Comparison and Evaluation of Deconvolution Techniques for Processing Space Charge Measurement Data

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ABSTRACT

The pulsed electro-acoustic method (PEA) is a widely used measurement technique to analyze space charge formation in polymeric HVDC materials. Because the obtained data does not directly correspondent with space charges in the sample a deconvolution step is necessary. To analyze the performance of different deconvolution techniques, measurement data is deconvolved using a Gaussian filter and/or a Wiener filter. The results are compared and evaluated based on physical parameters. An iterative method is introduced to ensure the comparability of the results. Finally, recommendations for the deconvolution of PEA measurement data are made.

KEYWORDS

Deconvolution, Wiener filter, regularization, Gaussian filter, spectral division, pulsed electro-acoustic method, PEA, signal processing, space charge, HVDC, XLPE cable

INTRODUCTION

Within the scope of energy transmission, high voltage direct current (HVDC) transmission systems and especially HVDC cable systems become more and more important worldwide [1]. Especially in Germany HVDC cables are an anticipated key technology for the grid development within the German Energy Transition [2]. Because of different advantages, such as higher permanent operation temperatures up to $90°C$ and more simple installation of cable accessories in comparison to oil-paper insulated cables, extruded cables gain more relevance [1]. The used polymeric materials tend to accumulate space charges, which represent the main reason for field enhancement effects in HVDC insulation systems [1, 3, 4]. To analyze these space charge induced effects in materials used for HVDC cables and its accessories, the pulsed electro-acoustic method (PEA) is a proven measurement technique [1, 5–7]. One of the most relevant parts in processing space charge data is the deconvolution, which is necessary to remove the influence of the transmission path on the space charge signal. Because of the ill-posedness of the deconvolution problem, high frequency components are amplified during this data processing step, so that filtering is necessary to obtain solutions with physical meaning. [8, 9] This point is assessed in the present work: According to the procedure in the technical specification [10] the use of a Gaussian filter in the course of the Spectral Division method is recommended. This proceed is found in latest literature also [11, 12]. Instead of Gaussian filtering only, two further approaches find application in literature: A Wiener filter [9, 13] and a simultaneous usage of Gaussian and Wiener [14, 15].

The aim of this investigation is a comparison and evaluation of those different deconvolution techniques leading to helpful advice which method to choose for processing space charge data gained by the PEA method. Therefore, a study on real measurement data is performed, in which the identified methods are applied. In a first step the basic measurement principle of PEA measuring cells for flat samples is explained. Subsequent, the relevant deconvolution techniques will be presented, shortly. Then the results are compared successively and the deconvolution methods are evaluated which is followed by a conclusion and outlook.

SPACE CHARGE MESASUREMENT AND DECONVOLUTION

Space charge measurement procedure

A schematic illustration of the PEA measurement procedure is given in Figure 1. The sample is charged via an HV-source and an impulse generator. The HV-source gives an HVDC output voltage while the impulse generator has narrow voltage pulses as output signals. The short electrical pulses stimulate occurring space charges in the test sample (cable insulation material) to emit acoustic waves travelling through the ground electrode, which are transformed back into an electrical signal by a piezoelectric device (PVDF-transducer). After that, the signal is amplified and recorded via an oscilloscope. The measurement data is processed on a PC where the deconvolution procedure is performed to obtain a physical space charge signal. A more detailed overview can be found in [1, 6, 7, 10].

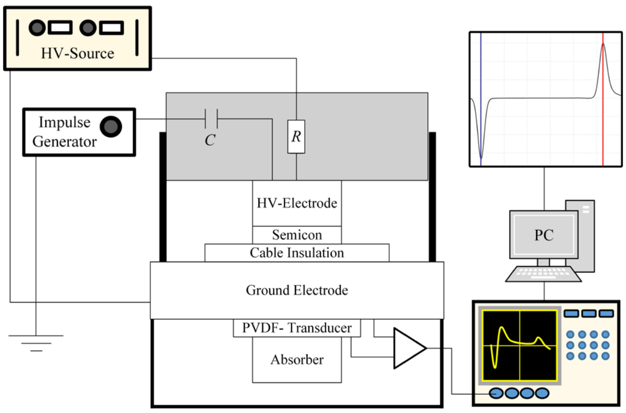

Fig. 1: PEA measurement setup – schematic illustration

To receive the space charge density $\rho(t)$ from the measured voltage signal $v(t)$, the influence of the transfer function $h_{PEA}(t)$ has to be removed.