Differences between PD charges measured by Partial Discharge and Dielectric Spectroscopy systems

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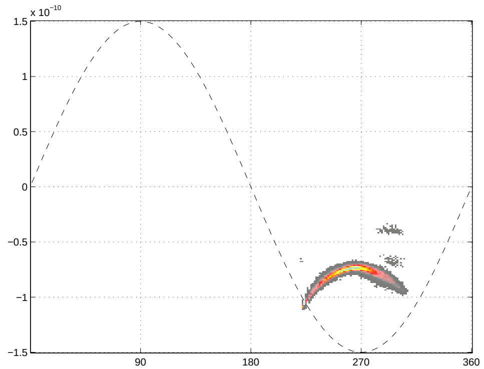
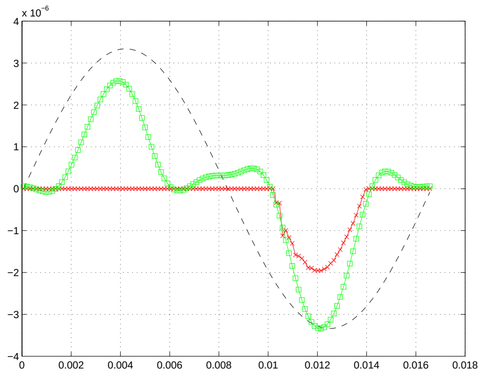




Overview

Partial **D**ischarge measurement: a common condition assessment method for HV insulation.

A PD event causes a change in potential of test-object electrodes. The currents that flow from an external source to restore the original potentials might be able to be measured as PD-pulses or as an extra component of the ‘smooth’ current in the dielectric (C', etc.).

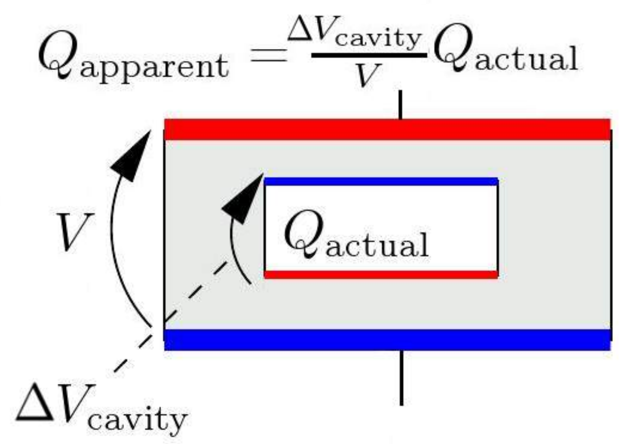
Particularly in large complex apparatus the different methods of measuring PD can give different results: these may give useful complementary information.

This work is a strand of a project on low-frequency diagnostics of HV stator insulation, hence an underlying bias to machines.

Similarity of PD and DS measurement of PD

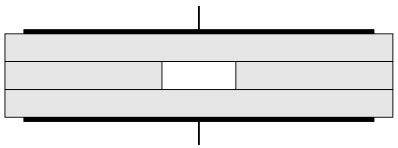
‘PD’ measurement: interest in HF, individual pulses.

‘DS’ (dielectric spectroscopy): total current ‘in’ insulation.



PD events or microscopic dielectric polarisation both change the dipole moments in the insulation; the PD differs in having lots of charges, moving relatively far, quickly.

Constructions: simple to complex



Repetition rate. Dynamic range. Resonance, reflection, attenuation.

Industrial Practice

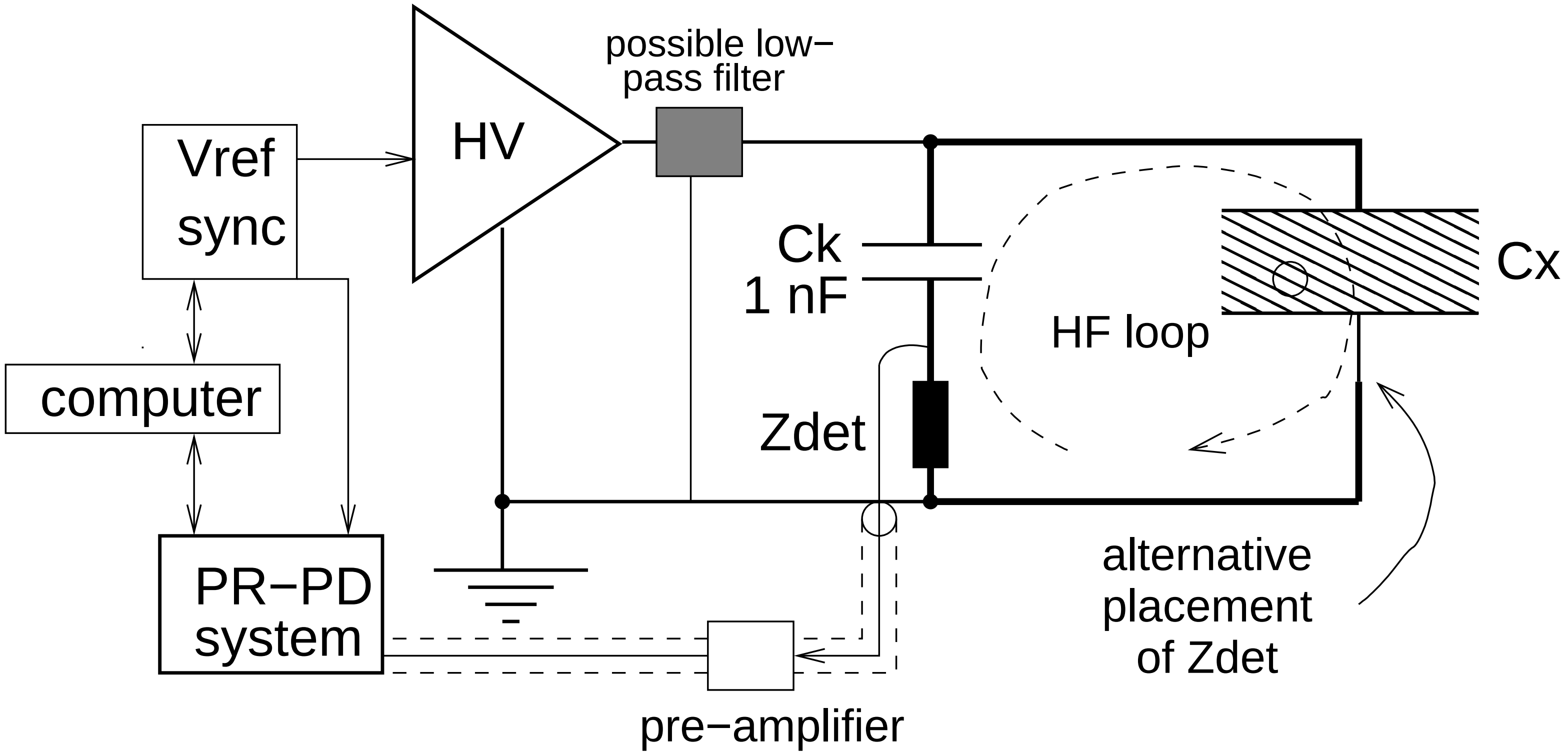
PD pulse measurement is widespread for machines and for many other types of equipment.

DS measurement in a pure sense (true interest in $i(t)$ or $I(\omega)$) has had success with transformers and cables but is uncommon for machines (end-winding grading?).

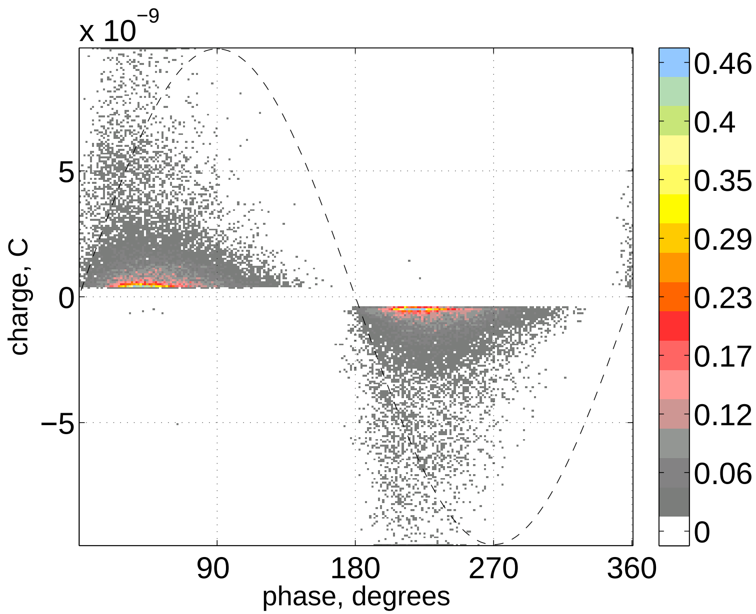
Stator 'tip-up' tests; increased current in the insulation beyond PD inception, could be seen as a primitive sort of DS; often this is viewed in fundamental-frequency form: C, $\tan\delta$.

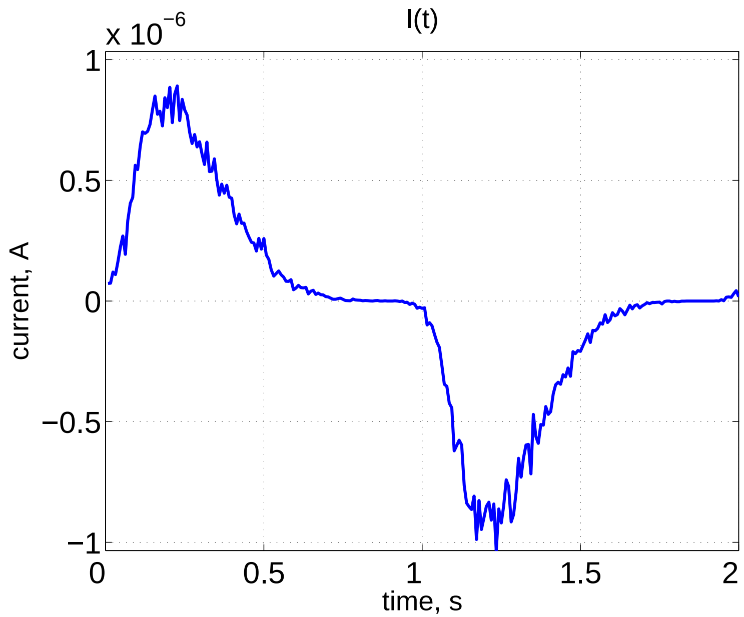
Stator insulation 'resistance', and polarisation index, could again be seen as a primitive form of (time-domain) DS.

PD pulse-measurement system



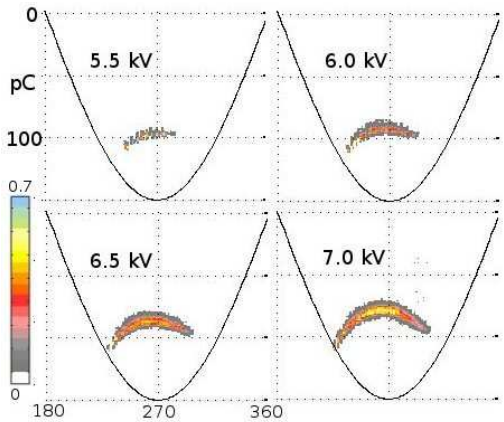
PD pulses $N(q,\phi)$ or mean current $i_{\mathrm{PD}}(\phi)$

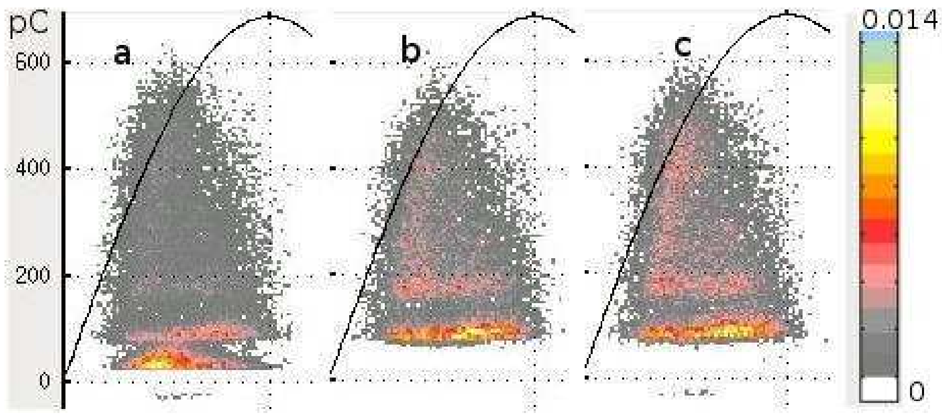




Phase-resolved pattern $\Longrightarrow$ Current ‘waveform’.

PD pulse-measurement troubles: Measurement System





High repetition rate: possibly many sources.

Dead-time: oscillatory response of detection circuit; limited speed of measurement system.

Dynamic range: different sources, time-lags, mechanisms.

Threshold: avoid noise, but lose small pulses too.

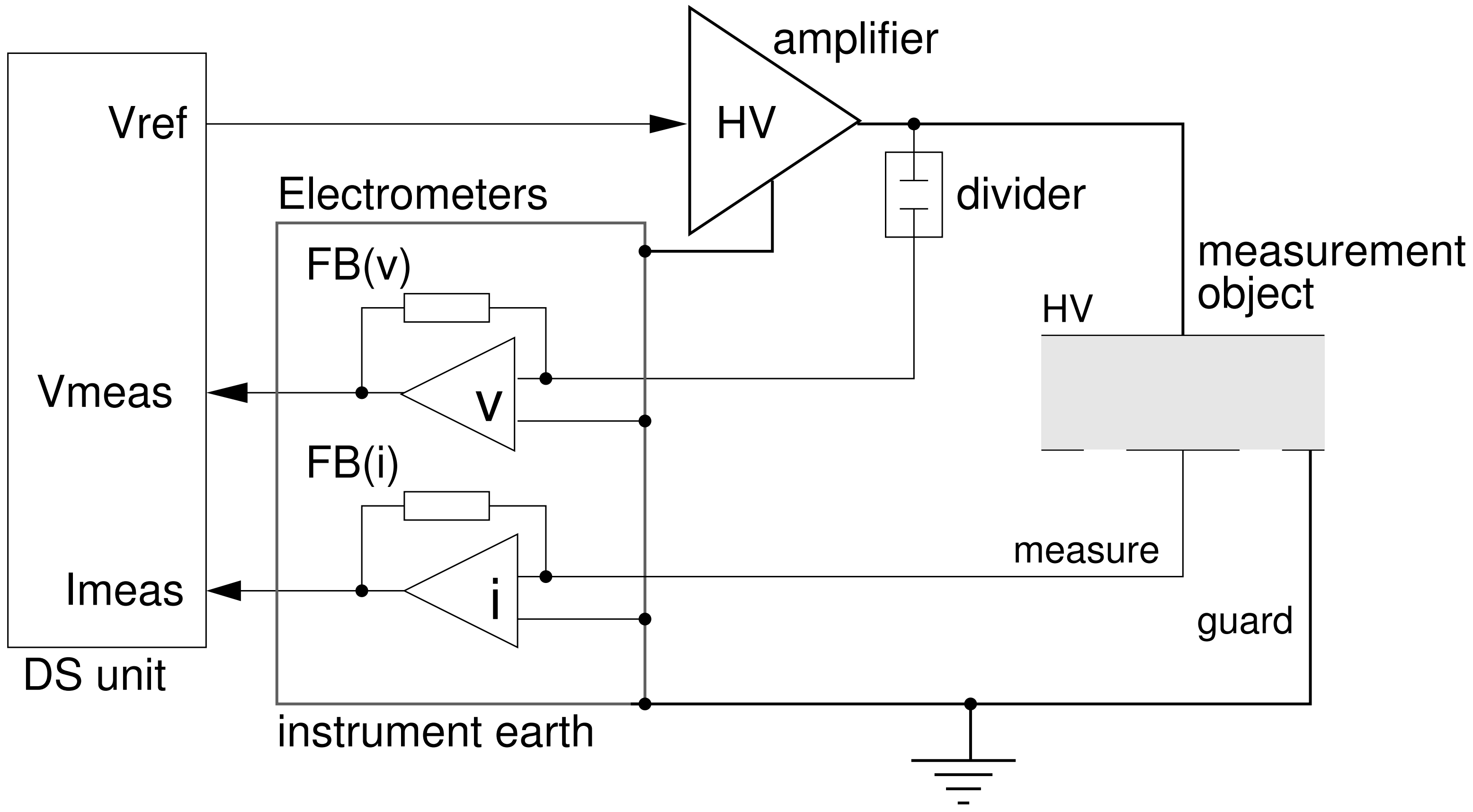
PD pulse-measurement troubles: Test Object

A stator winding is a very complex construction with inductance, capacitive coupling, different characteristics of the slot and end parts, surrounding iron core, ... The PD pulse seen at a terminal depends not only on the source but on its position. Calibration of stator PD measurements ‘can’t be done’.

High repetition rate. Measurement bandwidth is often low by comparison to pulse time.

PD in cavities in stator insulation can become more glow-like discharges after long periods of PD activity; it becomes less and less sharply detectable by pulse measurements, although the aging effect continues.

DS (integrated) current measurement



DS current: extraction of PD component

The measured current in the dielectric system includes conduction and polarisation in the bulk material and surface, as well as the polarisation effects of PD.

The component of the current due to PD may be calculated if the other components are linear: measure at a low voltage below PD-inception, then scale this current to the high voltage and subtract it from that current.

It is important to do these two measurements — above and below PD-inception — with the same measurement setup; small changes in measured quantities are being studied.

DS measurement of PD: troubles

PD pulses short compared to sampling rate of electrometer output?

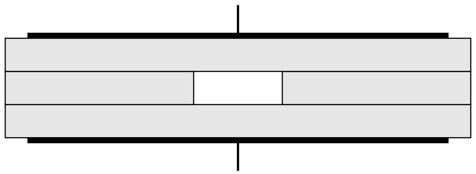
Paths for PD charge to leak from the circuit without full measurement?

All current in the insulation is included: the capacitive current will be far greater than the PD current.
(Stator insulation has, however, typically high PD; in our extreme case shown later, PD is $\approx 1\,\%$ of the total slot-region current.)

In some equipment, currents apart from the PD current could be assumed sinusoidal for a sinusoidal applied voltage. But in HV stators there is the end-winding stress grading, a nonlinear SiC-based coating.

Some measurements: DS & PD-pulse

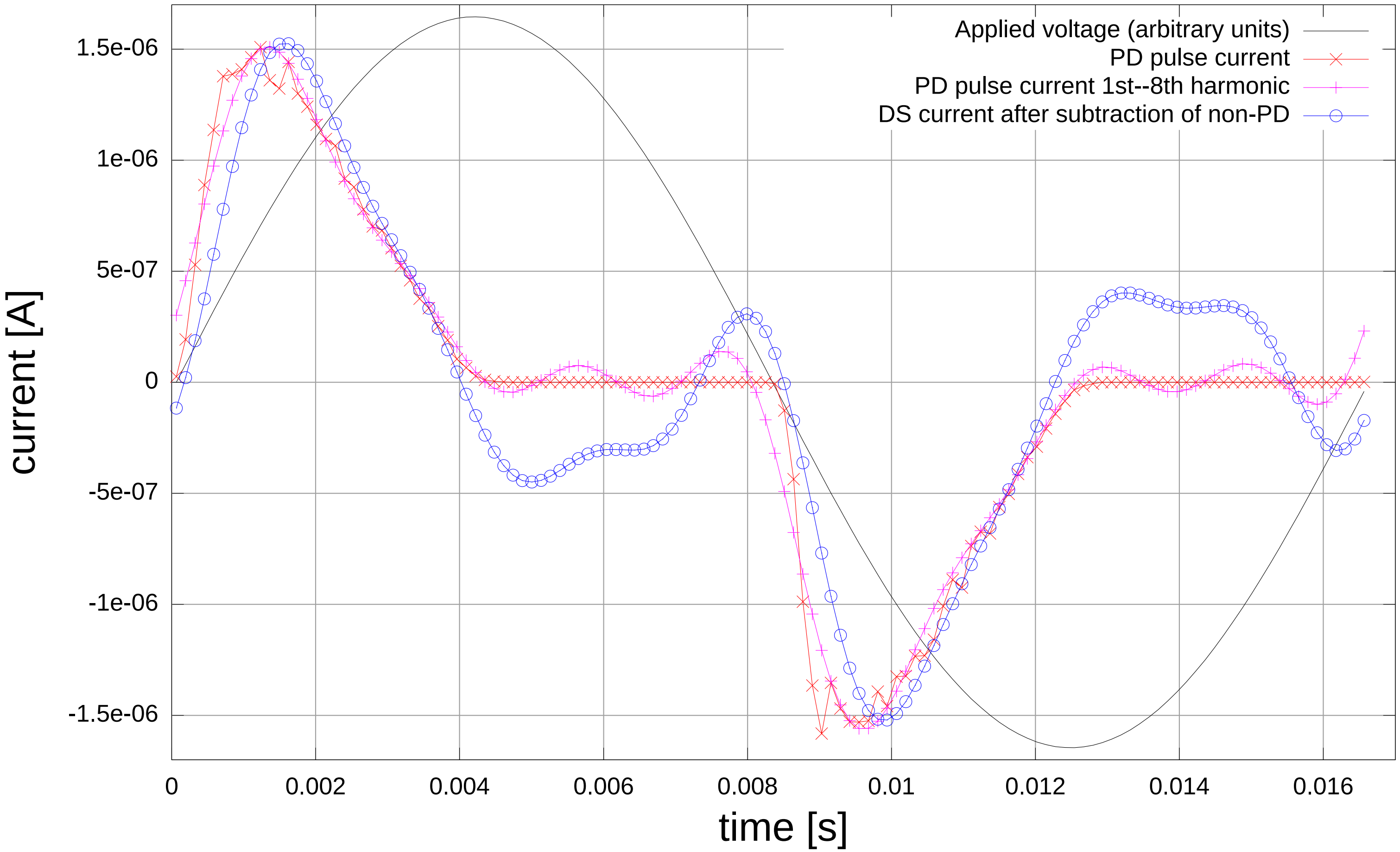
Three types of object: simple cavity or point; single stator coil.



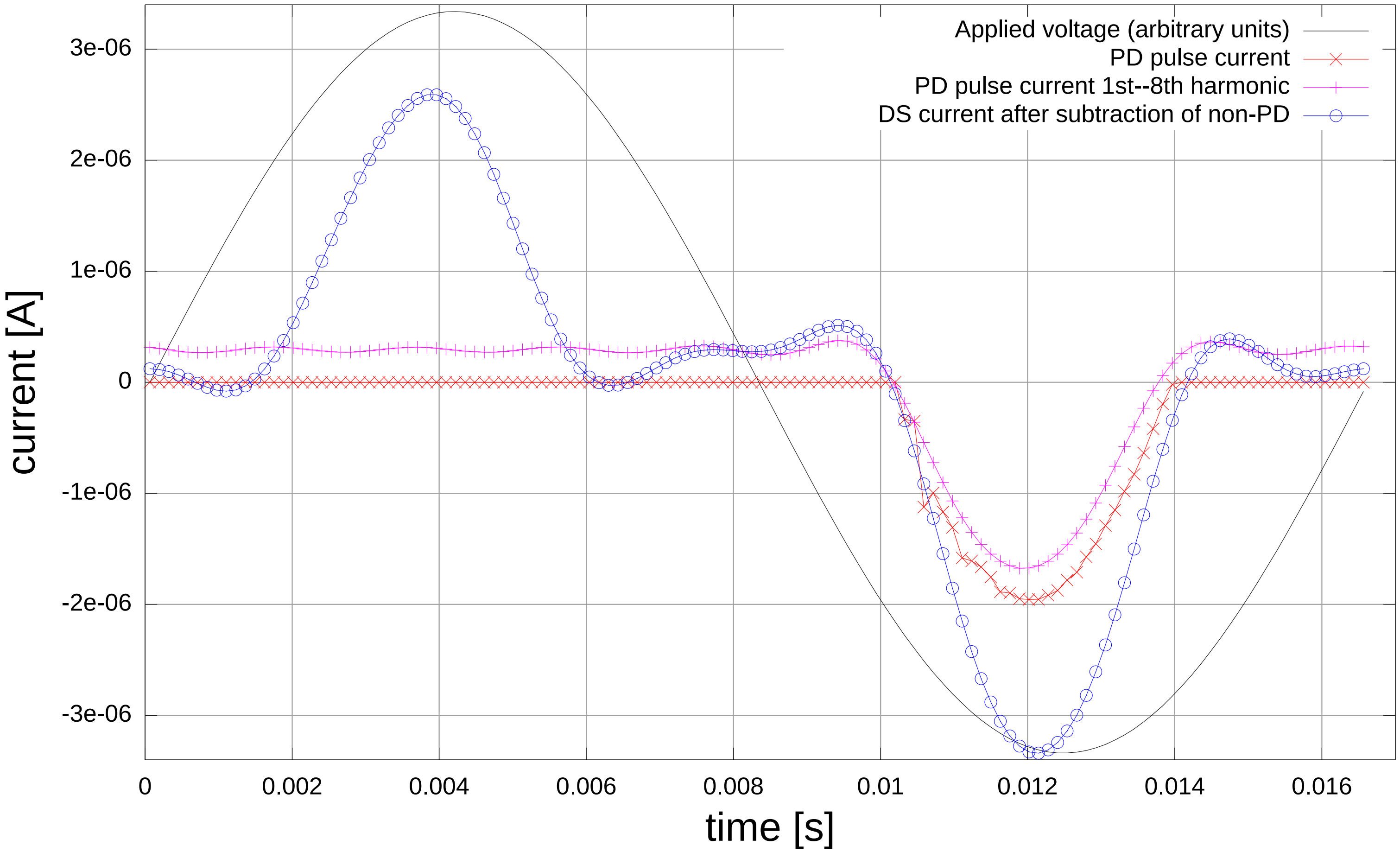
Simultaneous measurement of DS and PD-pulse for simple objects. (Separate measurement for coil.)

In each case, the DS measurement of PD current is done by removing an estimate of the large non-PD component based on a measurement well below inception voltage.

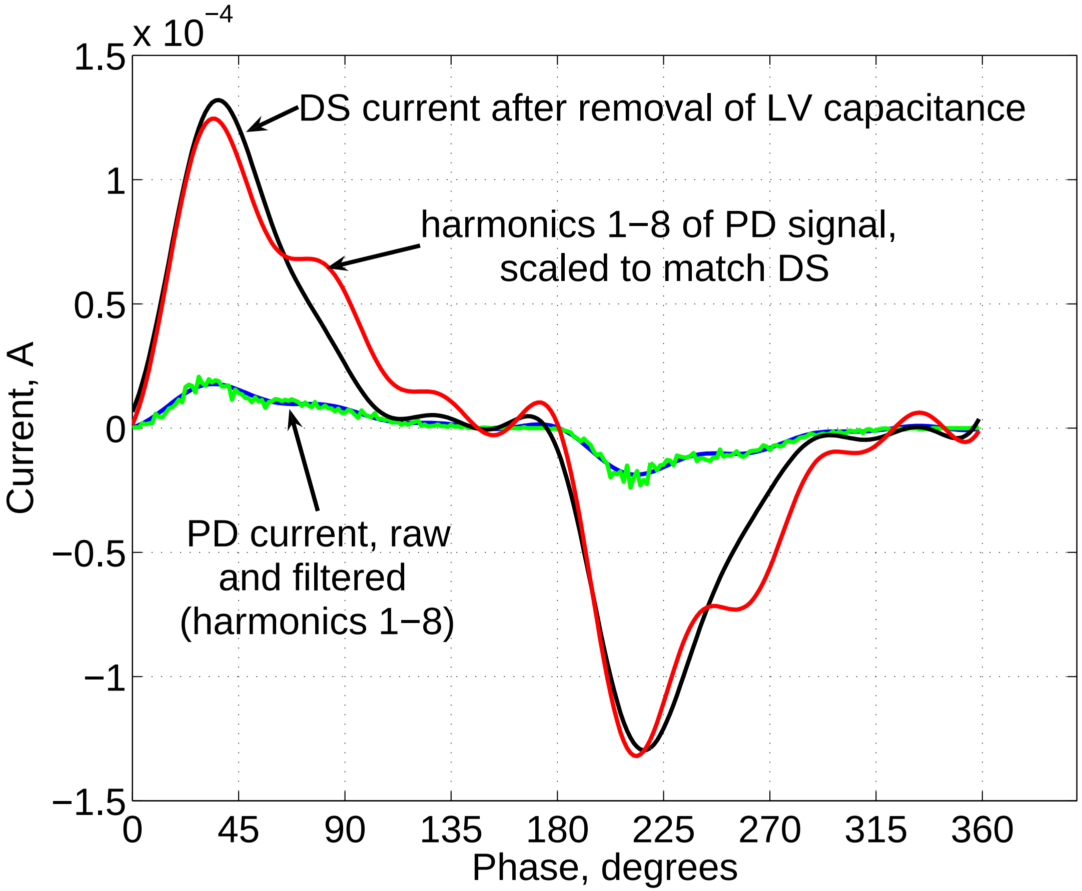
Cavity object (9 kV, 60 Hz)

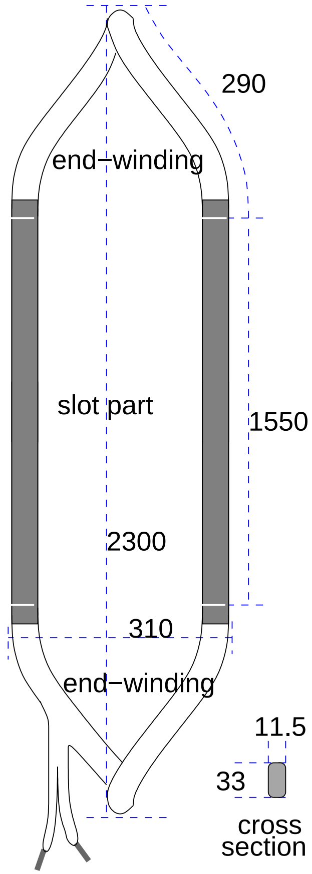


Point-hemisphere object (7 kV, 60 Hz)

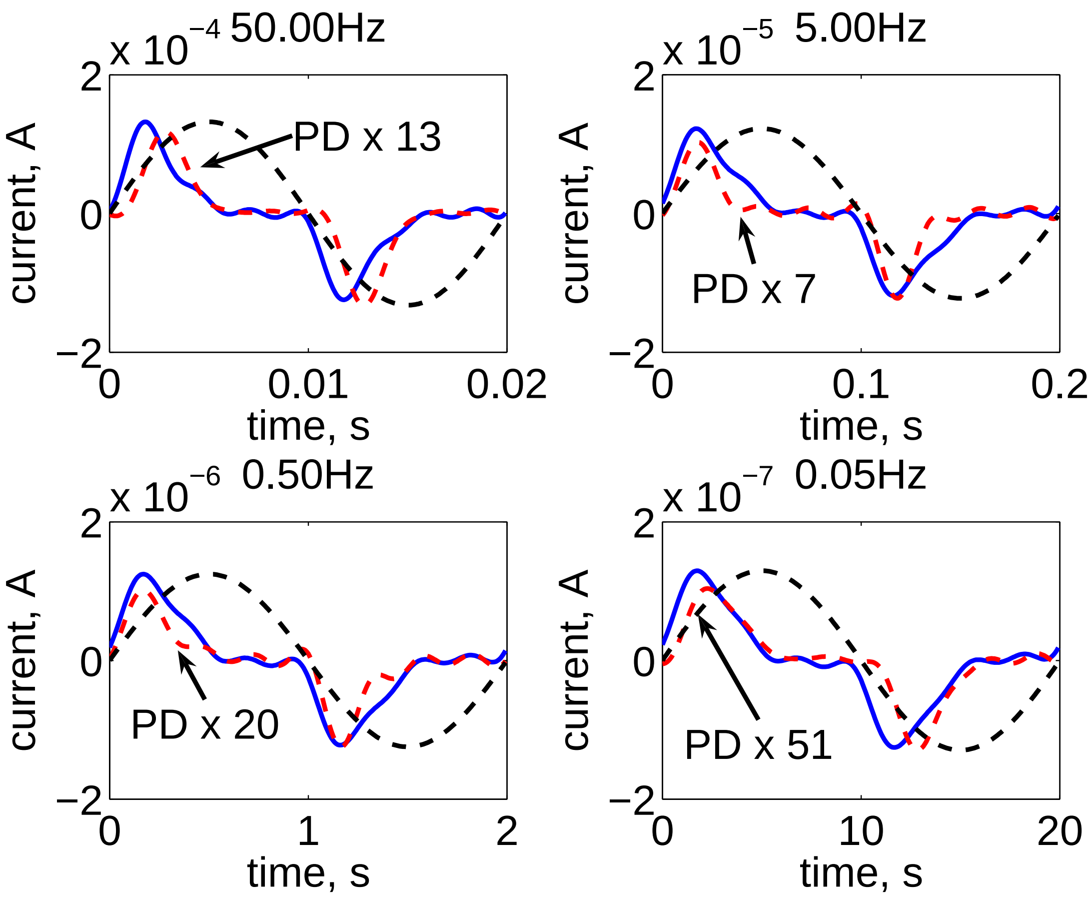


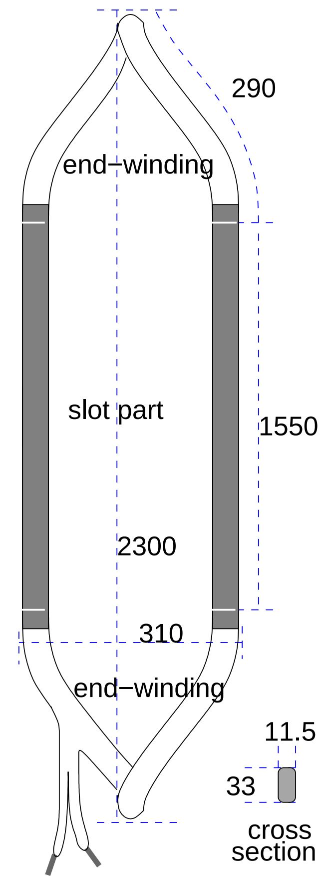
Single stator coil in air (8 kV, 50 Hz)





Variation in the relation DS to PD-pulse





Summary

Similar total PD apparent charge by DS and PD methods for ‘simple’ objects.

Large differences for complex objects (example: stator).

Frequency-domain DS with inclusion of some harmonics allows some of the PD distribution to be preserved.

Largest single pulses important $\Rightarrow$ need pulse method.

Total apparent charge important $\Rightarrow$ not pulse method for complex objects.
DS method has potential to measure on complex objects and glow-like PD.

For practical application to HV stator insulation, account needs to be taken of any nonlinear end-winding stress grading. The problem was avoided here by guarding, which is not practicable for whole windings.