UV-260 Corona Discharge Camera

## "Because a picture of corona is worth billions of photons"

Detecting corona discharge has not been easy for utility engineers, until now. This article describes UV camera technology designed to detect the radiation emanating from corona discharge, how to inspect and view corona in daylight, and how to document and create a site report.

About Corona Discharge

Corona discharge is one of three types of partial discharge: Corona discharge, surface discharge, and internal discharge. All forms partial of discharge are characterized by the breakdown of a dielectric, or insulation, created by a high voltage environment that causes ionization. The ionization results in electron flow, i.e. a current path. It does not always become a short circuit. It can sometimes be described as a steady trickle, but over time discharge current can lead to the complete breakdown and damage of electrical systems.

In the case of corona discharge the dielectric is air, and the discharge current is through air. Surface discharge of insulation and components occurs on contaminated insulator surfaces, such as when pollution build-up has coated an insulator. Internal discharge occurs due to the internal degradation of insulation, such as in cables where voids and cavities develop due to age, damage, or temperature extremes.

We can detect corona discharges because they emit electromagnetic radiation in the ultraviolet range as presented below.
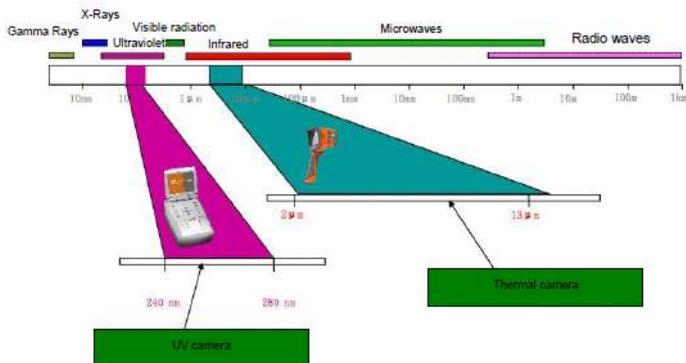

Electromagnetic radiation and wavelengths.

All partial discharges then are current flows. In the case of corona discharge it is the current flow in air, from a discharge electrode under high voltage. High voltages cause air ionization and creates a plasma around the electrode. A plasma is a region of ionized matter, sometimes described as a fluid-like flow of electrically charged particles. The resulting ions carry the electric charge from a high to a lower potential, thus a current path is created.

If the discharge electrode has a pointed shape, there is a propensity for a high voltage gradient to be generated around the point which can lead to a discharge. Sharp or pointed conductors tend to "spray" electrons, and tend to do so in the negative half-cycle. At very high voltage it may show up as intermittent sparking, or a full electric arc when a "plasma channel" is created. These are the extremes that are easily noticeable. But corona discharge is insidious since it may not be noticeable even though ionization is present, but is at too low a volume to develop a visible plasma. This is often the case, and is the major cause for concern since prolonged and continuous ionization creates corrosive nitrous compounds from air and pollutants that deteriorate electrical components. If left unnoticed failures will be inevitable.

Corona discharges generate electromagnetic radiation in the wavelength range from 200 to 405 nm. Solar radiation contains both visible light and ultraviolet radiation. Most shortwave solar radiation is absorbed by the ozone layer in the Earth's atmosphere. In order for a UV camera to operate in daylight without interference from solar radiation filtering is used to suppress the UV radiation generated by the sun in the range of 240 to 280 nm.
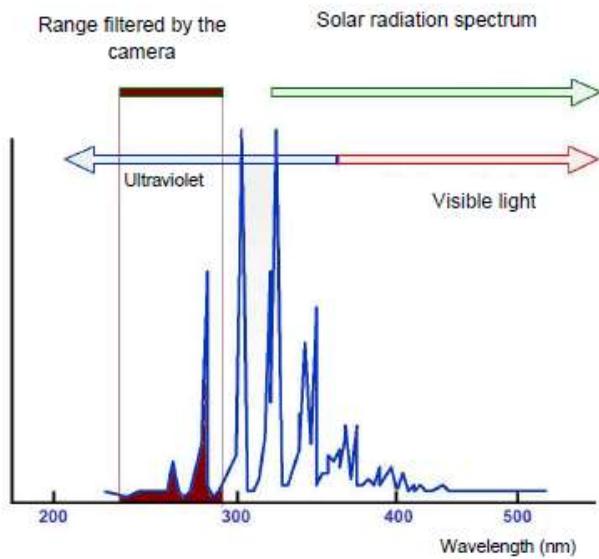
The spectrum of corona discharge

Ultraviolet radiation is invisible to the human eye. The radiation however is spread out over a range of wavelengths that can extend to longer visible wavelengths, but these are near impossible to see in daylight. Even in total darkness it is hardly visible and may be barely perceptible as a faint blue-violet glow.

Corona discharge may be positive or negative depending on which electrode we are referring to; the positive anode, or the negative cathode. In either case photons are the main source of radiated energy. Photons are released by ionized atoms when their electrons are bumped up into higher energy levels (orbits) as they become excited by the voltage gradient. In the resulting plasma the tendency of the excited electrons is to return to lower energy states releasing energy as photons. Consequently, UV cameras have "UV photon" scales to give an indication of the volume of photons being detected.

It has been observed that positive discharges tend to be concentrated close to the electrode since they are generated from a point. Negative discharge occupies a larger area as the energy is spread over a wider zone. This appears to be explained by the fact that the generated electrons "in flight" become dispersed as they leave the source, just as water from a nozzle tends to, and will find their way to the nearest entry point – the cathode. Since the cathode area is larger than the source the plasma spreads out and appears to be weaker and is more difficult to localize.

Effects of Corona

Corona discharges have many adverse effects. They cause interference with the reception of radio signals near to high voltage power lines. There is also energy loss since the radiated energy "escapes" to the air; via UV radiation, and local heating caused by the plasma current. Some of this energy is converted into an audible "crackling" due to the heating of air. The plasma actually turns on and off, as the mains voltage waveform goes from maximum to zero and repeats, 100 or 120 times a second. (It is double the mains frequency due to two peaks and two zero crossings per cycle.) The repetitive heat on/heat off causes the air to expand and contract at 100 – 120 Hz generating the crackling noise.

In fact, early methods of corona detection used either RF or acoustic techniques but the sources could not be precisely located with these methods. UV detection is much more precise and is replacing acoustic-based and RF detection methods. Imagine trying to locate the source of corona in a substation that has many possible sources, because of complex conductor and dense equipment installations. RF or acoustic signals could be coming from any number of sources in all directions. In such a situation UV detection is the only method for precisely identifying the source, or sources of corona.

The most adverse effect is the detrimental impact on insulation due to heating and corrosive action. Once degradation begins, even at low levels of corona, cracks and voids appear. Moisture can then penetrate into insulation and components and further accelerate degradation. The damage to insulation components can lead to the shutdown of the entire power transmission systems. Therefore, it is prudent to perform regular

inspections of high voltage systems to prevent corona discharges, and eliminate them at early stages. Failure to take appropriate action may result in permanent and expensive damage.

The UV-260 camera detects and localizes corona discharges by detecting and monitoring the UV radiation from corona discharges, so the discharge intensity can be evaluated. The object being studied, the target (such as a conductor or pylon or insulator bushing), is viewed by displaying a visible image in the same way a video camera is used. The visible image helps to locate and frame the target. Built-in autofocus allows a precise fix on the target. Remote viewing puts distance between the operator and high voltages ensuring safety.

The UV camera operates in both the visible and UV regions, and independent visible or UV images may be viewed. The UV image can also be superimposed on the visible image. UV radiation shows up on the screen as areas or blotchy spots of color. The color of the UV spots can be chosen as red, white, or blue, for the best presentation against different backgrounds, such as bright sky or complex installations. The observed discharges can captured and saved as still pictures, or they may be recorded as videos.
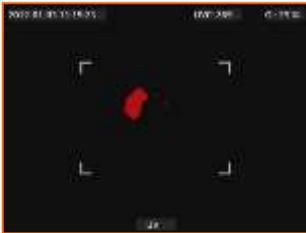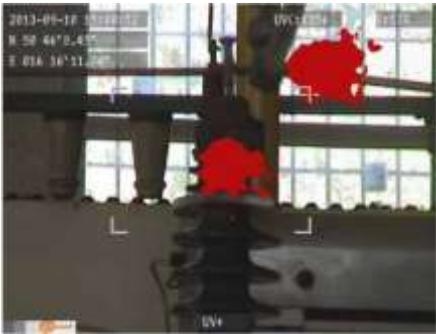

| UV image | Visual image | UV/visual mixed image |

Corona discharges under laboratory conditions.

Corona discharges in real power grids.

Corona discharge and its effects.

When inspecting long HV power lines it is important to record target location. A good UV camera, such as the UV-260, is equipped with a GPS module so that geo-location data is automatically saved with the image file. With a microphone or headset, voice annotations can be added to the image file. For long observations or to eliminate vibrations the camera may be mounted on a tripod.

UV-260 camera mounted on a tripod.

Software for Analysis and Reports

Recorded images and videos are saved in common file formats to a SD memory card that can be transferred to a computer for viewing. The image and video files can be opened with standard image or video viewing software. If the file contains a voice note it will be also imported. To create reports on a computer and perform further analysis the "Sonel UV Analyze" software is used to inspect and edit image and video files. The report can be arranged to include photos of damaged components, along with the UV radiation images or videos, and can be placed on a map with the GPS coordinates, along with voice notes and recommendations for remedial actions.

UV-260 camera.

Summary

Corona cameras have significantly improved the ability to detect incipient problems, on high voltage infrastructures such as improperly mounted or faulty components (e.g. broken porcelain or glass insulators) in newly built and commissioned installations.

Moreover, they are very useful for recording conditions as they develop and worsen in ageing infrastructures. The early detection of corona effects enables problems to be eliminated before more severe damage and failure occurs.

The latest high-quality UV cameras, such the Sonel UV-260, are ergonomic, easy-to-use, and safe devices. Their small size and rugged construction make them ideal for field inspections, both indoors and outside.

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