ENHANCING PARTIAL DISCHARGE MEASUREMENT WITH EXTENDED RESOLUTION ANALYSER

S. Senthil Kumar, M.N. Narayanachar and R.S. Nema

Abstract: Partial discharge fingerprints are generally obtained for model samples with known defects with computer-aided partial discharge analysers. These fingerprints help in generating a data base for classification of PD defects. Due to differences in PD detector characteristics, the measurements can he different with different PD detectors. The fingerprints obtained then, are dependent on the characteristics of PD detectors and the fingerprints obtained may lead to wrong classification and interpretation. The present paper proposes a solution of parallel detector scheme which will help obtain standard Angerprints independent of the PD detector characteristics.

1 Introduction

Computer-aided partial discharge measurements are commonly in use and partial discharge quantities /1/ are used as quality index which forms an important tool for diagnosis of insulation defects. PD is conventionally measured as a voltage drop caused by the movement of apparent charge across a series impedance (known as measuring impedance or quadrapole) in the PD circuit. The voltage across the measuring impedance is snitably amplified with a wide band or a narrow band amplifier and measured as a pulse height on a CRO or a PD analyser. The measuring impedance along with the amplifier does quasi-integration on the PD pulse whereby the pulse height is proportional to the apparent charge.

1.1 PD Detection System

Partial discharge current pulses have pulse widths of the order of 10-100ns. The frequency spectra of such pulses exceed tens of mega Hertz. The PD detector performs quasi-integration in frequency domain with the help of a filter which responds to the frequencies within the flat region of the PD pulse spectrum. Integration in frequency domain results in the response of the detector proportional to the charge of the current pulse. Filters with bandwidth in the range of 200-400kHz are called wide band systems. The upper limit on the bandwidth is to minimise the influence of the external high frequency interference as well as to ensure that the bandwidth of the filter remains in the flat region of the PD pulse spectra. If the bandwidth of the detector exceeds the bandwidth of the PD pulse, integration errors occur /2/. Hence, the upper limit is restricted to around 400kHz. The lower cutoff frequency is generally greater than 10kHz to avoid interference of power frequency signal and its harmonics into the detection system. Narrow band system has a bandwidth of about 10kHz with the center frequency tuned to a frequency in the flat region of the PD frequency spectrum where the influence of the external interference is minimum.

Superposition error will result in the measurement of pulse height if pulses occur within the resolution time of the detector /3/. Typically, wide band detectors have pulse resolution time of the order of $10\mu s$ and narrow band detectors have resolution time of the order of $100\mu s$.

1.2 Computer-aided Measurement of PDs

Computer-based PD analysers are used in conjunction with a conventional PD detector. These PD analysers give records of the pulse height, the phase of occurrence of the pulse with respect to the zero crossing of the applied voltage and the pulse counts familiarly known as $\phi - q - n$ distribution. This distribution is taken to characterise the PD phenomenon and to obtain fingerprints for diagnosis purposes /4/. It is to be noted that the analysers have an associated dead time which is the time duration required to process the pulse. The dead time is mainly due to the ADC conversion time and the time to transfer the ADC data to some temporary storage (buffer) or to the computer. Analysers with dead time of $10\mu s$ or less are easily available today.

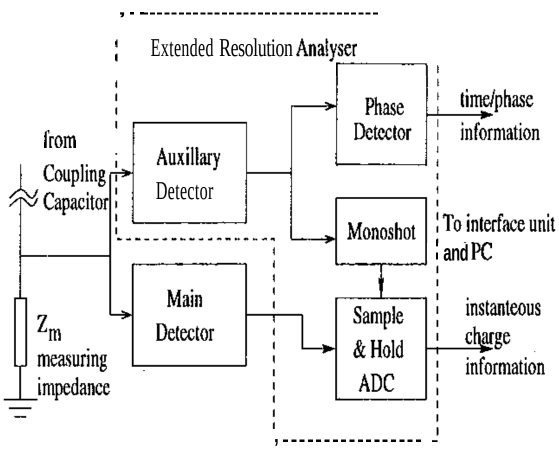

Figure 1: Block diagram of the proposed PD detection system.

2 Errors in the Measurement of PD

It is important to know the detector's pulse response characteristics and the analyser's mode of data acquisition as mismatch in the detector resolution time and the analyser dead time can result in erroneous measurement. The detector resolution time can either exceed or he within the dead time of the analyser.

Dead time of the analyser smaller than the resolution of the detector may result in multiple measurements **for** the same pulse /5//6/. This error can be avoided by setting the dead time of the analyser higher than the resolution time of the detector. Another method is to shape the PD pulses to unipolar pulses by envelop detection.

Given that the dead time is higher than the resolution time, errors in the measurement can still appear due to overlapping pulses within the resolution time /3/.

Thus it can be seen that the PD pulse measurement is dependent on the measuring instrument performance and the fingerprints obtained therefore may lead to wrong classification and interpretation of the results.

3 PD Measurement System with Extended Resolution Analyser

The present paper gives a novel scheme by which the resolution of the detector can be extended to match the dead time of the analyser. This is made possible by evolving a computer-based system which integrates the PD detector and the analyser.

The resolution problem is mainly due to the limitations of the detector. The lower the bandwidth poorer is the detector resolution /?/. Bandwidth of the PD system is mainly decided by the measuring impedance and the amplifier. The frequency characteristic gets defined for the system which permits to quantify the apparent charge as proportional to the pulse height. This filter characteristic also defines the time domain response of the detector. The fixed time domain characteristic of the detector is used to advantage in the present scheme of measurement.

The block diagram of the Extended Resolution Analyser (ERA) is shown in Figure 1. The ERA includes an auxillary detector, phase detector, monoshot and a sample & hold ADC. The main detector in Figure 1 is the conventional PD detector which can have a narrow band or a wide hand characteristic. The measuring impedance has **a** high bandwidth and gives **a** pulse with settling time less than the dead time of the analyser.

Pulses can occur within the resolution time of the main detector resulting in superposition errors. The ERA provides for **a** pulse correction algorithm which helps in correcting superposition errors in the measurement. A normalised lookup table is used to convert the amplitude error due to superposition depending on the time of occurrence of the pulse.

The auxillary detector has a wider bandwidth so as to give a settling time less than the dead time of the analyser. The auxillary detector along with the phase detector detects the instant of occurrence of the pulse with a time resolution of $1\mu s$ or

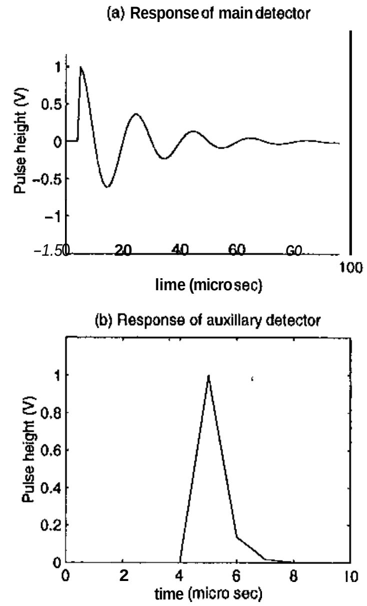

Figure *2:* Response of **(a)** the main detector ($80\mu s$ resolution) and (b) the auxillary detector ($4\mu s$ resolution).

less. The auxillary detector can be a logic comparator with an appropriate threshold for noise immunity. On the occurrence of a pulse, the monoshot generates a programmable delay trigger to the sample & hold ADC. This will help capture the peak of the main detector response.

The preparation of a lookup table required to correct for superposition errors and the tuning of the monoshot to capture the peak of the pulse are two important steps required for the ERA calibration.

3.1 Calibration

The calibration of the **ERA** system is performed in two steps.

Step 1. The pulse response of the main detector is digitized with the help of a digitizer. It should be ensured that the detector response is not modified by the envelop detector which is generally in the narrow baud system. It is suggested that the sampling time of the digitizer should be such that the difference in the magnitude between two successive samples is less than 5%. Normalisation of the response is performed by dividing each sampled value by the peak amplitude of the pulse so that the whole response lies between -1 and 1. **A** lookup table can be created to give the normalised value at different sample times. Table 1 gives one such normalised lookup table for the example considered (Figure 2(a)) in the utility demonstration (section 3.2).

Table 1: Normalised lookup table

time (	Digitized response				
1-5	1.000	0.905	0.732	0.506	0.253
6-10	0.000	-0.229	-0.414	-0.542	-0.606
11-15	-0.607	-0.549	-0.444	-0.307	-0.153
16-20	-0.000	0.139	0.251	0.329	0.368
21-25	0.368	0.533	0.269	0.186	0.093
26-30	0.000	-0.084	-0.152	-0.200	-0.223
31-35	-0.223	-0.202	-0.163	-0.113	-0.056
36-40	-0.000	0.051	0.092	0.121	0.135
41-45	0.135	0.122	0.099	0.068	0.054
46-50	0.000	-0.031	-0.056	*-0.013*	-0.082
51-55	-0.082	-0.074	-0.060	-0.042	-0.021
56-60	0.000	0.019	0.034	0.045	0.050
61-65	0.050	0.045	0.036	0.025	0.013
66-70	0.000	-0.011	-0.021	-0.027	-0.030
71-75	-0030	-0.027	-0.022	-0.015	-0.008
76-80	-0.000	0.007	0.013	0.016	0.018
81-85	0.018	0.017	0.013	0.009	0.005
86-90	-0.000	-0.004	-0.008	-0.010	-0.011
91-95	-0.011	-0.010	-0.008	-0.006	-0.003

Step 2. The time required for the pulse response to peak is estimated from the lookup table prepared in calibration step 1. The monoshot is tuned to this time so that the peak of the main detector response is captured on detection of the pulse.

These two steps completes the calibration required for the ERA.

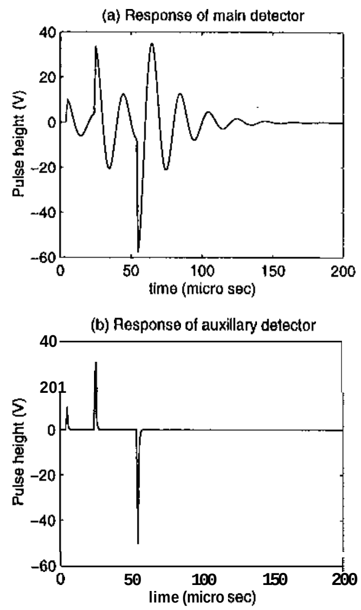

Figure 3: Response of (a)the main detector and (b) the auxillary detector with three pulses appearing within the resolution time of the main detector.

3.2 Utility Demonstration

The utility of the ERA is demonstrated with results of a simulation study carried out for the case when superposition of pulses occurs. Figure 2 shows the response of the main detector and the auxillary detector. The settling time of the main detector is taken as $80\mu s$ and that of the auxillary detector is taken as $4\mu s$. Figure 3 shows the case when three pulses appear within the resolution time of the main detector. The time difference between the first pulse and second pulse is $20\mu s$ and the time difference between the second pulse and the third pulse is $30\mu s$. The three pulse considered have the charge value of 10pC, 30pC and -50pC. The third pulse is considered negative to demonstrate the effectiveness of the system. Figure 3(a) shows the response of the main detector for case of three pulses considered. It can be seen that the three pulses cannot be resolved and have superimposed on the response of the earlier pulses. However, the auxillary detector (Figure 3(b)) can resolve the pulses and the times of occurrence of the pulses are measured by the phase detector. The charge magnitude is obtained with the help of the pulse correction algorithm as explained in section 3.3.

3.3 Pulse Correction Algorithm

When pulses appear well beyond the resolution time of the main detector, the correct peak value of the response is captured and there is no need for any correction. However, corrections are required when pulses appear within the resolution time of the main detector depending on the instant of occurrence of the following pulses. As a general **rule,** whenever a pulse is detected, it should be checked whether the previous pulses have appeared within the resolution time of the main detector. Figure 3 shows two pulses appearing before the response **of** the first pulse has settled. Therefore, the second and the third pulse require amplitude corrections. The second pulse will have magnitude correction due to the effect of the first pulse and the third pulse will have magnitude correction due to the effect of both the first and the second pulse. Table **2** demonstrates the procedure used to calculate the exact pulse peak magnitudes in the example considered.

The first pulse peak is measured to have a magnitude of 10pC. The time difference ($20\mu s$) between the first pulse and the second pulse is measured. As the time difference is less than $80\mu s$, superposition error occurs. Hence, the value (33.67) measured by the sample & hold ADC will give the algebraic sum of the first pulse component and the second pulse peak. The normalised value of the first pulse component (0.368, at $20\mu s$) can be determined from the lookup table. The normalised value is multiplied by the peak magnitude **of** the first pulse to give the magnitude of the first pulse component **(3.68)** at that instant. This value when subtracted from the measured value, gives the peak magnitude of the second pulse (29.99). Similarly, the peak magnitudes for the subsequent pulses are also corrected. The algorithm worked out is given in Table 2.

Table **2:** Pulse correction procedure demonstrated for the example considered

Pulse number	**1**	**2**	**3**
Charge measured q_{meas} (pC)	10	**33.68**	**-87.51**
Measured time of occurrence (μs)	4	24	54
Time difference between the n^{th} and $(n-1)^{th}$ pulse (μs)		20	30
Is correction required? (resolution $80\mu s$)		yes	**yes**
Normalised value q_{norm} **(from lookup table)**		**0.358**	-0.223
Correction required Aq $q_{prev} \times q_{norm}$ (pC)		3.68 (0.368 × 10)	-6.69 (-0.223 × 30)
Corrected value q_{meas}-Δq (pC)		29.99	-50.82
Time difference between n^{th} and $(n-2)^{nd} pulse$ (μs)			**SO**
Is correction required'! (resolution $80\mu s$)	-	-	yes
Normalised value **(from lookup table)**	-	-	-0.082
Correction required Aq $q_{prev} \times q_{norm}$ (pC)			-0.82 (-0.082 × 10)
Corrected value q_{meas}-Δq (pC)			-50
Final value (pC)	10	29.99	-50

4 Conclusions

To conclude,

1. the PD measuring system can measure pulses to the limit of the dead time of the analyser.
2. it is possible to standardise the measurement for a given dead time of the PD analyser. Hence, standard finger-prints of the PD phenomenon can be obtained.
3. the system is independent of the main PD detection system. The advantages of both the wide band and the narrow baud detectors can be fully exploited in so far as noise suppression, the polarity information and the resolution is considered.

5 References

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