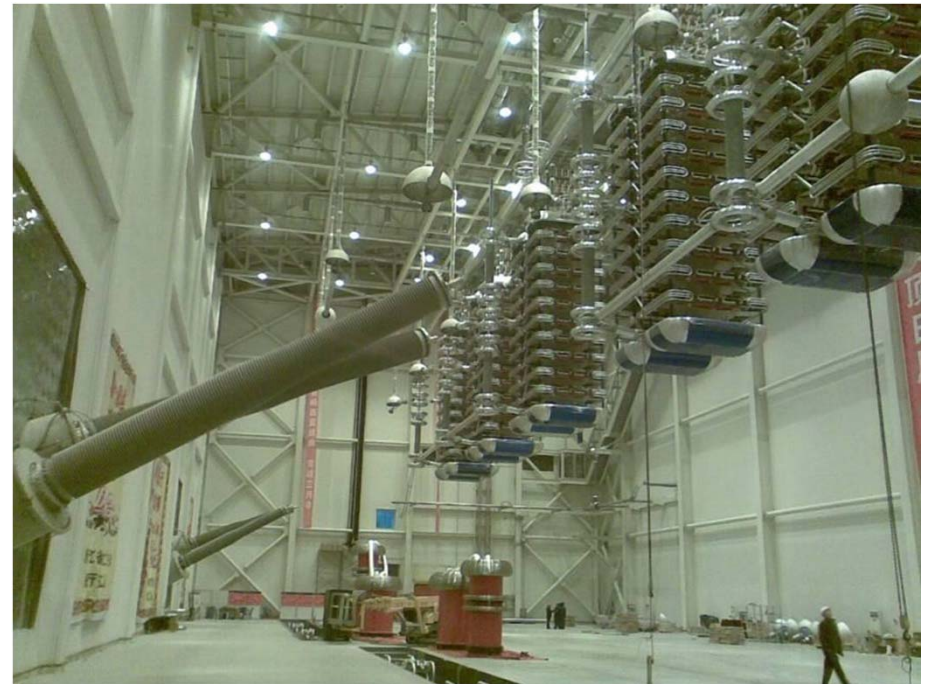


On-line Partial Discharge Detection and Evaluation in HVDC Power Systems

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Dr W.H. Siew

Contents

- Introduction
- PD theory
- Samples under test
- Test methods
- Analysis methods
- Results
- Conclusion



Source: 660 kV thyristor valve image Alstom

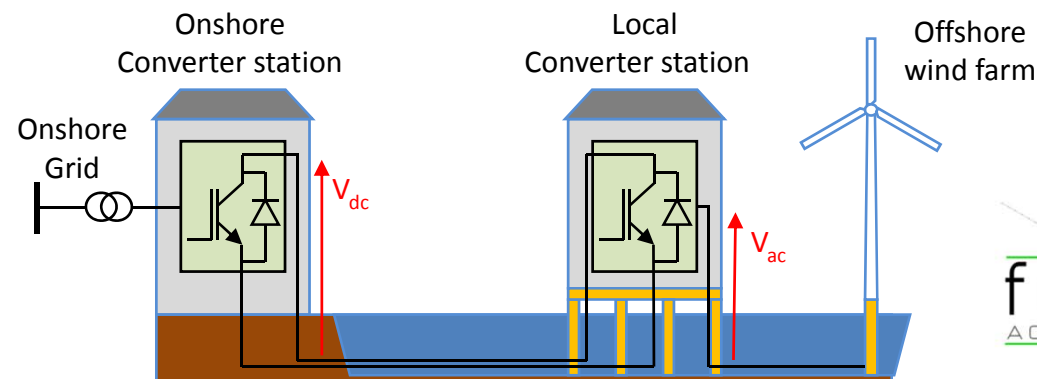
Aim of PhD



The aim of this PhD is to further the knowledge of insulation degradation under DC voltage which requires a fundamental understanding of the underlying mechanisms, coupled with new approaches to the interpretation of Partial Discharge (PD) data.

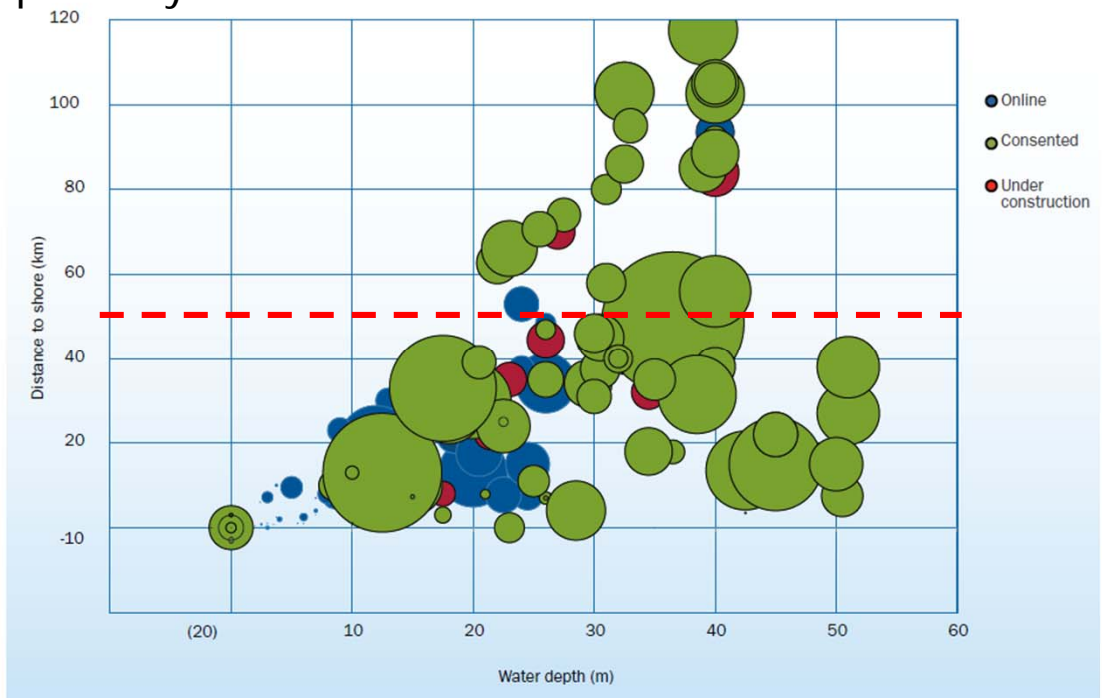
Introduction

- HVDC important part of UK electricity supply infrastructure
- PD monitoring to determine health of HVDC insulation
- Basis of work was conducted at TU Delft
- Expand through considering new materials and analysis techniques
- Basis of last years work was to investigate AC and DC PD behaviour of dielectric samples
- Aim of identifying type of PD apparent in a HVDC system



Introduction

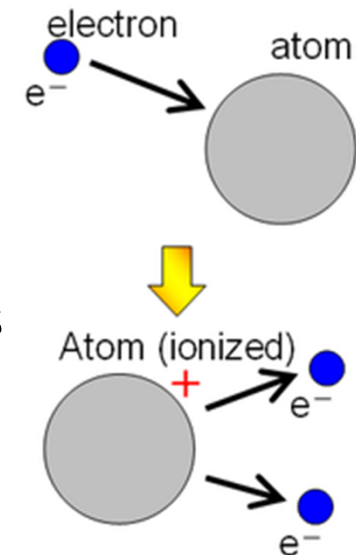
- Breakeven distance
 - Dist. Where AC and DC system investment costs are matched
 - Approx. 50 km for DC submarine cable
- Applications of HVDC transmission links:
 - Distributed generation (Offshore wind farms)
 - Interconnection in congested power systems
 - Links for power trading



Source: EWEA, "The European offshore wind industry - key trends and statistics 2014"

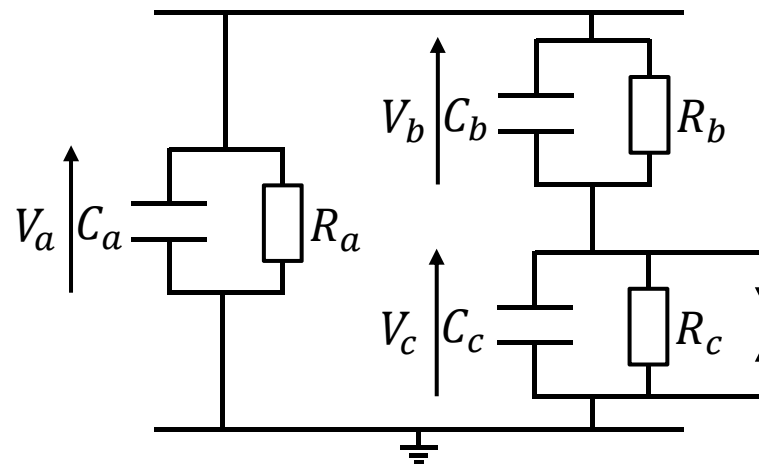
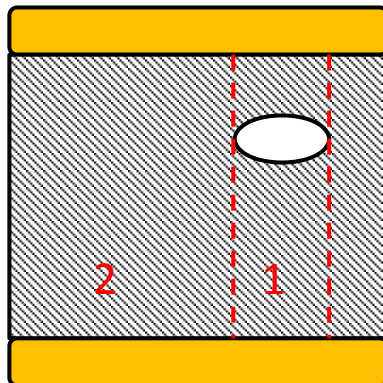
PD theory

- PD produced when there is an issue with the insulation of an electrical system
 - Manufacturing defect
 - Degradation over time
- Electrical discharge activity centres on the ionisation of materials to produce charge carriers
- Free electron impacts on other outer electrons of atoms and molecules (if electrons have enough energy => chain reaction)
- Leads to a positive ion and free outer electron
- Externally applied field determines the energy of the free electrons



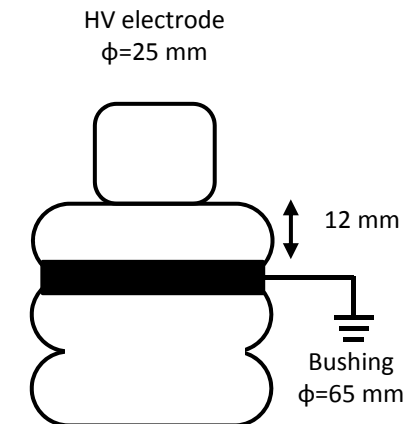
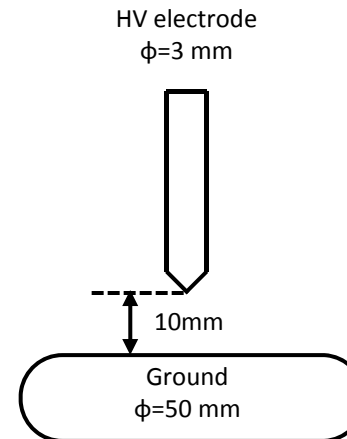
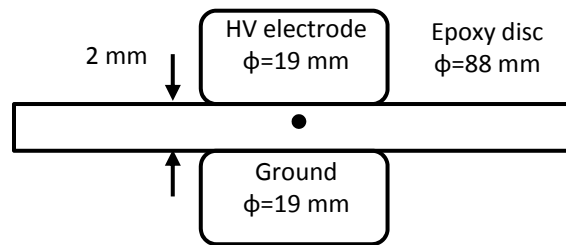
PD theory - DC mechanism of PD

- The PD repetition rate under DC is several orders of magnitude less than under AC conditions
- ABC model of Germant and Von Philippoff requires fundamental changes
 - Model must be adapted to show the charge dissipation into the surrounding insul. around the void
- For PD to initiate two conditions must be satisfied:
 - The minimum breakdown voltage must exist across the defect
 - A free electron must be available to start the ionisation process

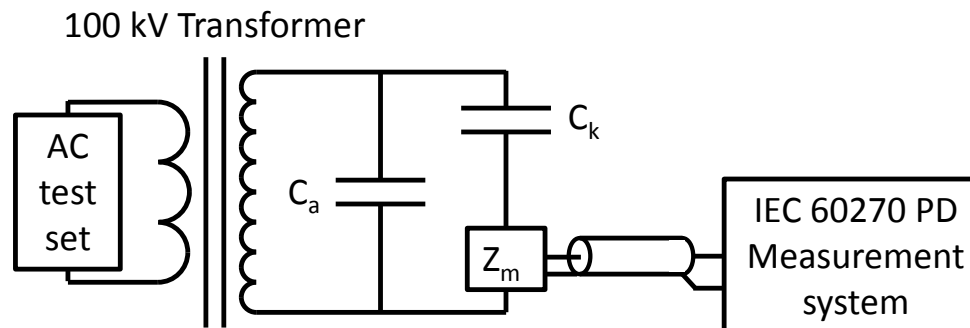


Test method

- 3 dielectric samples under test

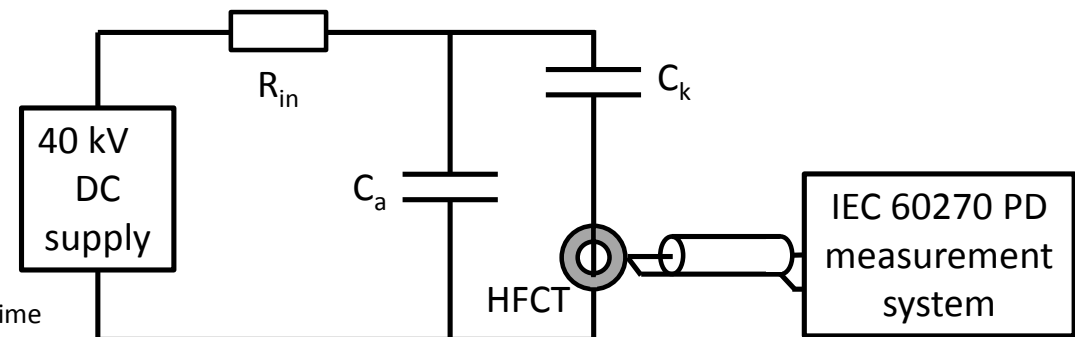
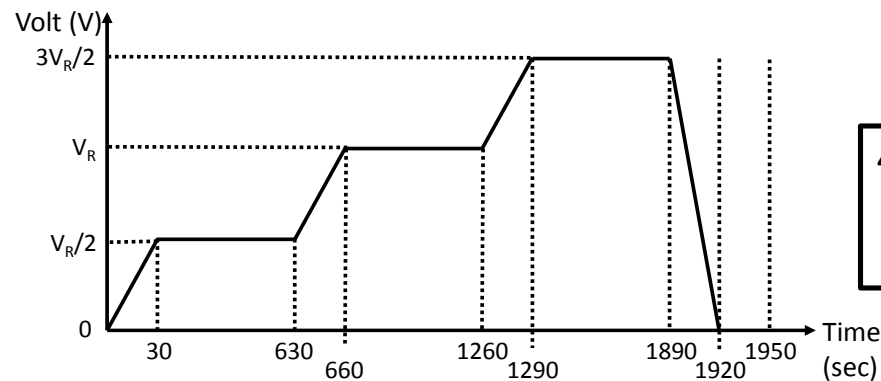


- AC testing initially performed
 - Determine the AC inception voltage
 - Confirm the dominant PD source apparent



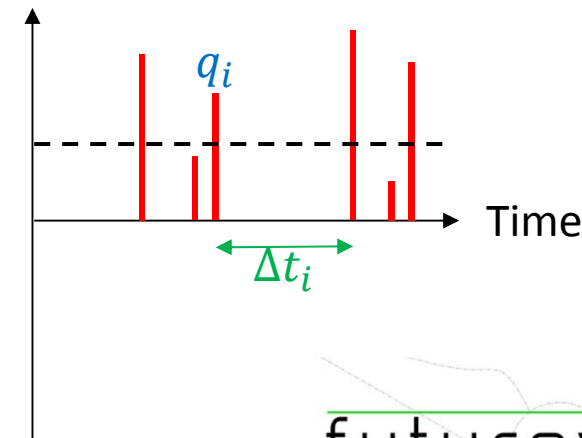
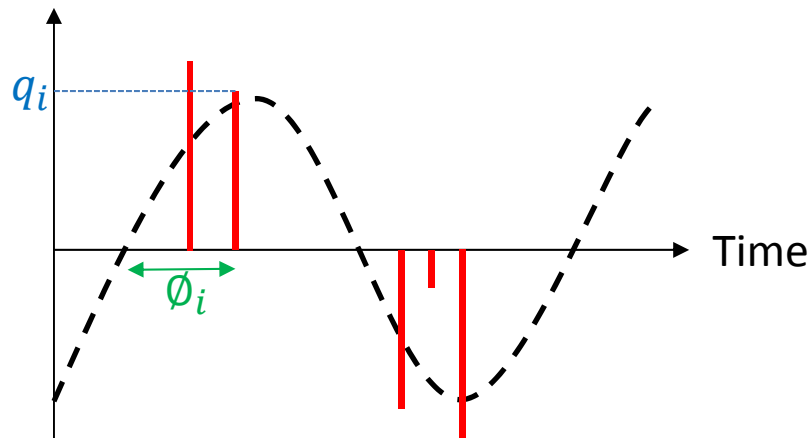
DC test method

- DC ramp test, consisting of 3 voltage increments ($V_R/2$, V_R and $3V_R/2$) where V held const.
- Increments determined by the peak value of the AC inception voltage (V_R)
- PD measurement via IEC standard PD system and a HFCT



Analysis methods

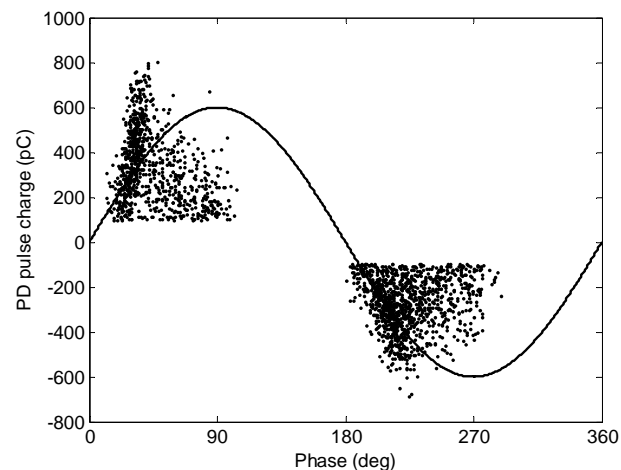
- AC analysis was performed by the visual inspection of PRPD plots
 - Measured quantities are PD charge and the phase reference
 - Common PD sources exhibit particular behaviour on PRPD plots
- DC analysis was more suited to statistical methods
 - Measured quantities are PD charge and time of occurrence
 - Histogram generally used to illustrate spread of data
 - Calculation of skewness and kurtosis for the PD data sets



Results - AC case

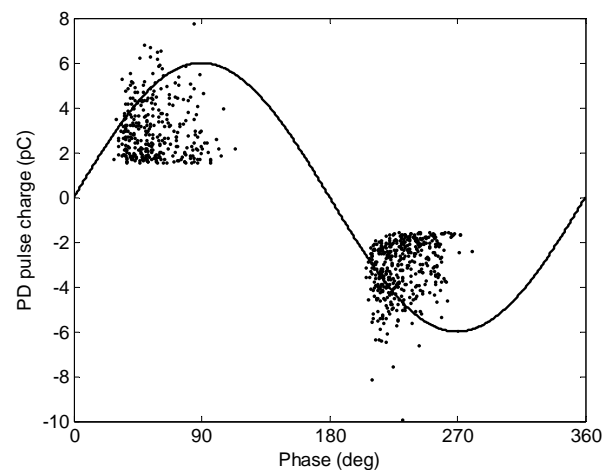
Internal

- Inception voltage was 7 kV rms
- PD occurs before the test voltage peaks
- The peaks are triangular in shape suggesting a large cavity



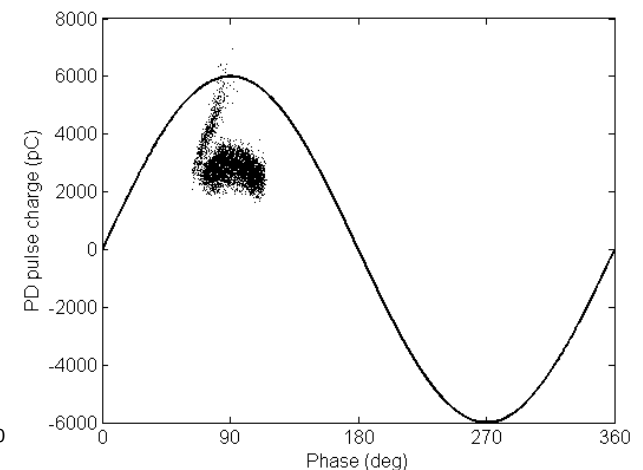
Surface

- Inception voltage was 4.7 kV rms
- PD before the test peaks
- Smaller number of larger discharges in the positive half cycle and a larger number of smaller discharges in the negative half cycle



Corona

- Inception voltage was 5.8 kV rms
- PD occurs at 90 degrees matching the test voltage peak
- PD was expected in the negative half cycle but the detection threshold was above the PD level



Results - DC case

Internal

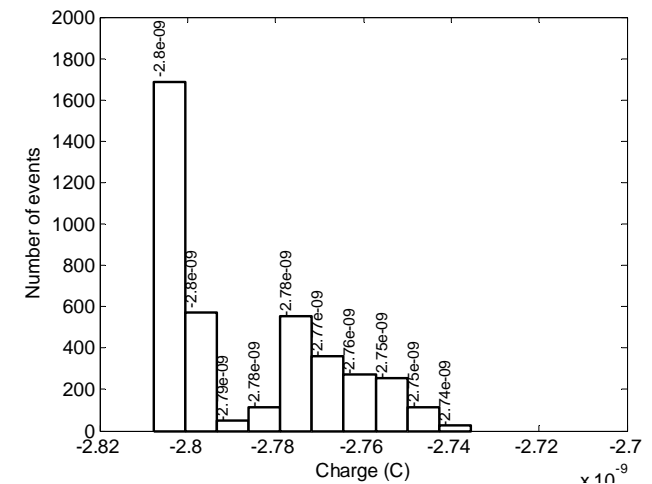
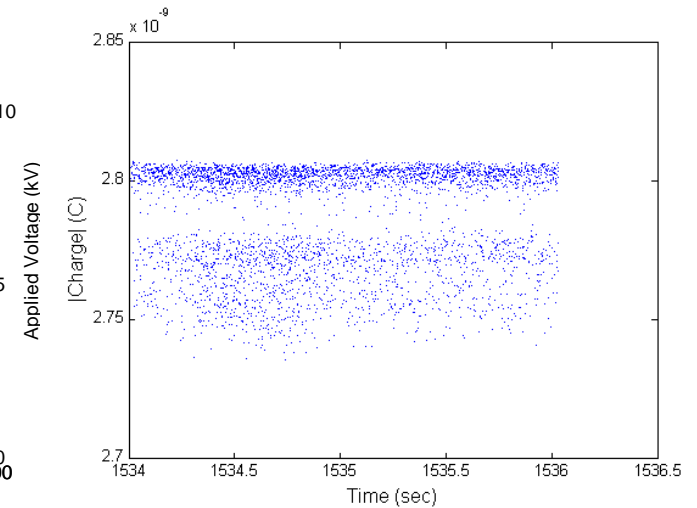
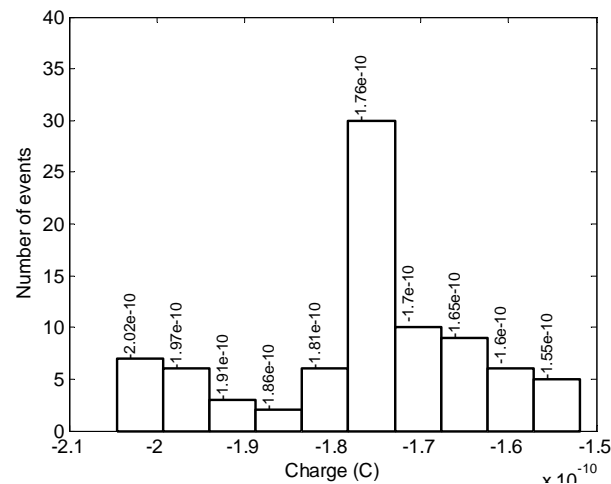
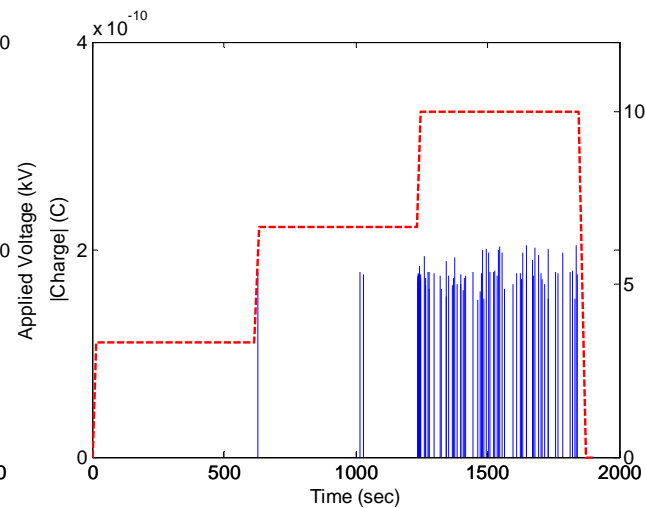
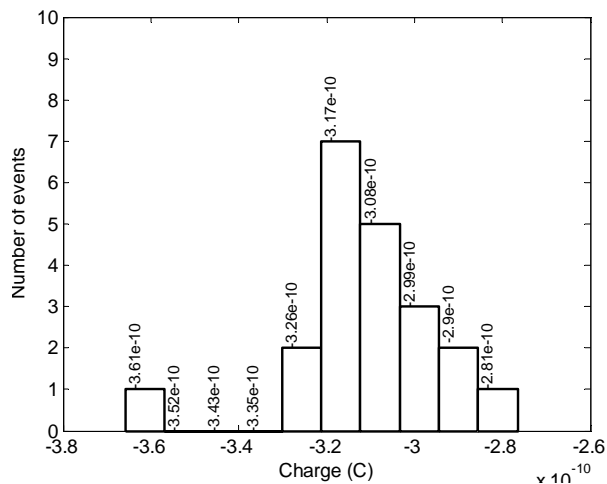
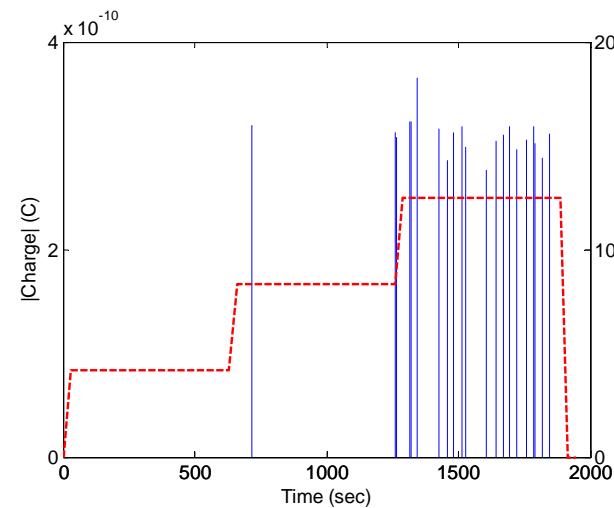
21 events @ V_R and $3V_R/2$

Surface

84 events @ V_R and $3V_R/2$

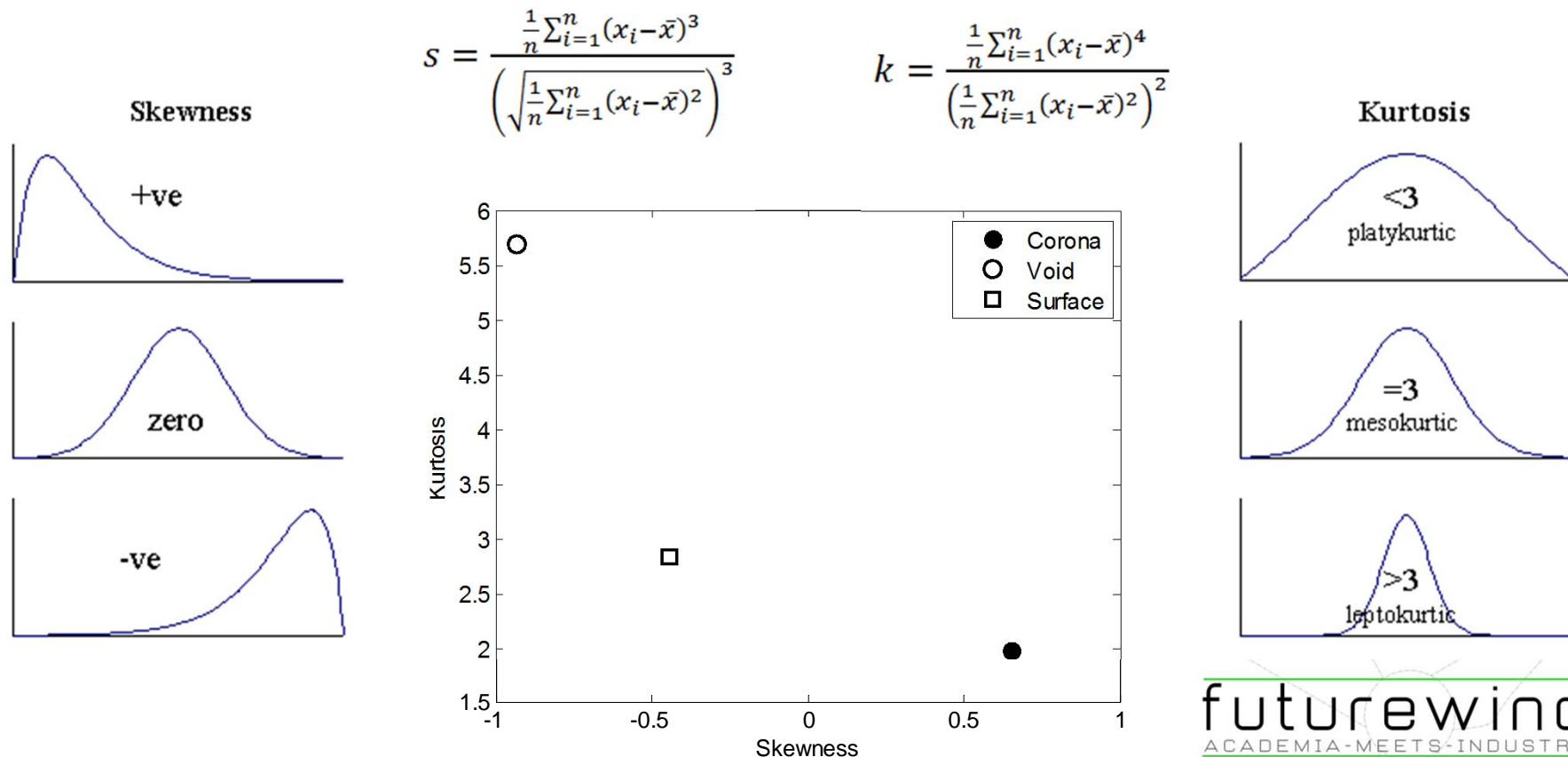
Corona

4k events 3.2 Sec @ V_R (4.2 kV)



Results - DC case

Methods were applied to the three data sets to assess the shape of the distributions namely skewness and kurtosis



Conclusion

- PD was apparent when the DC voltage was increased to $3/2$ times the peak AC inception voltage (V_R)
- PD under AC excitation was of larger magnitude and more frequent than under DC conditions
- DC PD testing requires longer term tests:
 - Tens of seconds under AC conditions
 - Tens of minutes under DC conditions
- The application of statistical methods can allow the mapping of PD activity from different sources

Future work

- Development of further DC PD analysis methods
- PD testing of further dielectric samples (AC and DC)
- Investigation of voltage ripple on PD activity

Questions



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