Development of Compact On-Line Partial Discharge Analyzer Assessing Nanocomposite Insulation Performance for Research Purpose

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***Abstract*—Analyzing on-line partial discharge (PD) data using commercially available spreadsheet application software like Microsoft Excel is possible but very difficult to do. The problem is because the PD data are quite long and depend on the sampling rate used during testing. Increasing the sampling rate will increase data samples in one cycle of 50 Hz waveform, and longer time is needed to analyze the data. A further problem is associated with compiling the PD data; Excel uses a large memory to run, plot and calculate the PD data for analysis purpose, and sometimes this leads to computer memory crash. Due to this problem, an alternative on-line PD analyzer (on-LPDA) needs to be developed. This paper reports on the performance of the software that was developed using LabViewTM 8.5. The result shows that the software can extract PD parameters like PD numbers, PD magnitude, and plotting PD pattern without large time and memory consumption, compared with Excel, and experiences no memory crash up to 125 mega sampling (MS) rate.**

***Keywords*—component; formatting; style; styling; insert (*key words*)**

1. INTRODUCTION

In high voltage (HV) equipment, the insulation system is the most vital to preventing any discharge surrounding the protected system. Partial discharge (PD) is a low-level electrical breakdown confined to localized regions of the insulation between two electrodes at different voltages [1]. This phenomenon can lead to insulation breakdown when subjected to prolonged electrical stress. Thus, PD measurement and monitoring is one of the most important diagnostic tools for detecting incipient faults in HV insulation systems [2, 3].

PD measurement and technique on HV equipment has been reported by many researchers in the last two decades in relation to improving computer and information technology. The techniques were implemented to detect, measure, and analyze PD activities on insulation of HV equipment such as power cable, transformer, gas insulated switchgear (GIS), and generator, on-line or off-line system, and on-site or off-site system [4-19].

As the most effective tool to avoid a sudden accident in electrical equipment, PD measurement and PD analysis need a data acquisition system (DAQS) consisting of hardware and software [20]. A typical hardware consists of an individual sensor with necessary signal conditioning, data conversion, data processing, multiplexing, data handling and associated transmission, storage and display system. DAQS process can take a long time and is complicated because of procedures and protocols needed before acquiring the data [21]. DAQS for PD measurement can be designed to detect the pulse peak and its phase information as well as pulse count [22]. For easy data handling, plain ASCII text was a good choice and the data could be processed further using text editor and a commercial spreadsheet program [23]. With the rapid advances in hardware and software technologies, this has resulted in relatively easy and efficient adoption of personal computer (PC) in various precise measurement and complex monitoring system.

Data acquisition system (DAQS) consists of a sensor [24], DAQ board, and software system that play an important part in PD analysis. This system allows the researcher to read the analog data on-line or store the data for further analysis either by a human expert or a PD-based smart computer [23]. The commercial price of this operated PD data acquisition system (PDDAS) is expensive and takes longer to acquire because of a very specific demand for this kind of analysis. By developing a portable and simple graphical interface of PDDAS, the cost could be significantly reduced and the analysis addressed to a specific objective of a research project.

The choice of the hardware depends on some parameters like the speed of data transfer, accuracy, price, simplicity, and sampling rate. For PD pulse count purpose, 1 mega sampling per second (MS/s) could satisfy the objective, but for PD pulse and PD waveform analysis purpose, a higher sampling rate is a key part of an on-line monitoring system [25], and it is necessary to study the change of the waveform to the aging process in the insulation material.

Rather than a handmade DAQS, choosing to use a fabricated DAQS, but with an affordable price, is a good alternative to avoid the high cost of hardware calibration and human error. Our choice of DAQS is an A/D converter called *Picoscope*^{TM} (PC oscilloscope) produced by Pico Technology.

2. System Design

The system design for this work including the instrumentation specification can be described as following.

2.1. Personal Computer and Data Acquisitions System Specification

Personal computer (PC) and data acquisition specification are shown in Table 1 and Table 2, respectively. PC in this work used *Windows 7 Home Premium* edition 64-bit operating system.

2.2. Flow Chart of PD Measurement and Data Acquisition System

Fig.1 shows the flowchart of PD measurement and data acquisition system (PDM-DAS). PDM-DAS is turned on soon after the PD test circuit, ready and arranged accordingly. Some parameters like numbers of sampling per second and threshold value need to be adjusted to make sure that PD data can be acquired correctly. By clicking the button ‘RUN’ in *LabView*^{TM} *8.5*, the PDM-DAS is ready to capture and record the PD data on-line for the whole length of time of PD measurement. The PD measurement system should be discharged using a discharge rod every time a sample is changed or measurement stops to avoid electrical shock.

The graphical user interface (GUI) of the PDDAS is shown in Fig.2. The data acquisition system (DAQS) used is *Picoscope 5203*, which can give the highest sampling rate 1 GS for one channel enabled or 500 MS for two channels enabled. Channels coupling could be set to AC or DC and channel range is from 100 mV up to 20 V. DAQS can be stopped any time by pressing the STOP button and the data can be saved by pressing the SAVE button.

Table 1. PC Specification

Item	Detail
Processor	Intel(R) Core(TM) i7-2600 CPU@3.40GHz
Installed memory	8 GB
System type	64-bit operating system

Table 2. Data Acquisition System

Item	Detail
Bandwidth	250 MHz
Real-time sample rate	1 GS/s
Buffer memory	128 Mega sample

2.3. Experimental Setup

To test the system, an AC voltage of 6.5 kV_{rms} at 50 Hz was applied to the rod electrode, while the plane electrode was earthed. Within the given experimental conditions, it was believed that no PD took place from areas other than in the void at the electrode arrangement. Fig. 3 shows the laboratory set-up consisting of an AC high voltage supply and its measuring system, the CIGRE Method II (CM-II) electrode system [23], and the data acquisition system (PC-connected *Picoscope* 6).

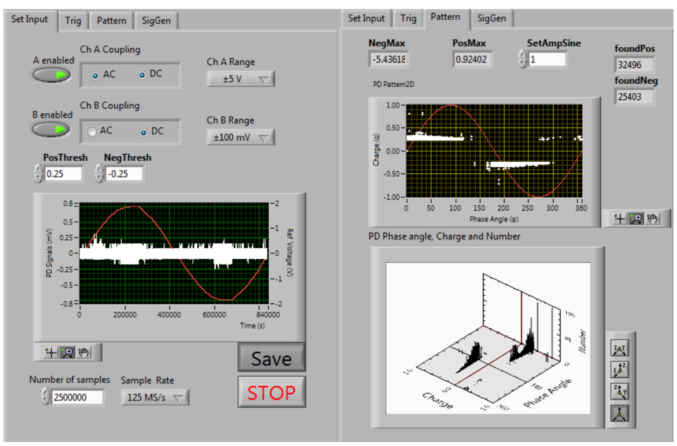
The samples used in this research work are natural rubber blends nanocomposite with 1 mm thickness placed in the CIGRE Method II test cell [26-28].

3. RESULTS AND DISCUSSION

The results of the case study have been applied in this study for testing the on-line PD monitoring system.

3.1. PD Waveform

Fig. 4(a) shows the PD signal, noises, and 50 Hz power supply waveforms, while Fig. 4(b) shows the zoom out of corresponding PD. Only one positive PD was detected in this example. However, in many cases, positive and negative PDs were possibly detected in the same short screen window.



(a) (b)

Fig. 2. Graphical user interface (GUI) of PDDAS; (a) GUI for enabling and setting the channel range, setting up the threshold voltage (V), setting up the sampling rate (MS/s), and numbers of samples to represent one cycle 50 Hz sine voltage (360 degree). Buttons STOP and SAVE are also available. (b) The example of PD data representing maximum and minimum value of PD charge magnitude, PD pulses count, two dimension (2D) PD phase resolved, and three dimension (3D) PD phase resolved.

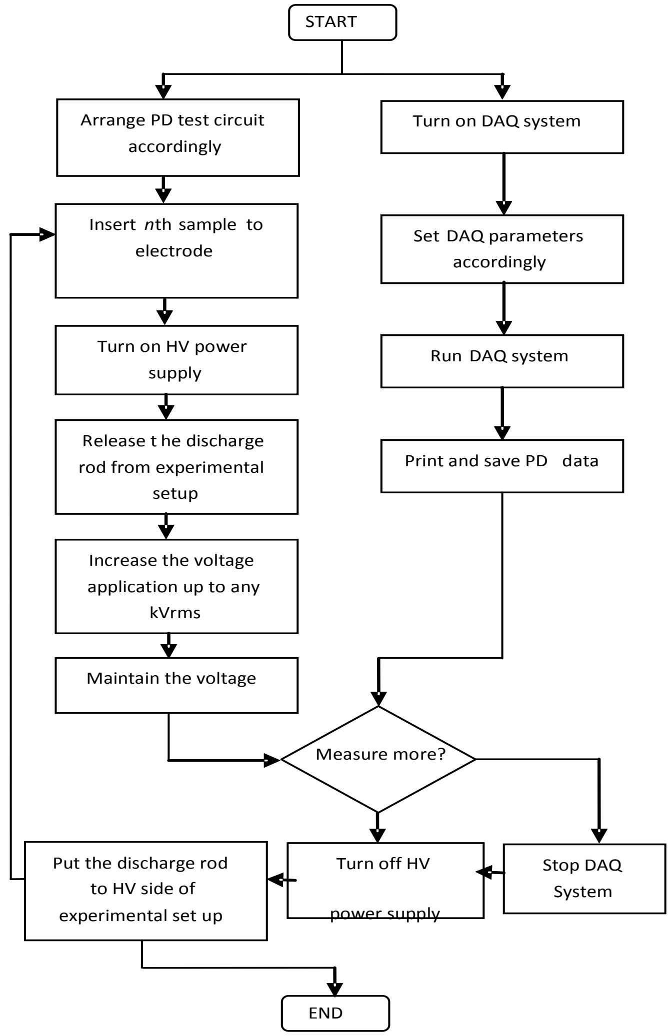


Fig. 1. Flowchart of the on-line PD data acquisition system (PDDAS), which has been developed in this work.

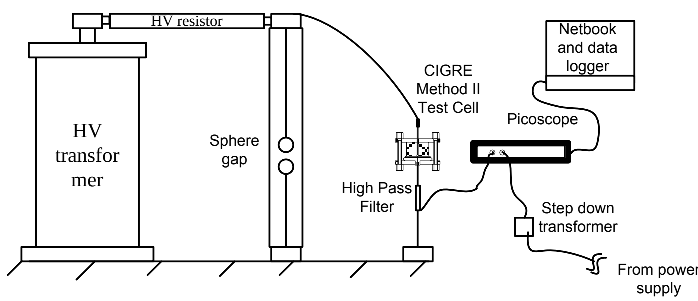
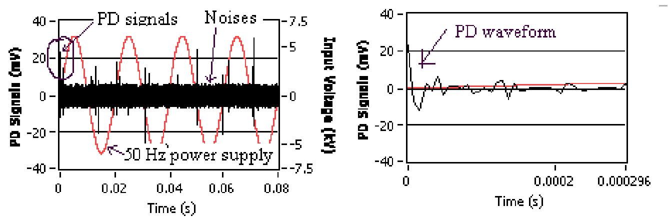


Fig. 3. Experimental setup for the PD test.



(a) (b)

Fig. 4. PD signal waveform; (a) PD and 50 Hz power supply signals; (b) zoom out of corresponding PD signal waveform [24].

Table 3 shows the comparison between the different sampling rate and the memory used by PC to store the files every minute. Table 4 shows the average value of waveform parameters in different sampling rates. The sample used is a new sample of LLDPE/NR and nanotitania (TiO_2) of 4.5 wt% composite insulation. The highest front time is 1000 ns own by 1 MS/s, and the smallest front time belongs to 42 MS/s. The tail time belongs to 1 MS/s, and the smallest tail time belongs to 250 MS/s. Table 2 in section 2.1 gives the starting point as the guidance to choose the most suitable sampling rate for PDDAS.

3.2. Phase-Resolved PD Analysis

To plot PD phase and PD charge for two dimensions (2D graph), and PD phase, PD charge, and PD number for three dimensions (3D) is not straightforward, but needs a short list of programs. To plot phase-resolved PD pattern, the output of Peak Sub VI, which is *Amplitudes* and *Location*, is connected to new Sub VI namely PLOT2D PD PATTERN. This Sub VI converts the peak and valley values and their related index into the PD Charge and phase angle. By adding a Collector Sub VI to PLOT 2D PD PATTERN, all the PD charge and related phase angle are collected and saved on the screen memory. To save the PD pattern automatically onto hard disk is also possible by adding another Sub VI, which can save the figures based on specific interval of time or file size.

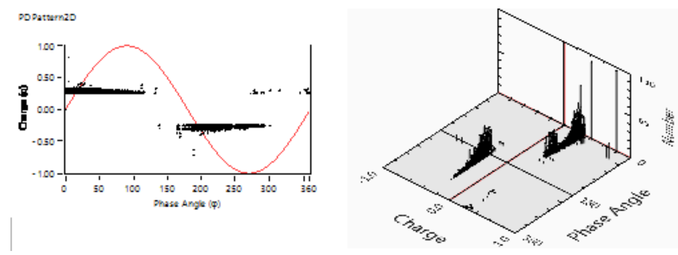
It is possible to plot the PD pattern in 3D using *LabVIEW*^{TM} by using Stem 3 Sub VI. The same input for amplitudes and location plotting the 2D are maintained. Another input is needed to count the total PD. The result of the PD pattern plot is shown in Fig. 5(a) for 2D and Fig. 5(b) for 3D.

Table 3. Memory used and number of files could be saved every minute in a different sampling rate

Sampling rate (MS/s)	File size for 1 file (MB)	Number of files/minute	Total size of file/minute (MB)
1	0.314	825	186
42	13.127	175	1100
125	39.064	81	1520
250	N/A	NA	NA
500	N/A	NA	NA

Table 4. Pulse waveform in different sampling rate

Sampling rate (MS/s)	Front time (ns)	Tail time (ns)	Waveform (ns)
1	1000	1500	1000/1500
42	24	240	24/144
125	48	256	48/171
250	96	156	96/174
500	52	172	52/138



(a) (b)

Fig. 5. Phase-resolved PD pattern: (a) 2D (phase angle and charge), (b) 3D (phase angle, charge, and pulse count).

4. Conclusion

Partial discharge data acquisition system (PDDAS) was developed and presented in this paper. The optimum sampling rate determined by considering the PC capability is an important issue and could be set based on a real experimental result.

This system could be implemented for an on-line PD monitoring system assessing the insulation performance of nanocomposite samples for research purpose, which was relatively easy, compact, and economic.

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