

Safer, Stronger, Smarter Networks

# Advancements in online partial discharge monitoring and assessment of MV through EHV Substation assets

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#### Abstract:

For decades it has been recognized that partial discharge assessment is an excellent method for determining asset health.

- On line non-invasive techniques for monitoring and surveying have been proven to provide the necessary level of detail for condition assessment without impacting system operation.
- Techniques exist now to test assets from 3KV to 500KV and beyond. Metal clad switchgear and busswork, GIS switchgear and busses, air insulated assets (insulators, arrestors, bushings, etc.), as well as paper insulated and extruded cables can all be tested on-line without an outage.

This presentation will give a brief overview of the causes and effects of partial discharge and then examine the various technologies available for finding it on-line.

Examples of field success stories will also be given.



**Topics for Today** 

- Who is EA Technology
- Causes and effects of Partial Discharge
- Sensing Technologies
  - Transient Earth Voltage
  - Ultrasonic Reception
  - Radio Frequency Current Transformers
  - Ultra High Frequency Radio Detection
- Recent Advancements in Detection



- Provide products and services for measuring, monitoring and managing physical assets for electric utilities
- Consulting on a wide range of power system issues
- Produce inspection and maintenance standards and procedures
- Forensic failure investigation services
- Major patron of the Institute of Asset Management
- Instrumental in PAS 55 and ISO 55000 development
- EATLLC US Subsidiary in NJ

## What is Partial Discharge (PD)?

Partial Discharge – A flashover of part of the insulation system due to a localized electric field greater than the dielectric withstand capability of that part where the overall insulation system remains capable of withstanding the applied electrical field.



One effect of this flashover is a high frequency current pulse that travels through the capacitance of the insulation (C1 & C3)

## **Products of Partial Discharge**



Partial discharge breakdown of insulation produces:

Light, Heat, Smell, Sound, Electromagnetic Waves, and an HF Electric Current

## Partial Discharge (PD)

#### Where can it occur

- Any insulation (Air, Oil, Solid, GIS)
- Wide range of voltages (>4KV)
- Any age equipment
- Types of equipment
  - Metal clad circuit breakers / switchboards
  - Bus ducts (Segregated phase, ISO Phase, GIS)
  - Cables
  - Overheard insulators

## Types of PD

• Internal discharges occurring in defects, voids or cavities within solid insulation

- Detected through TEV and UHF measurement

• <u>Surface discharges</u> occurring across the insulation surface. Most common form of PD

- Detected through UHF & Ultrasonic measurement and UV Light Cameras

• <u>Corona discharges</u> occurring in gaseous dielectrics in the presence of inhomogeneous fields

- Typically not considered a condition problem
- Detected through VHF & Ultrasonic measurement and UV Light Cameras

# Practical Non-Intrusive PD Detection Methods

#### Internal discharge activity

- Transient Earth Voltage (TEV) Detection
- **RFCT Detection of Current Pulse**
- UHF Detection of EMI

#### Surface discharge activity

- Ultrasonic Detection
- TEV Detection high amplitude surface discharge
- **RFCT** Detection of Current Pulse
- UHF Detection of EMI

## Internal Partial Discharge Effect 1 (current pulse - TEV)



#### Internal Partial Discharge Effect 2 (EM Wave)



## Partial Discharge Frequency Spectrum

PD Spectrum (Simplified)

- Partial Discharge causes a broadband EMI emission (approx. 3-3000 MHz)
- Corona causes a smaller band EMI emission (30-400 MHz)
- TEV caused by capacitive currents are typically in the 3-80 MHz band



### Partial Discharge TEV Interpretation

**TEV** Interpretation



### Partial Discharge damage found through TEV sensing

Channel cut through resin by discharge



# Surface Discharge Detection Through Ultrasonic Sensing

- In severe cases, audible sound may be present
- Less severe deterioration may be detected using ultrasonic detecting instruments
- Sound spectrum in the 40kHz range
- Characteristic sound more important than absolute level

# Surface Discharge



Designed to work though cabinet metalwork, no direct air path needed

Contact probe

#### **Environmental Factors**

- Moisture in air will play a significant role in whether discharge is active
- When monitoring ultrasonically the environmental conditions (%RH and Temperature) should also be monitored



#### Surface Discharge Activity Detected by Ultrasonic Sensing



#### Tracking due to PD on a panelboard



# PD Current Pulse Detection using an RFCT How Does It Work?



#### Cable Termination Screen Failure Found through RFCT sensing



## Utility Field Results of RFCT Sensing

UK utility Electricity North West Limited (ENWL) shared the results of a two year evaluation of RFCT based Cable PD detection that involved the online condition assessment of 191 33KV MV cables on their network

over a two year period.

Over the course of two years, they experienced the following failure rates:

■ Green ■ Amber ■ Red

- *Red* 41.2%
- *Amber* 21.7%
- Green 1.9%

#### *They classified their results into Green, Amber, & Red*

- *Green* is a test where no partial discharge was found.
- *Amber* is a test result where some levels of PD were detected.
- *Red* means that PD levels indicating significant degradation were detected.



#### Internal Partial Discharge Overhead insulator (EM Wave)



#### **Example of Internal PD Found in Outdoor Switchyard**

#### • Internal Partial Discharge in a 12KV Medium Voltage Cable



#### Phase Resolved Plot Showing Internal Partial Discharge

12KV Medium Voltage Cable

#### Example of Surface PD Found in Outdoor Switchyard

#### • Surface Partial Discharge in a 66KV Circuit Breaker





**66KV Circuit Breaker** 

Phase Resolved Plot Showing Surface Partial Discharge

#### **Re-cap of Non-Intrusive PD Detection Methods**

- Metal Clad Switchgear / Busses / Air Cooled Transformers
  - Internal discharge Transient Earth Voltage
  - Surface Discharge Ultrasonic
- Medium, High, and Extra High Voltage Cables
  - Internal discharge RFCT Detection
  - Surface Discharge (Terminations) Ultrasonic
- Air Insulated Switchgear
  - Internal discharge UHF Detection of EMI
  - Surface Discharge Ultrasonic & UHF Detection
- GIS switchgear
  - Internal discharge UHF Detection

#### **Recent Advancements in Online - PD Detection**

dBuV

270

180

- Phase resolved plots for TEV, Ultrasonic, RFCT, UHF
  - Helps discern desired signal from noise





- Waveform plots for TEV, Ultrasonic, RFCT, UHF
  - Helps discern desired signal from noise





#### **Recent Advancements in Online - PD Detection**

- Automatic PD Detection Algorithms
  - Assist user, reduce mis-readings



- NFC (Near Field Communications) Tags
  - Eliminate data entry and reduce possible mistakes



#### **Recent Advancements in Online - PD Detection**

- Full time non-invasive monitoring
  - Monitor cables, metal clad switchgear, GIS Switchgear



- On-board storage and report generation with WiFi / USB / HTML
  - Promotes standardized test reports and sharing of data







# Thank you

# **Questions**?

For further information

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