# Partial Discharge Measurements in the Sub-VLF-Range

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## *ABSTRACT*

*By reducing the test voltage frequency, the physical stress on a potential PD defect inside a cable insulation or at interfaces in joints or terminations is consequently differing from power frequency stress. Nevertheless, VLF testing and VLF cable diagnosis are worldwide accepted tools for dielectric quality control. With further increasing cable length, as HV export cables (of some 10 or even some 100 kilometres) connecting offshore converters with the grid on land, the lower limit frequencies of VLF testing have to be discussed. When reducing the test voltage frequency finally to DC, the electrical field control of the cable system may be defeated, leading finally to a breakdown of the cable even without a failure. On the other hand, diagnostic parameters, as the partial discharge level or the PD inception voltage may also be determined with reduced VLF frequency. This paper describes the PD behaviour of typical cable defects at 50 Hz in comparison to VLF test voltages of 0.1 Hz down to 0.01 Hz. All typical PD defects could be identified by their PRPD patterns for all test frequencies. The 50 Hz patter was very comparable to the ones at 0.1 Hz and even 0.05 Hz, 0.02 Hz and 0.01 Hz. For the PDIV, a decreasing tendency could be found for decreasing test voltage frequencies. In particular, VLF 0.1 Hz measurements are sufficiently comparable to VLF measurements with further decreased test voltage frequency.*

## *KEYWORDS*

Partial Discharges, PD, Very Low Frequency, VLF, Cable Testing, Cable Diagnostic, Super-long cables.

## INTRODUCTION

Due to the high demand of capacitive power, high voltage cable testing is related to high effort, especially on site. With respect to this effort, the test voltage frequency can be varied from power frequency. For resonance test systems with fixed inductance the frequency range is extended from 20 Hz to 300 Hz [1]. But also power electronic operated test system with synthetically sinus shapes are admitted by testing standards. For medium voltage cables, VLF test voltage with 0.1 Hz is very common [2]. Nevertheless, with further increasing cable length even these extended frequency ranges have their limits, as on a cable test of a 74 km HV cable of ca. 18 µF capacitance, where a resonance test frequency of not more than 17 Hz was reached [3]. Finally, customers and test institute agreed to perform the test with this reduced frequency.

But also for the mobile VLF test systems the test frequency can be decreased in case of higher capacitive loads. As the mandatory test voltage level and testing time for VLF often is intensified compared to power frequency tests [2], a further reduction of the test frequency may consequently demand a further increase of test voltage level or testing time, in order to compensate the reduced number of high voltage test cycles applied to the test object. With focus on diagnostic measurements, the PD behaviour of high voltage cables tested with reduced frequency may also be of interested. Therefore, this paper focuses on the effect of the test voltage frequency of the phase resolved partial discharge diagrams (PRPD) and on other PD data, as the inception voltage (PDIV) and extinction voltage (PDEV).

## ALTERNATIVE TEST VOLTAGES

To bypass the problem of the large capacitive power demand of long cable systems, alternative test voltage shapes have been presented to the market. Damped AC (DAC) for instance, uses the resonance effect of the capacitive test object combined with the inductance of the test voltage generator. Here, the resulting test voltage frequency can be close to power frequency. As the amplitude of the outcoming oscillation is decreasing due to the internal losses of the test system, this voltage shape cannot be used for cable testing. Nevertheless, it can be used for PD tests, especially for PD location.

Combining a VLF rectangular test voltage with defined transitions from minus to plus, a 50 Hz behaviour of the test voltage cab be simulated with so-called CosRec test voltages, or “Slope 50 Hz” test voltages. With this voltage shape, cable testing is as well possible as PD location. The generation of phase resolved PRPD patterns is difficult here, as the 50 Hz slopes only covers a very short phase window (<1%) of the test voltage cycle.

## VLF GENERATOR

For these laboratory tests, a sinusoidal test voltage was used. With sinus test voltage, PRPD patterns can be generated and directly compared to 50 Hz patterns. VLF test voltage allows cable testing (withstand voltage test) as well as PD location and other diagnostic measurements. The HV test voltage was generated by an HVA 120 VLF test system [4]. This VLF generator can provide sinus voltage with up to 85 $kV_{RMS}$ to a capacitive load of up to 5 µF.

## PD SYSTEM

PD tests were recorded and analysed with the MPD 600 system [5]. As this system was originally designed for test voltage frequencies clearly above the VLF range, there are some limitations which have to be kept in mind.