DIAGNOSTICS OF MEDIUM VOLTAGE CABLE SYSTEMS USING VERY LOW FREQUENCY

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ABSTRACT

This paper discusses a practical issue that arise when testing healthy and unhealthy cables by using Very Low Frequency (VLF). This issue is the Partial Discharge (PD). This study based on data from laboratory experiments and field testing. Partial discharge will be measured on 12/20 kV cables with power frequency, DC as well as with VLF. These cables are mainly used in medium voltage distribution network in Egypt. Cavities with different dimensions used as artificial defects to simulate the unhealthy case. The ability of using VLF to detect the partial discharge activities as an alternative for both of DC and AC of power frequency has been investigated.

INTRODUCTION

Medium voltage distribution cables and their accessories form an essential part of the power delivery systems. Many of these systems employ insulating materials that have superior insulation properties such as Cross Linked Poly Ethylene (XLPE). With aging of the insulating system, its dielectric properties change so that they could be used to provide a convenient way for monitoring the degradation of the system insulation. In the past, it was generally not practicable to conduct the testing of cables using AC voltage as large capacity is needed to charge up the cable to the required level, so cables were tested by DC voltage. This type of voltage leads to growth of water trees, especially with cables insulated with XLPE. This constraint had since been overcome with the introduction of Very Low Frequency (VLF) testing technique [1]. Very low frequency (VLF) systems seem to provide results that are more accurate than those obtained using higher frequencies [2]. The advantage of very low frequency test voltages is the low demand of reactive power which leads to smaller and lighter test devices with optimal mobility under on-site conditions [3]. AC testing conducted at 0.1 Hz will require a capacity of only 1/500 of that of 50 Hz. On the other hand, the rate of channel growth is about twice that of test performed under power frequency [4]. In practice it is convenient to measure the dielectric properties at VLF of 0.1 Hz; this value reduces both size and power requirements of the testing voltage source; in addition to increasing the resolution of the measured value of the insulation losses. Although the power frequency is 50 Hz, on-site testing is often performed with lower test voltage frequencies as 0.1 Hz with sinusoidal voltage shape [5,6]. Using VLF test voltage sources lead to reduction in system size and weight and more important to lower system costs. Several standards such as VDE, CENELEC and IEEE 400.2-2004 have adopted the VLF site-test being adequate for medium cable after laying commissioning and diagnosis test methods [7]. The future IEC 60060-3 standard on High Voltage Test Techniques recommends the alternative methods voltage with sinusoidal very low frequency range of 0.01 Hz to 0.1 Hz as a voltage test and for diagnostic tests such partial discharge measurement and dissipation factor measurement [8].

TECHNICAL REASONS FOR USING VLF

- Weight and volume of test equipment - mobility for field application - higher efficiency in finding insulation defects.
- Higher sensitive and precision on PD measurement compared to power frequency or oscillating wave.
- Diagnostic efficiency, using true sinusoidal HV source for PD measurements.
- Fault distance monitoring during commissioning and proof tests with PD monitoring.
- VLF testing is far more effective than DC.
- DC may produce space charges in the dry cable insulation with long term damage to the cable.

TEST VOLTAGE SOURCE

The VLF test voltage with frequency range between 0.01 Hz to 0.1 Hz was generated with a commercial mobile VLF generator.

Fig. 1: Portable VLF test set

This generator has a very low noise level, so sensitive PD measurements could be performed. The generator has three shapes of output voltage, VLF true sinusoidal of 24 kV_{eff} , VLF rectangular of 34 kV peak and DC voltage of ± 34 kV

PARTIAL DISCHARGE MEASUREMENT

The term partial discharge (PD) refers to a discharge that does not completely bridge the space between the electrodes. It is not always possible to prevent minor manufacturing faults, cavities or in homogenates in the insulating material causing weak points. These weak points can cause over stressing by the electric field. This can lead to extremely rapidly progressing local electric discharge, i.e. electric partial discharge. For decades the PD measurement and the location was based on time base propagation fault location and it has been the most important and efficient non-destructive method [9]. The quality and the lifetime of the insulation can be assessed. PD measurement on- site using adequate filtering and sensitivity starting at several Pico Coulombs (pC) today are commercially available. For PD measurement onsite, compared to laboratory, different requirements have to be fulfilled. The absolute magnitude of PD level itself is not as important as that one from laboratory measurements. Even more interesting is the location of PD sources. In most cases the PD does not result from the internal cable insulation, but from the accessories like joints and terminations. Therefore the source location becomes more important. With partial discharge measurement one can prevent local mounting faults or electrical trees to prevent incipient faults [10].

PARTIAL DISCHARGE MEASURING SYSTEM

The measurements of the PD have been executed using the MPD 540 as it's well known diagnosis instrument. The MPD 540 Partial Discharge Analysis System is an acquisition and analysis toolkit for detecting, recording, and analysing partial discharge events in many applications.

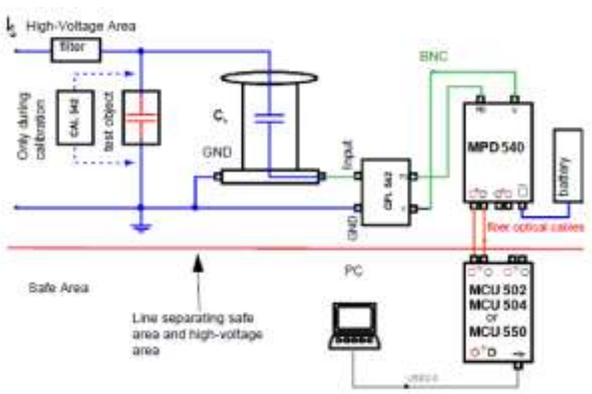

Fig. 2: Circuit diagram of MPD 540 tool kit.

It is suited for laboratory and on-site measurements of high-voltage systems such as power transformers and rotating machines. It is controlled by the integrated MPD/MI software featuring real-time visualization and analysis options of PD detection and system parameters.

The PD signals are filtered, amplified and digitized. Having an amplitude quantization of 14 bit and a sampling rate of 64 MS/s, the time accuracy of detection of a PD signal is at about 2 ns. The quasi-integration is realized by a digital band-pass filter. The centre frequency for the digital filter can be chosen in a frequency range from DC up to 20 MHz, the bandwidth between 9 kHz and 3 MHz, respectively.
Hence an optimal frequency band can be chosen to avoid disturbances and to reach a high SNR even under noisy conditions on site. Furthermore, the test voltage signal is digitized in the acquisition unit to document the test voltage during the PD measurement (see figure 3).

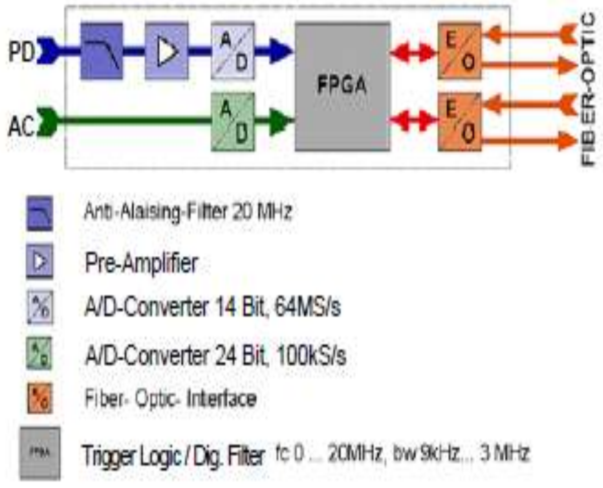

Fig. 3: Block diagram of the acquisition unit of MPD 540.

TEST SAMPLES

In order to investigate the ability of Very Low Frequency (VLF) to detect hidden defects in cables, 6 m cable length of 12/20 kV, 1*70 mm^2, XLPE were used as test objects. The first sample was healthy without any defects and was produced in Oct., 2011. The second sample was not healthy and it has an artificial cavity made by drill at the middle of the cable. The cavity was 3 mm depth in XLPE and 4 mm diameter and it has the same production date.

PRACTICAL RESULTS ON PD DIAGNOSIS

1-The first sample (Cable with cavity)

The cable was subjected to AC voltage with VLF of 0.1 Hz, AC voltage with frequency of 50 Hz and DC voltage.

In each case the voltage was increased from 5 kV to 24 kV ($2U_0$) in steps and the maximum value of PD was measured at each step. For example, at 12 kV the value of PD was 1.927 nC which was very high if compared to 50 Hz (1.6 nC) and DC (39.8 pC). In fig. 4 it is clear that the VLF voltage is more sensitive than the 50 Hz and DC voltage. The main reason lies in the much higher discharge capacity at power frequency compared to VLF. The number of discharges decreases per unit of time proportionally to the frequency applied which agrees with reference [11].

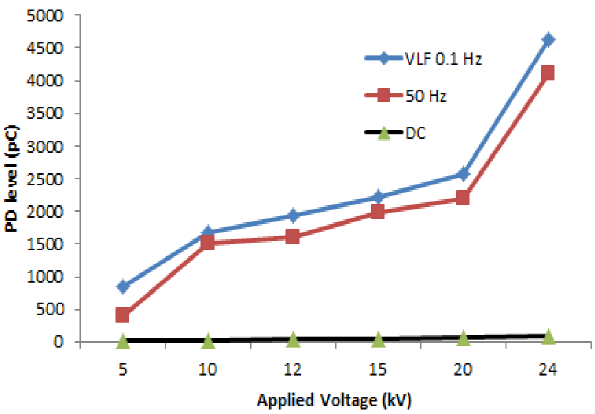

Fig. 4: Effect of applied voltage on magnitude of PD.

2-The second sample (Cable without cavity)

Here the cable was subjected to AC voltage with Very Low Frequency (VLF) of 0.01 and 0.1 Hz, sinusoidal and rectangular wave shapes. Also it was subjected to 50 Hz and DC voltage. The same procedure was followed as in the first sample. The 0.1 Hz rectangular gives higher results compared to the other wave shapes as shown in figure (5).

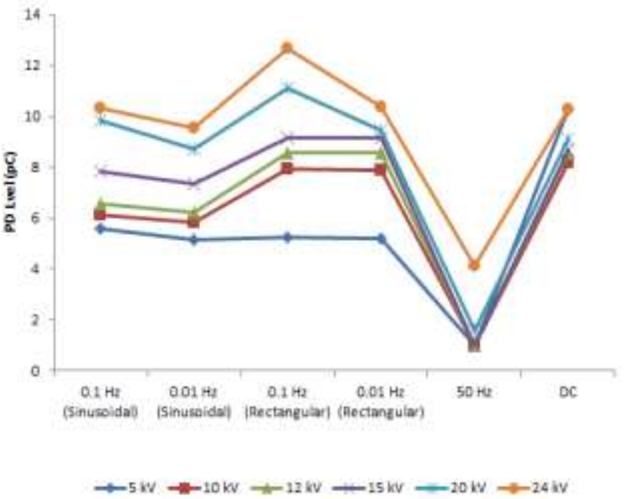

Fig. 5: Effect of different applied frequencies on magnitude of PD.

In fig. (5) As the applied voltage increases, the PD magnitude increases. The VLF value and voltage wave shape affect on the PD magnitude.

CONCLUSION

Partial discharge (PD) is a diagnosis tool for on-site tests of cables which can improve the reliability and extend the lifetime of the whole cable system. The VLF test voltage is much more sensitive to detect hidden failures compared to power frequency and DC test voltages. Also it can be stated that PD measurements performed with VLF voltage lead to better results which reflect the cable condition.

Acknowledgment

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