FIELD OF INVENTION

The present invention relates to a process for detecting and measuring the partial discharge occurring in electrical insulations provided in power appliances operating under high voltage, for example cables and bushings, including the power appliances, where the insulation material contain voids and/or dissimilar dielectric materials developed during manufacturing of the appliances. In particular, the invention relates to a process for detecting partial discharge occurring in electrical insulations. The invention further relates to an integrated system for detecting and monitoring the partial discharge within an electrical insulation.

BACKGROUND OF INVENTION

Life span of high voltage insulation gets considerably shortened due to partial discharge activity taking place in the electrical insulation of the power appliances, particularly in the voids and /or dissimilar dielectric interface while the power appliances are operative. The presence of voids leads to localized enhancement of electric field strength that result in partial discharge. The phenomenon of partial discharge, not being externally perceivable, it silently accelerates the degradation processes by internal carbonization and tree formation, and eventually leads to an ultimate failure of the power appliances. Hence it is useful to apply diagnostic techniques that can measure the amount of discharges occurring inside the insulations. However, the technique of measurement and calibration of partial discharge signal is quite difficult and requires a significant and consistent human intervention to implement the technique. Accordingly, it is desirable that the measurement and data acquisition process be implemented in an integrated system having all the necessary data acquisition hardware and software with a user-friendly interface that can guide an operator step-by-step.

OBJECTS OF THE INVENTION

It is therefore an object of the invention to propose a process for detecting the partial discharge in electrical insulations provided in power appliances, which eliminates the disadvantages of the prior art.

Another object of the invention is to propose a process for detecting the partial discharge in electrical insulations provided in power appliances, which can pre-process, acquire and digitize the partial discharge signal for storage and analysis.

A still another object of the invention is to propose a process for detecting the partial discharge in electrical insulations provided in power appliances, which is enabled to adapt a denoising module to denoise the partial discharge signals for improved analysis.

Yet another object of the invention is to propose a process for detecting the partial discharge in electrical insulations provided in power appliances, which is enabled to adapt a first analyzer module for direct classification of data relating to the partial discharge signals.

A further object of the invention is to propose a process for detecting the partial discharge in electrical insulations provided in power appliances, which is enabled to adapt a second analyzer module for analysis of the processed data.

A still further object of the invention is to propose an integrated system capable of implementing the process for detecting the partial discharge in electrical insulations provided in power appliances.

SUMMARY OF THE INVENTION

The present invention in a first aspect provides an integrated system for monitoring the partial discharge within electrical insulations provided in power appliances such as cables and bushings where the insulation material contains voids. The inventive system is a single, portable, integrated unit which acts as the platform for software modules to be implemented and is capable of detecting and analyzing data respecting to partial discharge signal acquired from electrical insulations provided in power appliances.

The hardware part of the system comprises:

- at least one digitally controlled programmable analog data acquisition and scaling means for pre-processing signals representing data relating to partial discharge (PD) within electrical insulation occurring when the power appliances remain in operational mode;
- at least one two channel digitizer which is enabled to convert the PD signals into accurately sampled digitized data preserving the waveshape substantially identical to a waveshape as originally transmitted from a first terminal of the appliance including digitizing a scaled-down power frequency signal transmitted from a second terminal as a phase reference;
- at least one main processor for digital signal processing and computation;

- at least one display device capable of displaying the output from the system;
- a multiple voltage output SMPS;
- a housing for accommodating the processor and the peripherals enabling interconnectivity and communication with all the constituent components of the system using different communication protocols;
- a data storage device for storage of input, processed and output data; and
- a software module that synchronizes the activities of all the hardware components allowing the integrated system to operate under seriatim and sequential instructions from the software mode.

The hardware components of the system as described hereinabove are operably interconnected and can be explained according to the following flow indicator:-

Analog PD Signal → Analog Data Acquisition Unit→ Digitizer → Processor with *User Interface* → Storage → Analysis → Display

In a second aspect, the present invention provides a process for detecting and measuring the partial discharge occurring in electrical insulations provided in power appliances. The process comprises the following steps:

- injecting a low voltage signal across a sample to calibrate the system without switching on the high voltage, the *Third User Interface* involving an application of high voltage across the sample to record the actual partial discharge that occurs inside the sample by the application of this high voltage;

- storing data in a storage device representing different threshold values including multiplication factors during the low voltage calibration process; and
- determining the partial discharge amount occurring during application of high voltage by adapting the stored data.

The term analyzing as stated hereinabove includes execution of various processes and tasks comprising configuration of the hardware by the central processor under software instructions.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

Fig. 1- a block diagram of the system of the invention.

Fig. 2- a block diagram of the analog data acquisition unit of Fig. 1.

Fig. 3- shows a pictorial view of the system of invention, as viewed from the top.

Fig. 4- shows a pictorial view of the system in a casing.

Fig. 5- shows a pictorial view of the system including a sample illustrating a process of measuring and detecting partial discharge in electrical insulations.

Fig.6- depicts a flow chart illustrating a process of measurement and detection of partial discharge occurring in insulations of high voltage power appliances.

Fig.7- shows a data acquisition window for denoising PD pulses.

Fig. 8- shows a data acquisition window for calibrating PD pulses.

Fig. 9- shows a data acquisition window for actual intake of PD data.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 illustrates in a block diagram of an integrated system for detecting and monitoring the partial discharge within an electrical insulation provided in power appliances, according to the invention. The system comprises:

- at least one digitally controlled programmable analog data acquisition and scaling means (1) for pre processing signals from a first terminal representing data relating to partial discharge (PD) within electrical insulation occurring when the power appliances remain in operational mode;
- at least one double-channel digitizer (2) capable of converting the PD signals into digitized data substantially retaining the waveshape of the signals initially transmitted from the first terminal (3) including digitizing a scaled down power frequency signal from a second terminal (4) as a phase reference;
- a switching mode power supply (6) for providing power to the system;
- a processor (7) including a housing for connecting the processor and the peripherals, for performing computing and providing the control signals;
- at least one storage device (8) for storing the data needed for the system to operate;
- at least one display device (5) for displaying the output; and

- a software module that synchronizes the instructions enabling the hardware components to cause the integrated system to operate under the instructions from the software module.

The stated hardware components of the system are operably connected to perform under the synchronized instructions from the software support structure.

The system is enabled to draw power from a single AC wall outlet.

Fig. 2 shows the analog data acquisition and scaling means (1) which operates the system under the software instructions. The means (1) comprises a protective device (9), a variable attenuator (10) combined with an amplifier (11), a bypass switch (12), capable to disable the amplifier (11) when the value of the signals exceeding the threshold limits of the signal. The settings of the switches (12), attenuator (10) and the biasing of the amplifier (11) are controlled by respective control lines (13) fed from the central processing unit (7) for automatic scaling of the signal level under the software instructions.

Fig. 3 illustrates one possible way as to how the components could be packed into one unit. Since noises are the greatest impediment to data acquisition, the disposition of the components is an important consideration. An external box (body) is made up of GI sheet for a shielded housing (C).

Fig. 5 illustrates one possible way as to how the inventive system can be adapted for detecting the partial discharge within the electrical insulation of a power appliance. The setup comprising components (15) to (19) which can be kept in a separate shielded enclosure (20 and the data acquisition, analysis and display unit (14) can be kept in a control room (21). First, a power frequency test voltage is applied by means of a transformer (15) across a sample (18), which initiates partial discharge (PD) inside the voids in the sample (18). PD pulses are filtered from the applied high voltage through a coupling capacitor (17). PD signal (3) appears across an inductor (19). As and when required, the sustained oscillatory signal in the output can be damped. C1 and C2 constitute potential dividers (16) for the power frequency high voltage and the corresponding low voltage is used as a phase-reference (4) of the PD pulses.

User Interface is integrated into the system.

A first data acquisition window that appears for PD data acquisition is given in Fig. 7 showing all the necessary components of display, for example:

- a raw data acquisition frame (55) which shows the magnitude of PD signal in volts (V) vs. time in milliseconds (ms);
- a denoised PD data frame (56) which shows the magnitude of PD signal in volts (V) vs. time in milliseconds (ms);
- a run button (57) for triggering the data acquisition process; and
- a user entry box (58) for the predicted noise level that is eliminated from the noisy signals during implementation.

The second window that appears for PD signal calibration is given in Fig. 8 showing the necessary components of display, for example:

- an acquired and denoised PD frame (59) which shows the magnitude of PD signal in volts (V) vs. time in milliseconds (ms);
- a calibrated PD data frame (60) which shows the magnitude of PD signal in picocoulombs (pC) vs. time in milliseconds (ms);
- a run button (61) for triggering the calibration process; and
- an user entry box (62) which adjusts the scale factor for conversion of voltage to picocoulomb.

A third data acquisition window that appears for PD data acquisition is given in Fig. 9 showing all the necessary components of display, for example:

- a phase resolved plot frame (64) which shows the occurrence of the PD signal in picocoulomb (pC) in the entire phase of the power frequency signal in degrees;
- a XY plot frame (65) which shows the occurrence of PD signal in an ellipse of power frequency cycle;
- a capture button (63) which recalls the parameters stored under the first and *Second User Interface* and adaptable as under *Third/Final User Interface* to capture and display the actual PD data; and
- an indicator (66) for the maximum discharge in the entire duration of a power frequency cycle.

The system is capable of storing data in a flash-memory-type device through pressing a key provided to the interface under software instruction. The communication is primarily, but not limited to, through USB protocol. They type of data storage is mainly, but not limited to, ANSI type data file.

According to the invention, the process for detecting the partial discharge (PD) that occurs within the electrical insulations of power appliances for example, cable, bushing, transformer, breaker and other related type of high voltage equipment in the inventive system in association with at least one each of a first, second and *Third User Interface*, comprises the steps of:-

- injecting a low voltage signal across a sample to calibrate the system without switching on the high voltage, the *Third User Interface* involving an application of high voltage across the sample to record the actual partial discharge that occurs inside the sample by the application of this high voltage;
- storing data representing different threshold values including multiplication factors during the low voltage calibration process; and
- determining the partial discharge amount occurring during application of high voltage by adapting the stored data.

The flow-chart of Fig. 6, can be divided into three parts each respectively operable under the first, second and the *Third User Interface*, by the user. The detailed description is provided as under:

The *User Interfaces*:

Starting (22) the process by transmitting a calibrated pulse from a PD calibrator into an input block (24). The calibrator is capable of producing pulses in a set value of picocoulomb ranging from 5-5000pC (or millivolts) according to user settings. Starting from block (22), data from this pulse is acquired in block (25). After reception of the pulse, the instrument adjusts its attenuator (10) and amplifier (11) settings automatically in block (26) so that the peak value of the input pulse lies within a value for example , ± 2.5V, or, as required for the ADC to function properly. Too low an input voltage creates unwanted noise in AD conversion, and too high a voltage creates overrange error in the ADC. A decision block (27) observes the input range of the signal and if it is not within the range, adjustment of the attenuator (10) and the amplifier (11) are required as in block (23) and the data taken again through block (25), this time, with a converging adjustment. The loop continues until the block (27) decides the data to be in suitable range and passes the signal to the denoising block (30). Meanwhile, the scaling factors that are required to adjust the amplifier and attenuator are stored in block (28) for future reference.

The denoising module block (30) can be operated under several techniques.

THE DETAILED STEPS AS ILLUSTRATED IN Fig. 6 CAN BE DESCRIBED AS UNDER:

(a)- the first user enters the noise level to block (29) when the signal is on the display.

(b)- subtracting (30) the entered noise level from the signal where the signal being substantially large compared to the noise level, or if the block incorporates other suitable techniques like wavelet denoising, the signal need not be substantially large compared to the noise level.

(c)- eliminating the noise level and extracting the PD pulses from the noisy signal by adapting a denoising technique for example, wavelet based technique, the amplitude of PD-data being represented by the unit of pC;

(d)- storing the denoised data in block (32) and the threshold values in block (31) which being adaptable under the *Second User Interface*, the value of stored data being represented by the unit of volts;

(e)- injecting the denoised data from block (32) under the *First User Interface* to block (36) of the *Second User Interface*, the block (36) being connected to a scaling block (37);

(f) correlating the values of stored data and PD-data in blocks (37 to 41) in a loop, the block (41) in the loop being a decision block, the reference input is provided in the block (41) by the user through an input device, in block (40);

(g)- storing the calibrated data in block (43) and the conversion factor in block (42) to be utilized in the *Third User Interface*;

(h)- applying through the *Third User Interface* a high voltage in block (47), the amplifier settings stored in block (28) under *First User Interface* being utilized to record the partial discharge signal in block (48);

(i)- adapting the thresholding values obtainable from block (31) under *First User Interface* to denoise the partial discharge signal in block (49);

(j)- adapting the conversion factor obtainable from the block (42) under *Second User Interface* to convert the partial discharge amplitude directly in unit (pC) in block (50);

(k)- storing the determined partial discharge data in the form of time vs. amplitude in unit (pC) in block (52);

(l)- displaying the data through block (51);

(m)- ending (53) the process.

Example: If the injected pulse is 50 pC by the calibrator through block (40) and the voltage peak in block (36) is 0.3V, the scale factor is adjusted in (37) until the peak value equals 50 in block (38). The conversion is done in block (38) and the decision is done in block (41) and the loop continues until the result is equal to 50, i.e. equal to the user input at (40).

THE BEST MODE OF WORKING THE INVENTION:

All electrical connections along with the sample under test are made according to the circuit diagram explained in Fig. 5.

The PD detector unit (14) is powered on, but the voltage source to the input of the transformer (15) is kept off. At this stage the *First User Interface* window as shown in Fig. 7 appears.

PD pulses of sufficiently high magnitude above the ambient noise level are injected across the sample by means of a calibrator.

The operator predicts a noise level and enters the predicted value through the text box (58). This step can have a few iterations until the right frame (56) is achieved. Fig. 7 shows such a frame (56) with almost no noise at the baseline.

At the back end of this window, the following sequence of operation takes place inside the detector:

- Noisy data is acquired as shown in the left frame (55).
- Depending on the magnitude, the attenuator (10) and amplifier (11) are automatically scaled (26) under *First User Interface* in Fig. 6.
- The range factors are stored (28) as indicated in Fig. 6 and data is again acquired with scaling (23) under *First User Interface* in Fig. 6.
- Denoising algorithm (30) performs the denoising by eliminating the ambient noise level from the captured signal under *First User Interface* in Fig. 6. High magnitude of the pulses (24) helps to ascertain the position of PD pulses and is useful to verify the efficiency of the denoising operation. The threshold values are stored (31) at this stage, which can be correlated under *First User Interface* of Fig. 6.

Frame (56) on the right side of Fig. 7 shows the result after denoising in the case of an injected pulse of 50pC. Since the phase reference of the injected pulse from the calibrator is known, the result on the right frame is also important in the sense that it gives an indication whether the denoising has caused any phase shift or not.

The *Second User Interface* screen appears for the calibration process as shown in Fig. 8. Here the scale factor and other coefficients are correlated between the obtained value of the charge and the actual charge injected by the calibrator (40). The actual charge injected is entered by the user in this window through the text box (62) so that the voltage obtained is converted to the corresponding charge and the conversion factor is stored (42). This conversion factor is actually the proportionality constant between the actual amount of discharge during the occurrence of partial discharge inside the sample and the amplitude of detected voltage. Frame (60) shows the calibrated data.

When the calibration is completed, final data acquisition window appears as *Third User Interface* shown in Fig. 9. Now the calibrator is removed from the test circuit and the high voltage is powered on. The required test voltage is applied to the sample. Then the 'run' button (63) provided at the top left side of the window is pressed. All the previously stored scaling (28), denoising (31) and calibrating parameters (42) are utilized in this case to determine the phase resolved data directly from the sample (64), can also be correlated under the *Third User Interface* of Fig. 6.

The left frame of Fig. 9 shows the phase resolved plot (64) and the right frame shows the X-Y plot (65) after acquisition and processing of the data. The parameters that are required for amplifier and attenuator adjustments (28), denoising (31), conversion from voltage to charge (42) and the resulting data can be stored in a test file and taken by a flash drive attached with the unit for future reference and analysis purpose.

The system and process of the invention is compatible with various types of sensors. Moreover, the developed process is capable of classifying the PD patterns, directly from the raw noisy recorded data, thus eliminating any requirement of denoising prior to processing the data.