DC Insulation Workshop
University of Manchester

DC Partial Discharge Measurement

Stephen Dodd
Department of Engineering
University of Leicester UK
Outline

• Background
• What is a Partial Discharge?
• Conditions for PD under DC
• Partial Discharge Detection
• Analysis and Interpretation of PD Data
• Conclusions
Background
Background

HVDC Transmission:

- Supergrids
- Interconnection of AC grids
- Connection of Off-Shore Wind Farms

HVDC converter technologies:

- Line commutated converters
- Voltage Source converters
Background

Voltage Stresses on Insulators:

- Pure DC
- Ramped DC
- Polarity inversion
- Transient Voltages
- Combined AC and DC voltage
- Harmonics
- Voltage Ripple
• Consequences of failure of high voltage electrical equipment
  • Power Outages
  • Power System Stability
  • Repair Costs
  • Environmental
  • Compensation
  • Health and Safety
What is a Partial Discharge?
Consider a small void embedded in an insulating material:

Electric field in void:

\[ E_L = E_A + E_{SC} \]

Partial Discharge:

\[ E_L > E_{INC} \]

Extinction when \( E_L < E_{EXT} \)

Self extinguishing due to space charge decreasing \( E_L \)
Conditions for PD under DC
What happens next?

$E_L$ must change:
• Change in $V_A$
• Change in SC

Voltage Ramps
• Change in Power Flow
• Polarity Reversals

Transient Voltages
• Thyristor Commutation

$$E_L = E_A + E_{SC}$$
What happens next?

Change in SC:

Transport of void charge on void surface.

Charge transport in insulation material neutralises void charge:

- Drift of charge carriers
- Diffusion of Charge Carriers

Both processes are temperature dependent.
What happens next?

SC accumulation in the insulating material:

If the void is close to the electrode.

Homocharge accumulation leads to a reduction in $E_L$.

Heterocharge accumulation leads to a reduction in $E_L$.

$E_L = E_A + E_{sc}$
Master plot of the temperature dependence of CY1311 sample, absorbed moisture 0.6%, thickness 1.7mm
Partial Discharge Detection
Typical Circuit:

Apparent Charge:

\( Q_{in} \) – induced charge on electrodes – flows in external circuit
PD Detection

Equivalent Circuit – High Pass Filter!

\[ I_Z = C_T \frac{dV_A}{dt} \]

Transients:
- \(dV_A/dt\) may be very large
- May overwhelm PD signal
Analysis and Interpretation of PD Data
Unlike AC, we do not have a phase reference.
Analysis and Interpretation of PD Data

Need to identify discharges from transient and noise

Isolate different discharge sources

Time sequence analysis – possible way forward

Relate different TS signatures to physical defects

Amplitude of PD may indicate degradation state

Repetition rate of PD may be temperature dependent
Conclusions

More work is required on the failure modes of insulation under DC voltages.

PD signatures will depend on the type of DC stress, voltage ramps, constant DC voltage, transients, superimposed AC etc.

Frequency of void discharges dependent on voltage ramp rate and temperature when under steady DC.

Work is required to be able to separate PD activity from that induced by transients etc.

Time sequence methodology needs to be developed to analyse and interpret.