Africa Utility Week Focus Day 2014

Substation Condition Monitoring
Benefits of Ultrasound

Reliability is Everything™
Agenda

- Review - Substation Condition Monitoring
- Electrical discharge
  - Types and origin
  - In switchgear
  - Results/consequences
- Detection methods used
- Metal clad switchgear issues with PD
- Ultrasound a versatile technology
- Case studies
- Conclusion
Substation Primary Components

- Transformer
- Overhead infrastructure
- Cable
  - Joints
  - Terminations
- Switchgear
  - Breaker
  - Bus Sections
  - VT/CT/Insulators
  - Surge Arrestors
- Capacitor Banks/Reactors
Transformer

- Typically well maintained and monitored.
- Commissioning and major outage tests. (Winding Resistance, Impedance, Megger, Turns Ratio, Tan Delta, SFRA etc)
- Oil Quality (Dielectric, Moisture, Acidity etc.)
- DGA (On Line and periodic sampling)
- Bushing (On Line Tan Delta and Capacitance)
- On Line PD
- Acoustic/Ultrasound PD detection & location
- Infra Red inspections
Transformer Monitoring

Change in Imbalance Current - 500 kV bushing

Time - Days
% Imbalance Current

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Overhead infrastructure

- Nothing
- Visual
- Infra Red
- Ultrasound
- UV
Cables

• Commissioning tests and then typically fault location and replacement rather than condition monitoring (New SANS Specification 10198 -13)

• Cable
  – VLF, Tan Delta, Off/On Line PD

• Joints
  – VLF, Tan Delta, Off/On line PD

• Terminations
  – VLF
  – IR
  – Ultrasound
  – UV
Metal Clad Switchgear

- Nothing (Often the case)
- IR thermal imaging often considered “the only way” to inspect electrical switchgear
- What are other tools that can be used
  - Visual (When a plant is shut down)
  - Ultrasound (Done on line with a good chance of success and increasing trend)
  - TEV (Need a gap and low noise)
  - IR (IR Windows for Switchgear demand is increasing for new and retrofit)
Switchgear IR Inspections

- IR Windows IEEE C37.20.7 63 kA
  Arc tested at KEMA, UL50/50E/50V, UL1558, IEC60529-1: IP67, IEC60068, NEMA 4/12, CSA C22.2 NO. 14-13:2012, and CE
- Require an understanding of the network and loading.
- Training for Inspectors
Why test for partial discharge?

- PD activity is an indication of an developing fault in MV and HV insulation and is widely regarded as the best 'early warning' indicator of the deterioration of the insulation system.
- Weak insulation = higher probability of failure
- When to perform diagnostics
  - After manufacture
  - Commissioning
  - During Service Life
  - New Equipment
On-line PD detection aspects

• Detect PD signals without an outage
• Use non-intrusive sensors
• Simple technology used in first instance for initial detection/safety
• Advanced instruments for diagnosis & location
• Temporary and permanent devices for continuous PD monitoring
What is partial discharge

- **IEC definition:** PD is a localized electrical discharge in an insulation system that does not completely bridge the electrodes.
There are 7 Main Types of PD

Internal:
- Void in Insulation
- Sharp, Irregular surface on conductor
- Tree Growth in insulation

External:
- ‘Floating’ metalwork near conductors
- Corona from sharp objects at high voltage
- Discharges from induced voltages onto sharp points at ground
- Surface Discharges

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Internal Discharges
External Surface Discharges
Consequences of PD

- **PD is destructive.** It directly destroys all organic insulation materials and produces byproducts that form aggressive chemicals which can attack both insulation and conductors. The end result of PD is a full discharge (complete failure) of the insulation system.
Result of PD in Switchgear

- Insulation in some electrical equipment is designed to be PD resistant, but
- Switchgear is designed to be PD free, so Switchgear insulation is NOT PD resistant
- When PD occurs in switchgear it is because of a defect
- Early detection allows relatively quick and easy repair
- If PD is not detected and eliminated it will eventually bridge the insulation and result in an Arc Discharge
PD Technologies

- PD Detection
  - Off Line
  - On Line
  - Permanent Monitoring

- Use numerous technologies
  - Acoustic
  - Ultrasound
  - RFCT’s- HFCT’s
  - TEV’s
  - Regowski coils
  - Couplers
PD produces:

- Wide spectrum electromagnetic radiation, including radio frequency emissions and light, especially UV
- Electrical signals in conductors and ground circuits
- Wide spectrum acoustic emissions, especially ultrasound
- Ionised air
- Aggressive chemical by-products
- Initially carbonisation, then total chemical breakdown of all organic materials
- Heat, but highly localised so possibly detectable with IR thermography
PD Energy and Detection Methods

**Energies Released**
- Electrical Charge
- Electromagnetic Wave
- Optical
- Acoustic Wave
- Gaseous by-products
- Chemical by-products such as white deposit oxides
- Ozone

**Detection Methods**
- Capacitor/Inductive
  - RFCT/HFCT
- TEV, VHF/UHF Couplers
- Low-light/UV Cameras
- Contact/Airborne Acoustic
- Dissolved Gas Analysis
  - Visual inspection
- Smell / Ozone Detector

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PD Detectors

• PD detectors are hand held indicators of the presence of PD activity. They are **not designed** to provide accurate quantification but may rely for example on bar graphs or dB readings which can be employed for basic trending and pinpointing.
Hand Held PD Detectors

- Their purpose is to advise the operator of PD activity either for safety reasons or as an early warning to maintenance personnel that unwanted PD activity has started.

- They are designed to respond to one or more of the effects produced by PD, of which the most common are ultrasound, RF signals, Transient Earth Voltage and ultraviolet.

- Although there is a big area of overlap, there are many instances when particular types of defect will only be detectable with one or the other.
RF Sniffer

- 1st line of defence when entering a substation
- High radio frequency signals will be produced by the defects and can be detected with RF sniffers. The instrument is designed to detect and assist the test technician to locate fast transients such as those created by arcing, corona and partial discharges.

E-field is more directional to locate the source from the LF to the HF.
The higher the signal level the closer to the source.

H-field is more sensitive to arcing activities.
Transient earth voltage radiation of PD will be detected by the TEV sensors that are placed on the outside of the switchgear panel. In this way the TEV sensor works in effect as an external capacitive coupler that detects the PD pulses on the outer surface of the switchgear housing.
Partial discharges will produce sound waves and the waves can be located and pinpointed with ultrasound technology.
Metal Clad Switchgear

- Discharge sources are enclosed, so
- Infra red and UV are of limited value
- Open inspections are a safety hazard
- Physical connections are not an option unless permanent sensors have previously been installed
- Ultrasound is often the only viable option
Ultrasound Technology used in the field

- Safety – Before work, scanning of the sub station or adjacent panels with ultrasound will be conducted to locate PD, arcing or tracking activity.
- Periodic Scanning will identify defects
- Location of high background interference signals - scanning of the test area can detect or identify background noises that are present in the substation, but are not in issue (Florescent light ballast, UPS, VSD and electronic devises. (Why Level 1 and 2 training is available)
What is Ultrasound

Infrasound

Audible sound

Ultrasound

50 Hz

16 KHz/20 KHz

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Airborne Acoustics
Contact Ultrasound

Partial discharge in oil cooled transformers. (Use DGA Results in conjunction with ultrasound)
### Common Sensor Usage for On-line PD in Different Plant Items

<table>
<thead>
<tr>
<th>Plant</th>
<th>Power Cables</th>
<th>Cable Terminations</th>
<th>Metal-clad AIS</th>
<th>HV/EHV GIS</th>
<th>Rotating Machines</th>
<th>MV Transformers</th>
<th>HV Transformers</th>
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<tbody>
<tr>
<td><strong>Sensors</strong></td>
<td>HFCT</td>
<td>HFCT</td>
<td>TEV</td>
<td>UHF Coupler</td>
<td>HV Capacitor</td>
<td>Contact Acoustic</td>
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<td>TEV</td>
<td>Bushing Tap Adapters</td>
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<td>Contact Acoustic</td>
<td>HV Capacitor</td>
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<td>RTD Sensor</td>
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<td>TEV</td>
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Sensor selection depends on plant design and accessibility for sensor attachment.
You cannot open the panel

- Often hear that the comment our switchgear cannot be opened.
- With Ultrasound we do not need any panels opened.
Corona, Tracking and Arcing

Corona

Tracking

Arcing
Why Safety
Are substations Safe
Mini Substation Finding
ON Line PD Detection and Ultrasound Findings

Discharges verified by ultrasonic detection
PILC Cable Terminations
Ultrasound Findings
Ultrasound and IR can be complimentary
Conclusions

• Numerous technologies available for PD detection in Switchgear applications.
• For initial surveys and detection of PD activity Ultrasound has many advantages
• Ease of Use
• Low Cost
• On Line with the added benefit of the safety aspect
• Can be used on a wide variety of equipment
• No requirement to open up panels.
Thank You!

Questions?

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