Diagnostic Techniques of Composite Insulators

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Those which are considered low cost turn into pricy. This statement applies to various aspects but in particular to power lines NCI insulators. Their cost is approximately 3-5% of the total cost of installations but their impact of their performance on reliability in power systems is tens of times higher. One of the reasons for preferring NCI's is their hydrophobicity and good performance under high pollution. Yet the natural habitat of power grids where insulators are exposed to acid rain, salty dust depositions, fertilizing sprays, industrial contaminants amongst other factors, makes their degradation inevitable. Their hydrophobicity advantageous feature is at risk as are their insulation capabilities. Corona, more than any other factor, deteriorates the quality of polymeric housing and accelerates ageing and degradation processes. The question of asset management pertains therefor to the ability to diagnose composite insulators and be familiar with their stages of degradation.

Cost effectiveness is a target for any business, notwithstanding the power industry. In ours case, utilities seek answers to questions like: which insulators should be replaced, when, how often, chronology of failure, maintenance costs and what will the resulted impact in case of a failure. One of the ways to address this issue is to adopt a diagnostic methodology. Such a methodology can be formulated by any utility provided there is an accurate documentation and recoding of findings from inspections, maintenance activities, tests, replacements etc.

During Ofil's past users' group meeting, Eng. Andrea Colombo from CESI Italy demonstrated CESI's diagnostic methodologies that are applied to composite insulators. Their methodology emphasized the need for inspection as the main diagnostic channel. Their study involved using Ofil's DayCor® corona camera and other complementary inspecting technologies.

CESI found with regards to NCIs that there are two main defects classifications namely:

- **Damaged insulators** - irreversible changes of their characteristics that affect their performance present high risk
  Examples:

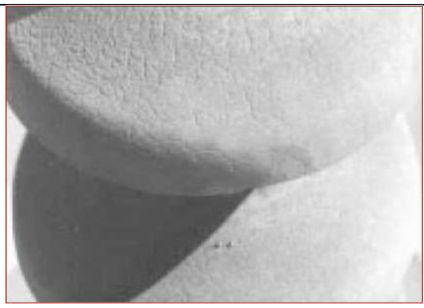
- Tracking/burning/carbonizing – conductive paths on the surface	

	
- Corona cutting – scissoring of the polymer material due to corona discharge	
- Erosion – significant loss of polymer material, high roughness	
	

- Rod exposure	
Power Arc damage – caused by high current or flashover	
Puncture - the polymer material is ruptured due to disruptive discharge occurring through the dielectric	
- Cutting /splitting – tear, crack which reduces the creepage distance or the thickness of the sheath	

- End fitting seal degradation – adhesion damage at the metal end-fitting by erosion or peeling	

- **Deteriorated insulators** - those with superficial ageing signs that will neither have a significant reduction in their performance nor represent any reliability risk. Although these conditions do not require replacement, utilities should monitor any deterioration.

- Chalking	
- Crazing	
- Aligatoring	

- Flange corrosion – end fitting rusting -	
- Loss of surface hydrophobicity – ability to repel moisture when wetted. Might result in electrical flashover under wet and polluted conditions -	

STRI the Swedish testing laboratory that owns Ofil's corona camera since 2001 offers an elaborated classification that plots CESI's above classification against the location of fault along the insulator. STRI refers to six areas: end-fitting, fitting & insulator interface, sheath, sheds, shed & sheath interface, rod. Following this classification (J. Burnham, "Guideline for Visual Identification of Damaged Polymer Insulators, http://ewh.ieee.org/soc/pes/iwg/NCIEvaluation/POLYMERDAMAGEGUIDELINE.doc." vol. 2009, 1998) helps the inspection and monitoring process.

EPRI, the Electric Power Research Institute, that owns DayCor® Cameras and was Ofil's partner in developing the DayCor® technology and cameras, published in 2004 a field guide with recommend rating. Based upon EPRI's research, insulator condition and maintenance priority rating table was published where faults are plotted against their location along the insulators (sheds, sheaths, sheds and sheath, corona rings, end fitting) and 4 priority ratings were defined: A – good or like new, B- Low degree of damage, C- moderate degree of damage, wear decay, D – High degree of damage, wear, decay. According to EPRI, any kind of damage where the core rod is exposed, flashover damage and seals damage are considered high risk and insulators should be removed from service(A. Phillips and T. Shaw, "Field Guide - Visual Inspection of NCI, Revision 1 (1008739)," EPRI, Palo Alto, CA, USA, 2004, A. Phillips, "Field Guide: Visual Inspection of Polymer Insulators. Technical Update, May 2006, (1013283) " EPRI, Palo Alto, CA, USA. 2006, pp. 104.)

Diagnostic techniques

Visual inspection

The first and most simple and intuitive technique is visual inspection. This method needs certain level of experience and knowledge about the project's criteria, materials and possible defects of the examined object. With this method it is possible to detect only superficial defects such as:

(1) Material surface deterioration and damage

(2) Hydrophobicity condition

(3) Pollution that may lead to corona discharges and/or dry band arcs

(4) Sealing defects

(5) Rod exposure

To perform visual inspection a pair of good binoculars and HD cameras with strong zooming are necessary.

IR Thermography

Infrared inspection aims at temperature gradients and variations that designate both internal and external defects. Thermal scanning is current related and needs full line load (Joule effect). IR thermography helps to detect cases such as

1. Internal moisture ingress
2. Large rod core voids and cracks
3. Polymer and rod surface tracking
4. Surface arcing
5. Flashunder – a process between the weathershed and the rod that neither a visual nor UV inspection can detect.

The major disadvantage of this technique, though, is that the changes in temperatures are usually very small and make it sensitive to environmental conditions. Furthermore, according to CESI water and high humidity make the results unreliable because interpretation of IR results may be affected by strong winds, dew, and rain temperature. On the other hand, relative humidity lowers than 80%, absence of wind and cloudy sky is a preferable situation for scanning.

This test requires infrared (IR) cameras.

UV - Inspection

Corona is a luminous phenomenon and an artifact of partial discharge (PD). It is triggered by localized high electric fields that exceed a certain critical value which ionize air and lead to discharge activity. Under normal atmospheric conditions the critical value is in the range of 20-30 kV/cm, this value will be reduced under conditions of low air pressure or high relative humidity. Partial discharge generates audio noise, corrosive materials like ozone and nitrogen oxides, radio and TV reception interferences and emits light, mainly in the UV spectral range.

During the PD process nitrogen molecules in the air are excited and emit ultraviolet radiation, generally in the 200-405 nm wavelength range. To detect corona, there is a need to look for the UV radiation it emits. One of the primary problems associated with observing UV radiation during daytime is that the wavelength of the emitted radiation corresponds directly to that of background solar radiation and therefore is basically blocked from normal view.

To see and capture corona during daytime Ofil developed the “DayCor®” technology. DayCor® technology is now being embedded within all of Ofil’s video cameras and allows pinpointing of both the UV radiation and its emitting sources.

UV inspection is designed to detect mainly external phenomena on the surface of the equipment being monitored and is voltage dependent only. While ambient humidity is advantageous, inspections can be performed under virtually any weather conditions (not including rain). Such inspections allow for detecting potential problems at their very earliest stages, before they have progressed to the point of serious damage and the corresponding need for rapid replacement of the affected component.

Being related to voltage rather than to current, corona discharge has a flashing periodic appearance that correspond the sinusoidal pattern of the line. To be able to perceive and capture corona for documentation purposes the phenomena must be recorded as video clips.

Once detected, deciding upon the relative severity of the findings depends on validating where the observed corona is taking place and on the substance of the emitting component. Often high definition visual inspection with good zooming complements the detection findings and assist obtaining a comprehensive picture of the condition.

For polymer insulators discharge detection using a day-time UV light sensitive camera may help to detect evidence of:

1. Internal moisture ingress
2. Large fiberglass reinforced core rod voids and cracks
3. Surface tracking
4. Localized electrical discharging which are often indications housing material erosion
5. Arcing

Corona is both an indicator and an agent and must be attended. Using a corona camera provides immediate authentic information about exiting reactions and processes that are otherwise left un-detected and un- attended.

UV inspection of distribution, overhead lines and substations with a corona camera yields information on the condition of the line or substation as well as the quality of the design and workmanship during the installation phase. Inspection for corona with a corona camera is simple and easy to carry out and requires no load of the line. UV inspection is cost effective to utilities since it allows early detection of faults that can cause outages at a progressive stage.

Other techniques:

Acoustic – uses directional microphones. For internal defects this method has a sensitivity that is lower than thermography. Corona effect could be detected due to its noise.

Electric field - based on a comparison between the values of E-field measured in a tested object against a known reference. The measure must be executed by trained personnel for live works. The adoption of this technique is difficult if the condition of the object is not well known.

Which diagnostic or monitoring technique to use

To make a selection of a diagnostic technique the following considerations should be discussed:

- Level of interpretation – is the data provided difficult/easy to interpret
- Level of training – of linemen inspectors
- Information relevance to get the full picture of the asset condition
- Destructive/ Intrusive testing method
- Interrupt/Ongoing line operation – is the test performed in a laboratory or during regular operation

Apparently, visual inspection with naked eyes or binoculars is easy and comes natural without any need for training, and it provides relevant information. It is conducted during regular working conditions, but it is time consuming because the whole structure gets attention. IR cameras are more difficult to use and require training. They provide only a medium rate of relevant information and are must be performed under line load. UV inspection requires more training, mainly because it is a relatively new technology (introduced only about 12 years ago). It provides excellent information with high relevance and is non-destructive and non-intrusive, and requires regular line operation. UV inspection presents flashes of light that alert inspectors and directs them to the suspected faulty locations. UV inspection is cost effective when it is being used in tandem with visual inspection

Consequently, it can be stated that to perform a comprehensive inspection that support asset management a combination of diagnostic techniques should ideally be deployed. Taking into account the high risk of corona and arcing to NCIs there is a greater need for UV cameras that are bi-spectral like Ofil's DayCor® that provide a winning combination of both sensitive UV detection and visual.