Partial Discharge Measurement with the Extended Resolution Analyser

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Abstract: **Partial discharge measurement techniques and methods are of direct concern in the validation experiments and interpretation of the PD phenomenon. Many limitations and errors in the measurements have been a topics of discussion for a long time. The paper proposes a simple method to overcome the problems with the use of computer-based instrumentation and also experimental validations of the proposed method. The authors demonstrate the superior ability of their measurement technique to resolve PD pulses independent of the PD detector and to correct the superposition error which exists when PD pulses overlap.**

1 Introduction

Partial discharge (PD) measurement and interpretation for insulation diagnostic work is challenging as ever. The present day instrumentation technology allows for automation with computer-aided methods for measurement and analyses. In the recent past, many researchers have drawn the attention to the practice of quasi-integration technique of PD measurement, its limits [1,2], the standards for measurement [1], and probable futuristic technique using the advantage of digital technology [3]. Other popular technique is the ultra-wide band measurement of PD pulse where the integration of the PD pulse in the time domain is performed. This technique is mainly used for pulse shape studies [4] and requires a careful design of the measurement system capable of high bandwidth measurement. For pulse height distribution studies using this technique, a continuous acquisition for the desired time interval is required bringing forth a need of a comparatively sophisticated instrumentation to take care of the limits identified in the quasi-integration technique. The authors have proposed a simple method with Extended Resolution Analyser (XRA) for PD measurement using the conventional PD detector [5] which takes care of the limits one find with the quasi-integration technique. This paper gives the implementation of the XRA, calibration tests for the XRA and experiments which show the advantage of the XRA.

2 Implementation of the Extended Resolution Analyser

2.1 Hardware block details

The block diagram of the XRA connected to the PD measurement circuit is given in Figure 1. The XRA has an auxillary detector which is a wide band PD detector built-in with the PD data acquisition system. The measuring impedance or the quadrapole output is connected to the conventional PD detector called as the main detector as well as to the XRA (auxillary detector). The quasi-integration of the PD pulse is performed by the conventional PD detector and it can be a narrow band detector or a wide band detector. The auxillary detector operates the phase detection system of the PD analyser which is a digital counter circuitry counting the time elapsed from the zero-detection of mains (applied voltage). The phase information is latched for every pulse detected by the auxillary detector and then transfered to the memory (buffer) for intermediate storage. The phase information is contained in 15bit data and another bit as a phase data identification flag giving a two byte data for phase. For every PD pulse detected, the control circuit generates the start of conversion (SOC) signal for the ADC (12 bit) used in a bi-polar mode, to digitise the peak of the main detector response. The delay from the PD pulse detection to the peak of the main detector response is adjusted by the calibration algorithm which operates a programmable monoshot implemented with a peripheral chip 8253 interfaced to the PC. The ADC, thus samples the main detector response at the expected time to peak. The digitised data is then transfered to the memory with identifier flag as pulse height data. The PC reads the data from

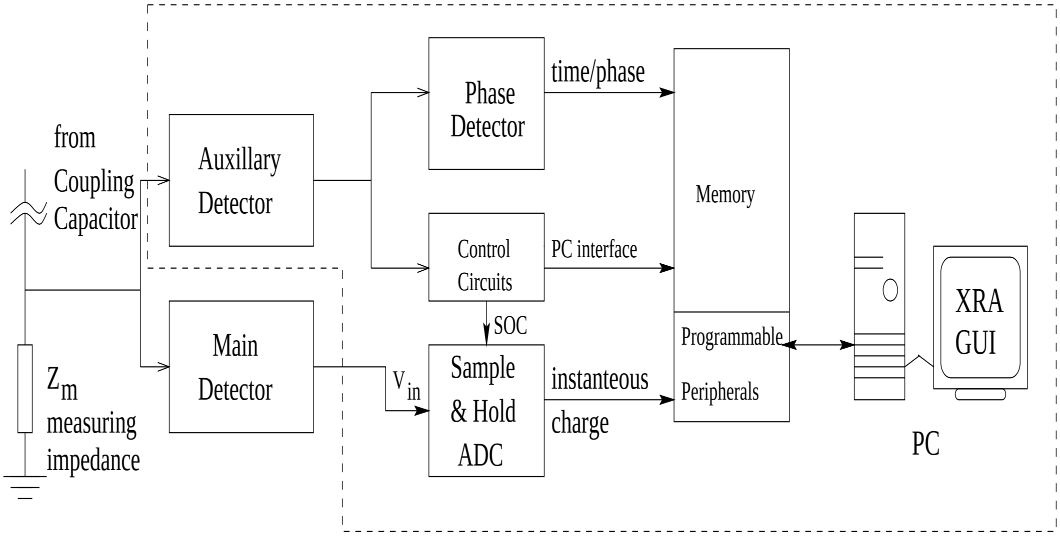


Figure 1: Block Diagram of the Extended Resolution Analyser

the onboard memory at regular intervals. The data I/O is managed with another programmable peripheral 8255.

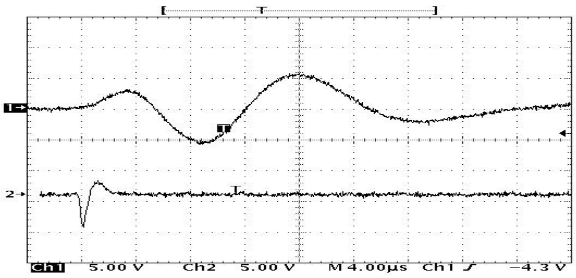
2.2 Software Details

The software operating the XRA takes care of the following: a) initialisation of the peripherals and various other modules like memory address counters. b) The I/O data transfer and control of the XRA which is the main routine. c) Calibration of the XRA for the main detector settings which is performed by obtaining the pulse response of the main detector sampled at 7MHz. The pulse is constructed by the principle of time equivalent sampling method where one sample is obtained per pulse (main detector response) for every calibrating pulse applied to the measuring system.

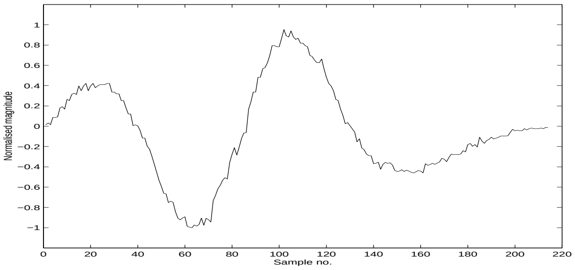
3 Calibration Tests

Calibration is performed to obtain the main detector pulse response for setting the delay to capture the peak of the response and also to obtain the normalised pulse response data in form of a lookup table for superposition error correction.

The main detector and the auxillary detector response is captured by the oscilloscope and is shown in Figure 2(a) on Ch1 and Ch2 respectively. The main detector response sampled and normalised with the XRA (the data used in the experimental work to be presented in the next section) is shown in Figure 2(b). It can be noted that the pulse peaks at the delay count of 63. This value is used to set the delay for peak sampling of the main detector response. The data obtained is stored in the array for post-processing of the PD data as a unit response. The response of the main detector in the oscillogram can be compared with the pulse shape obtained with the XRA. The pulse peak is seen to be at $9\mu s$ in the oscillogram and also in the XRA data ($63 \times (1/7MHz) = 9\mu s$).



(a) Oscillogram



(b) XRA

Figure 2: Pulse response (a) Oscillogram for main detector and auxillary detector response (b) Main detector response sampled by the XRA

Calibration tests to demonstrate the ability of the XRA to resolve the pulses and to correct the superposition error is performed with the square-wave pulse generator fed at the measuring impedance. The duty cycle of the square wave pulse was varied to cause overlapping of main de-

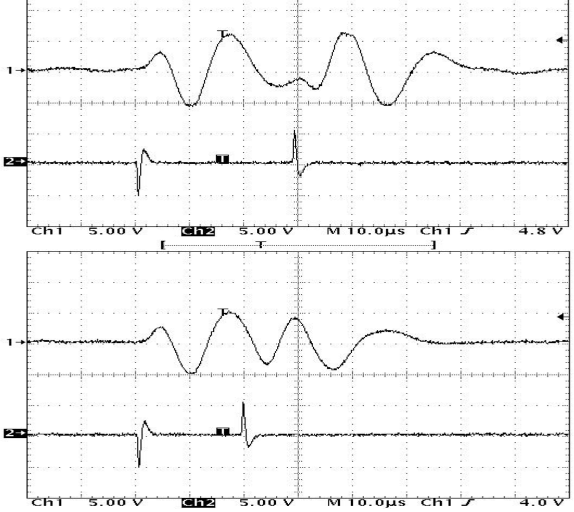


Figure 3: Pulses overlapped (a) no superposition error and (b) with superposition error

tector response. Figure 3(a) and Figure 3(b) show the oscillograms of pulses just overlapping ($30\mu s$ time interval) and sufficiently overlapping ($20\mu s$ time interval) respectively. It can be seen that the auxillary detector is able to resolve the pulses. The phase detector can therefore, capture the exact time interval between pulses and the ADC will sample the pulse at the expected time to peak for each pulse. In case of the overlapping pulse, a modified pulse height, because of superposition, would be sampled by the ADC. Since, the exact time interval between pulse is known and the magnitude of the previous pulse is measured, the modified pulse height can be corrected to the actual pulse height with help of the lookup table. The details of the correction method and functioning of the XRA can be found in the reference [5].

Figure 4 is the bar plots of the data obtained by the XRA. Figure 4(a) is the data obtained for just overlapping pulses with no error in the pulse height of the overlapping pulse ($30\mu s$ time interval) and Figure 4(b) is the data obtained for pulses with $20\mu s$ time interval with no post-processing for superposition error correction and Figure 4(c) is the data with superposition error correction on data shown in Figure 4(b). It can be seen that the XRA is able to resolve pulses and also correct for the superposition errors. The resolution of the main detector is extended with the XRA and practically only limited by the dead time of the analyser and the main detector pulse characteristic namely, the time to peak.

4 Experiments Results

PD experiments were performed with straight detection technique with point-plane electrodes for

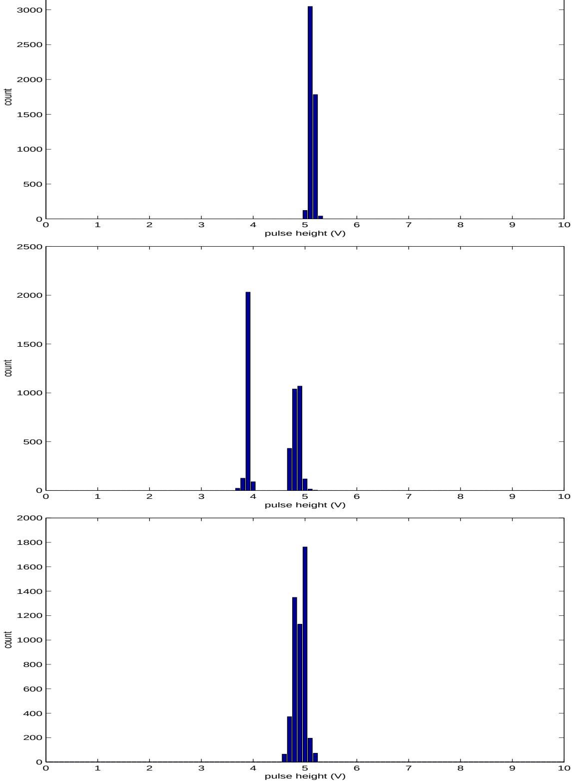


Figure 4: Pulse magnitude distribution (a) no superposition error, (b) XRA output before post-processing and (c) XRA output after correction

corona discharges to bring out the advantages of the XRA over conventional methods for PD measurements.

Corona discharge measurement was performed with the main detector as a narrow band detector (40kHz-80kHz frequency cutoffs) using the XRA. At overvoltage condition, the narrow band detector produced overlapping pulses. One such condition was captured by the oscillogram presented in Figure 5. Figure 6 shows the various PD 3D $\phi - q - n$ patterns (100×100) obtained using the XRA technique. Figure 6(a) shows the PD pattern with the narrow band detector obtained with XRA without superposition correction but with the ability to resolve pulses and Figure 6(b) shows the PD pattern with XRA correction for the narrow band detector. Hence, the technique of the XRA can be said to be able to produce PD pattern independent of the type of the PD detector as the XRA with the narrow band detector as the main detector could resolve pulses as good as the wide band detector. Also, the use of XRA for measurement allows measurement to be made without the problems of multiple measurement of a pulse or of no measurement due to superposition.

Next, the ability of the XRA for noise suppression is demonstrated with the narrow band de-

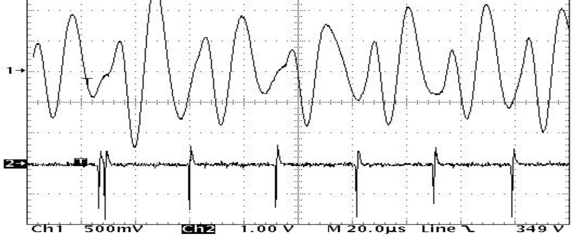


Figure 5: Oscillogram showing superposition of narrow band detector response and auxillary detector's ability to resolve

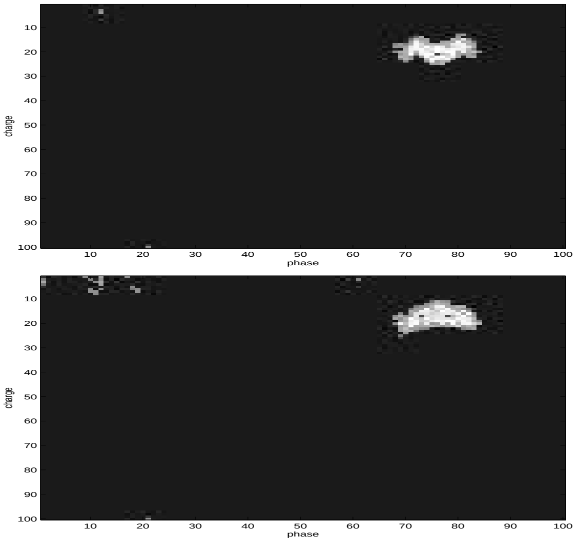


Figure 6: Corona results (a) without correction and (b) after correction

tector as the main detector. Pulsating noise was created with help of a RLC circuit having a narrow bandwidth. Figure 7 show PD patterns with the wide band detector measured in the convention way and with the XRA. Figure 7(a) is the PD pattern with the PD pulse with wide band detector with noise pulse masking the corona pulse data. Figure 7(b) is the PD pattern with the XRA which is able to discriminate the corona pulses and the noise pulses. The importance of this experiment will be appreciated by the fact that the auxillary detector in the XRA responds to the noise pulses and the ADC would digitise the main detector response (in this case, a nearly zero base line produced by the narrow band detector). The method differs from the simple use of the narrow band for measurement because of its ability to resolve pulses as good as a wide band detector and that would have the XRA to respond to the noise pulse detected by the auxillary detector and make measurement around the zero base line level (main detector response for the noise pulse), clearly bringing out the difference between the PD pulses and the noise pulses.

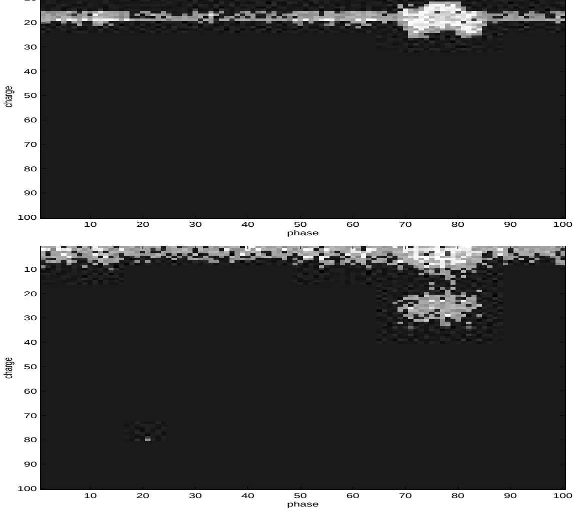


Figure 7: Noise reduction ability of XRA (a) wide band result (b) Narrow band with resolution ability of a wide band

5 Conclusions

In this paper, the advantages of the extended resolution analyser technique was experimentally demonstrated. XRA's ability to perform measurement independent of the PD detector with its ability to resolve pulse and account for errors due to superposition of pulses is demonstrated. This ability of the XRA allows it to be considered superior than the narrow band or the wide band detection method considered separately providing the advantage of the wide band and narrow band detection at the same time.

6 References

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