Electrical Power and Energy Systems 88 (2017) 141–149

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Effect of acquisition parameters on equivalent time and equivalent bandwidth algorithms for partial discharge clustering

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ARTICLE INFO

Article history:
Received 26 August 2016
Received in revised form 16 November 2016
Accepted 26 December 2016

Keywords:
Partial discharges
Clustering techniques
Phase resolved partial discharge pattern
Equivalent time
Equivalent bandwidth

ABSTRACT

The acquisition parameters of an unconventional Partial Discharge (PD) measuring system affect the way the PD pulses are recorded and in turn, the results of the data processing. The noise based on the oscilloscope's vertical resolution is a feature of the sampled signal that is always present when a digital acquisition system is used. In PD unconventional systems, several parameters such as the sampling frequency Fs, the acquisition time T, the number of samples N and the vertical resolution VR of the digitizer result in a wide oscilloscope-based noise variation, that could be quantified by the signal to noise ratio (snr).

The classification map is a tool that came available with the development of unconventional systems, that due to their wide bandwidth are able to resolve PD pulses in time and apply clustering techniques for PD source separation. The equivalent time T_{eq} and equivalent bandwidth W_{eq}, used to plot the classification map, attempts to extract features of the PD pulses to form clusters so that classification of sources can be achieved. The classification map is based on the ability of separating PD sources by resorting to the parameters T_{eq} and W_{eq}, that are believed to show significant differences for distinct PD sources, while they are clearly consistent for the same source.

This paper conducts a set of theoretical analysis and laboratory measurements to evaluate the influence of the oscilloscope-based noise on the results of T_{eq} and W_{eq}. The results proved that the classification map is heavily influenced by the signal to noise ratio.

1. Introduction

Partial discharge (PD) measurements are successfully used for diagnostics and monitoring of high voltage equipment. The technique finds a broad application scope by taking advantage of many of the physical properties that can be detected or measured from a PD event. Depending on the device under test, measurements are based on detection of acoustic emissions, chemical byproducts or current/voltage pulses in an external circuit [1]. The electrical method, i.e. the recording and processing of an electric signal induced in a detection circuit, is the most frequently used technique for detection and quantification of the PD magnitudes.

Since the PD signals occur as fast pulses having a duration of much less than the period of the power frequency waveform, specific requirements regarding the bandwidth of the measuring systems are to be met depending on the PD parameter of interest. Test and measuring circuits for apparent charge, in compliance with IEC60270 requirements, are described in [2] and are referred to as conventional systems. With such an instrument is also possible to compute phase resolved PD patters (PRPD) as a tool to assist in the recognition of PD sources. This is based on the fact that each PD source can be linked to a particular pattern (some examples of PRPD patterns are shown in [3]). If just a single source is active, the recognition process through the PRPD patterns is an easy task that can be achieved by an expert or even by an automatized system [4]. When multiples sources are active, the recognition of sources is no longer possible by resorting to a database of well-identified patterns for single sources. In these cases, a large number of unconventional test circuits have been researched. Typically, unconventional test circuits have extended the bandwidth of the measuring systems up to the MHz range or even GHz range. A bandwidth increase has the advantage of approaching the PD pulse shape. Conversely, in conventional systems the pulse phase occurrence and the pulse charge are the only two measured parameters that are acquired from each single pulse.

Unconventional systems became available with the development of modern wideband digitizers that are able to record and store thousands of individual pulses for further processing. Having the pulses resolved in time, the research efforts have been directed

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http://dx.doi.org/10.1016/j.ijepes.2016.12.017
0142-0615/

towards what is referred to as *feature extraction*. Assumptions are made that PD pulses coming from the same source should have similar shapes. Therefore, from the clustering point of view, the objective is to find any collection of features that show significant differences for distinct PD sources, while being clearly consistent for the same source, so that clusters can be formed in a plot. This approach has come up with different techniques to separate and recognize PD sources. Ranging from [5–10] all these techniques also deal with the need of detecting and cancelling external signals (noise) coupled to the measuring circuit. In on-field testing, noise, disturbances and interferences can give rise to complex PRPD patterns or clusters, leading to misleading interpretations.

Although each technique has proven to be suitable and even when they have gained practical application, it might be still difficult to compare results from different techniques and measuring devices. This has much to do with the PD-phenomena itself. Being a PD pulse an event that cannot be measured directly, but only the response of a detection circuit, then the results from a digital PD system become strongly affected by the particular parameters of each measuring system; detection circuit plus acquisition unit.

This paper aims to research several factors affecting the equivalent time and equivalent bandwidth cluster of the PD pulses (also referred to as *classification map*), taking into account the noise based on the vertical resolution of the acquisition system. To show the influence of the acquisition parameters, the results of a theoretical analysis and lab measurements are described in the following sections.

2. Set-up description

Measurements were conducted by means of an unconventional PD system comprised of a high frequency current transformer (HFCT) type sensor having a bandwidth of 34.4 kHz–60 MHz and two acquisition units. The first one was based on a high performance oscilloscope Tektronix DPO7354C with 8 bits of vertical resolution and maximum sampling frequency of 40 GS/s. The second one was a PXI acquisition card from National Instruments with 12 bits of vertical resolution and 200 MS/s sampling rate. The measuring circuit is shown in Fig. 1.

Acquisition parameters such as sampling frequency, vertical range and sampling period were then varied depending on the requirements of the test object. The high performance oscilloscope has some desirable features like for instance a 'Fast Frame Acquisition Mode' with enhanced capabilities for pulsed signal recording. Using this feature, the trigger rearming time is normally below 1 μs, which avoids to miss much PD pulses that arrive narrowly spaced. Once a PD pulse has fired the trigger level, a number of N samples are recorded. Each recorded pulse is called a frame. The maximum number of recorded frames depends on the sampling frequency and the sampling period.

The testing program included the use of electrodes for laboratory measurements of corona discharges, surface discharges and free moving particle type discharges. Dimensions and other details related to the electrodes can be found in [11].

Data processing was achieved by means of a software tool developed by TU Delft for the purposes of the test platform reported in [11]. Both the synchronization and the PD pulse signals

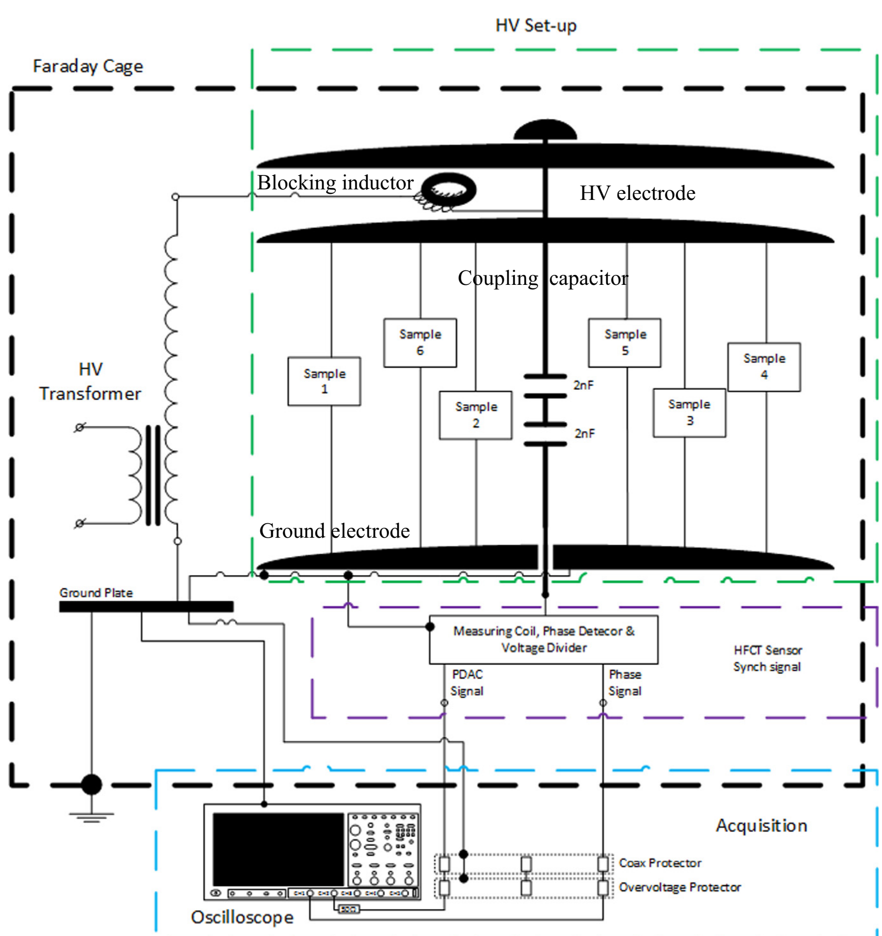

Fig. 1. Scheme of the partial discharge test platform.