltage at which corona occurs, and a mention is made of a useful application for corona.

What is Corona?
Corona, also known as partial discharge, is a type of localized emission resulting from transient gaseous ionization in an insulation system when the voltage stress, i.e., voltage gradient, exceeds a critical value.

The ionization is usually localized over only a portion of the distance between the electrodes of the system. Corona can occur within voids in insulators as well as at the conductor/insulator interface.

Corona Inception
Corona inception voltage is the lowest voltage at which continuous corona of specified pulse amplitude occurs as the applied voltage is gradually increased. Corona inception voltage decreases as the frequency of the applied voltage increases.

Corona can occur in applications as low as 300V.

Corona Extinction
Corona extinction voltage is the highest voltage at which continuous corona of specified pulse amplitude no longer occurs as the applied voltage is gradually decreased from above the corona inception value. Thus, once corona starts, the voltage must be decreased to get it to stop.

Corona Detection
Corona can be visible in the form of light, typically a purple glow, as corona generally consists of micro arcs. Darkening the environment can help to visualize the corona. We once attached a camera (set to a long exposure time) to a viewing window in a vacuum chamber to confirm that corona was indeed occurring, and thereby confirming our suspicions.

You can often hear corona hissing or cracking. Thus, stethoscopes or ultrasonic detectors (assuming you can place them in a safe location) can be used to find corona. In addition, you can sometimes smell the presence of ozone that was produced by the corona. (Who said you don’t use all your senses when troubleshooting?)

The corona discharges in insulation systems result in voltage transients. These pulses are superimposed on the applied voltage and may be detected, which is precisely what corona detection equipment looks for. In its most basic form, the following diagram is a corona (or partial discharge) measuring system:

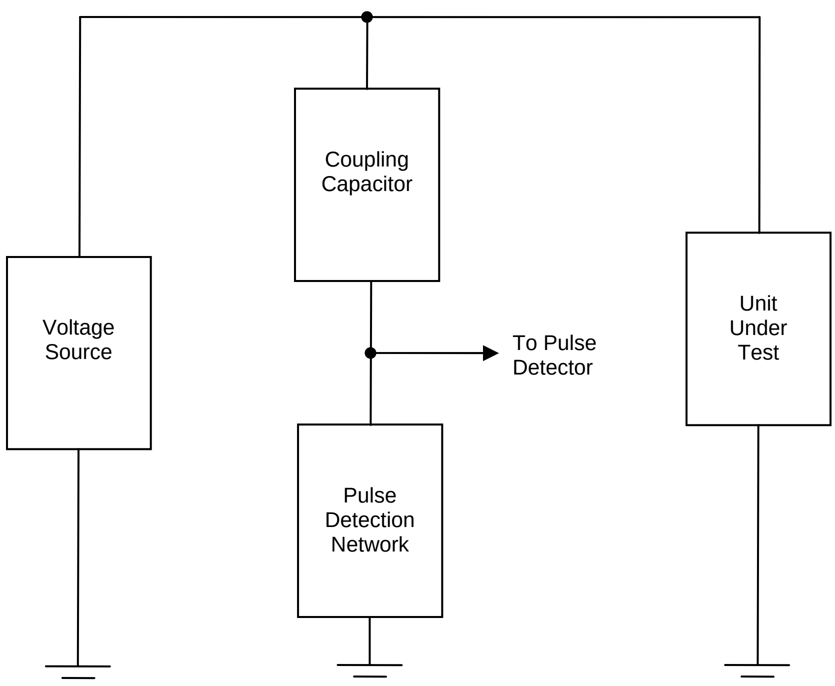

Figure 1. Corona Detection System

It is important that the voltage source and the coupling capacitor exhibit low noise so as not to obscure the corona. In its simplest form the pulse detection network is a resistor monitored by an oscilloscope. Don't dismiss this simple technique as crude, as we once used this method to observe the presence of corona in an improperly terminated high voltage connector, even after a dedicated corona tester failed to find any.

Commercially available corona detectors include electronic types (as above) as well as ultrasonic types. The classic corona measurement systems had been manufactured by the James G. Biddle Company.

Corona Effects

The presence of corona can reduce the reliability of a system by degrading insulation. While corona is a low energy process, over long periods of time, it can substantially degrade insulators, causing a system to fail due to dielectric breakdown. The effects of corona are cumulative and permanent, and failure can occur without warning. Corona causes:

- Light

- Ultraviolet radiation
- Sound (hissing, or cracking as caused by explosive gas expansions)
- Ozone
- Nitric and various other acids
- Salts, sometimes seen as white powder deposits
- Other chemicals, depending on the insulator material
- Mechanical erosion of surfaces by ion bombardment
- Heat (although generally very little, and primarily in the insulator)
- Carbon deposits, thereby creating a path for severe arcing

Beneficial Corona

The sound generation effects of corona can be utilized to build high accuracy audio speakers! The major advantage is that there is zero mass that needs to be moved to create the sound, so that transient response is improved. For more information, see the project report at http://www.ece.vill.edu/ion/p10.html.

Corona Calculations

The following corona calculations are from Dielectric Phenomena in High Voltage Engineering, F.W. Peek, 1929

For Concentric Cylinders in Air:

- Corona will not form when $R_O / R_I < 2.718$. (Arcing will occur instead when the voltage is too high.)

For Parallel Wires in Air:

- Corona will not form when $X / r < 5.85$. (Arcing will occur instead when the voltage is too high.)

For Equal Spheres in Air:

- Corona will not form when $X / R < 2.04$. (Arcing will occur instead when the voltage is too high.)
- Arcing difficult to avoid when $X / R < 8$

Where

- R_O = Radius of outer concentric sphere
- R_I = Radius of inner concentric sphere
- R = Sphere radius
- r = wire radius
- X = Distance between wires or between spheres

Corona Prevention

Corona can be avoided by minimizing the voltage stress and electric field gradient. This is accomplished by using utilizing good high voltage design practices, i.e., maximizing the distance between conductors that have large voltage differentials, using conductors with large radii, and avoiding parts that have sharp points or sharp edges. Corona inception voltage can sometimes be increased by using a surface treatment, such as a semiconductor layer, high voltage putty or corona dope.

Also, use a good, homogeneous insulator. Void free solids, such as properly prepared silicone and epoxy potting materials work well. If you are limited to using air as your insulator, then you are left with geometry as the critical parameter.

Finally, ensure that steps are taken to reduce or eliminate unwanted voltage transients, which can cause corona to start.

For more information, see Engineering Dielectrics: Volume 1: Corona Measurement and Interpretation, edited by R. Bartnikas, E. J. McMahon

Contact Information

Evan Mayerhoff
Application Engineering
High Voltage Connection, Inc.
516-466-9379
www.highvoltageconnection.com
evan@highvoltageconnection.com