Partial Discharge Measurements and Diagnostics on Power Transformers using a Multi Channel Digital PD Detector

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Abstract

The PD and RIV level of power transformers is often used as a quality test at the commissioning. It also shows very promising results for on-site testing.
To simplify the task of PD and RIV testing in the lab and on-site, the digital PD detector LDS-6 was adapted to automate these measurements and perform sensitive measurements under electrically noisy conditions. The special features for transformer testing are discussed more in detail.

1. Introduction

The electrical aging of power transformer oil and insulation are caused by Partial Discharges. Therefore a PD test or at least a so-called RIV test (RIV – radio interference) are part of the final quality test of a power transformer.

For on-site commissioning and testing after maintenance a PD test is also recommended. It can show problems which a dissolved gas-in-oil analysis might not be able to indicate, either because the time was too short to collect a significant amount of by-products (new commissioning) or the discharge happens outside the oil, e.g. in the bushing. Here often a simple repair can solve a problem which untreated would cause very expensive damage later.

While it is possible to use standard PD detectors for these tests, specialized detector systems offer several advantages:

- permanent scanning of three or more input channels monitors all phases quasi-simultaneously, the test has to be run only once
- automatic recording with consideration of the calibration sensitivity of each channel
- automatic test report
- digital recording of the PD pulses according to the phase allows all sophisticated PD analysis methods
- special noise suppression gives a better sensitivity and failure recognition and allows measurements under noisy laboratory or on-site conditions

These advantages reduce the time needed for set-up and testing the transformer and hence ultimately reduce the test cost.

2. Setup of the PD Test System

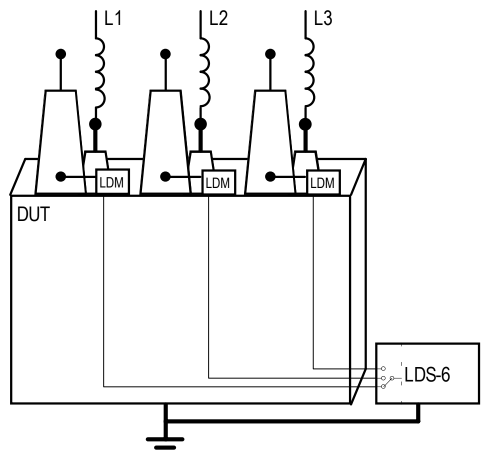
The standard setup of the LDS-6 for laboratory measurements is shown below.

2.1. Laboratory Setup

In the test laboratory, the transformer usually will be energized via the low-voltage bushings. The test voltage is higher than the nominal voltage. To avoid saturation of the iron core, the frequency of the test voltage also has to be higher than the power frequency (called “induced test”).

To prevent electrical disturbance and noise signals from the generator affecting the test circuit, blocking impedances are used. These high frequency chokes don't affect the energizing with lower frequency, but are an effective block against high frequency signals in the measured PD range from hundred Kilohertz to several Megahertz. As an additional benefit the measuring circuit itself becomes more sensitive, because a bypass for the PD signals thru stray capacitances of the connection leads and the generator will be blocked.

Figure 1: Connecting the LDS-6



The PD signals usually will be decoupled via the tap of the primary bushings or the primary and secondary bushings. This setup needs no coupling capacitors, but it is less sensitive compared to the standard setup using external coupling capacitors. It can be used nevertheless for two reasons:

- The insulation of a power transformer is less sensitive to partial discharge as e.g. the XLPE of an extruded power cable. So a less sensitive measurement is sufficient.
- The limiting factor for PD measurements on power transformers most often is the external noise floor. Because the noise will be attenuated in the same way as the PD signal, a less sensitive coupling branch does not affect the signal-to-noise ratio.

From the bushing tap, the signal connects to a measuring impedance (e.g. LDM-5). The measuring impedance adapts the bushing tap to the coaxial connection cable and suppresses the power frequency voltage. It also protects against transient overvoltages in case of a voltage flashover. An additional output of the measuring impedance can be used to monitor the high voltage because it has a built-in capacitance. This creates a voltage divider together with the high-voltage capacitance of the bushing.

The measuring cables connect to an automatic multiplexer, which selects one of up to eight input channels for the digital PD detector.

2.2. On-Site Setup

For on-site measurements, the setup is very similar to figure 1. The transformer can be fed from the primary or secondary side. Especially if the transformer is tested or monitored under normal operation a blocking impedance can not be used.

On-site tests are performed mostly with the line voltage of the transformer. Here the voltage can not be raised above the nominal voltage of the transformer. Therefore failures which would be started with transient overvoltages can not be detected. To detect PD failures that appear over the lifetime of the transformer, permanent PD monitoring of important transformers is recommended

For calibrating the PD measurement, the transformer has to be switched off at least once. If this is impossible other means for comparable measurements have to be used; e.g. the calibration with the so-called "reduced charge". /3/

3. Overview of the LDS-6

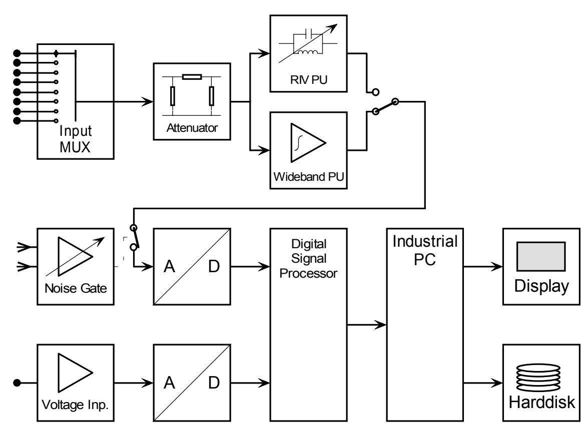


Figure 2: Overview LDS-6

Figure 2 shows an overview of the digital PD detector LDS-6 with the special setup for transformer testing. Important components are explained more in detail.

3.1. Input Multiplexer

The input multiplexer selects the actual channel to test. Up to eight inputs are possible. When testing transformer, the LDS-6 automatically scans the inputs in a user-programmable sequence. E.g. the inputs one to three can be tested repeatedly for one minute each.

	Test Channel 1 for 1 Minute
	Test Channel 2 for 1 Minute
	Test Channel 3 for 1 Minute
Repeat for 1 Hour	

Figure 3:Test Sequence for 3 phase transformer testing

3.2. Input Attenuator

The input attenuator consists of a switched resistive Π-Network to adapt the measuring sensitivity to the input PD level. The attenuation range is from 0dB up to 93dB.

3.3. Wideband Processing Unit

The wideband processing unit is the heart of the partial discharge detector. It integrates the PD signals to create an output signal equivalent to the "apparent charge" of the PD event.
The term "wideband processing unit" indicates that it uses a wider part of the electromagnetic spectrum (here from 100kHz to 400kHz) than the "narrow-band processing units" (9kHz).

3.4. RIV Processing Unit

An alternative to the wideband processing unit is the RIV processing. It is a narrow-band processing unit with a bandwidth of 9Khz. The center frequency of 1Mhz or 850kHz can be selected from the operator.

3.4.1. RIV versus PD

The RIV test is still widely used in the USA. Historically it was developed to prevent Radio Interference (RIV), so radio listener did not get interferences with their AM radio reception.

It was found that the RIV test indicates partial discharges and is therefore a useful tool to ensure the product quality. In theory, there is no difference between a RIV and narrow-band PD detection. The PD pulse has a widespread spectrum of frequencies, of which the narrow-band detector picks only a narrow part of the spectrum.
Based on this, the first narrow-band PD detectors developed were adapted RIV meters.

The main difference between RIV and PD measurements is the calibration procedure and the result of the measurement.
A RIV calibrator generates a HF signal with e.g. a magnitude of 10mV and a frequency according to the center frequency of the RIV detector. The sensitivity of the RIV meter will be adjusted so its output reads e.g. 10mV (80 dBμV).
The PD calibrator simulates a PD pulse of e.g. 100pC. The sensitivity of the PD detector will be adjusted so its output reads e.g. 100pC.

RIV measurements are expressed in "dBμV", while the PD reads in "pC" (Pico-Coulomb).

Nevertheless the RIV test is NOT a PD measurement; because it does not use a PD calibrator and does not take into account the attenuation of the signal by the capacitance of the test object etc.

4. Noise Suppression

PD tests are very sensitive to external electromagnetic signals. These signals can affect the measurement. They are not the desired PD signals, but noise. Especially in unshielded test laboratories and on site the noise level can be so high that it prevents successful PD measurements if the noise is not reduced.

4.1. Noise Filter

One kind of electromagnetical noise is created by the local AM radio station or other narrow-band HF transmitter.
The noise filter LDF-5 can be used to filter out these narrow-band frequencies.

4.2. Noise Gating

Some devices (e.g. variable frequency drives, power tools etc.) create short electromagnetic impulses. The spectrum of these pulses is similar to the PD pulse spectrum, so they can not simply be filtered out.
They can be distinguished by an antenna at a place were only the noise pulses can be received, but not the PD pulses.
Then the noise gating unit suppresses the measurement for the time of the occurrence of these noise pulses. Because the noise and the PD signals are not related, all PD measurements and analysis can still be done, even if some few PD events might be suppressed together with the noise.

4.3. Noise Windowing

The noise windowing works similar to the Noise Gating, but it uses the characteristic of some noise pulses that they are very stable over the phase angle of the power voltage.
So the Noise Windowing suppresses the measurement over a short period of the 60Hz voltage cycle.

5. Voltage Measurement

A characteristic of transformer testing is the use of induced test voltages with a frequency higher than the normal power voltage.
The voltage measuring circuit of the LDS-6 is able to measure accurately and synchronize to a test frequency of up to 500Hz.

6. Analysis of the PD Data and Test Report Generation

While testing, every PD event of the active channel will be written to the hard disk, together with the actual voltage, phase angle, time and channel number. This allows a replay of the test and all state of the art analysis methods. The LDS-6 also contains diagnosis functions, which compares the fingerprint of the PD measurement with the characteristic of previously recorded pattern and gives the most likely reason for the PD. This can help with the interpretation of the results.

After the measurement, the data will be written to an Excel spreadsheet. With adaptable templates, the report is fully customizable and can also be saved to a database.

A connection to the LAN let the data or a backup copy be saved on the network.

7. Transformer Monitoring Device LDWD-6

For on-site monitoring of the transformer PD level over a longer time or permanently, the LDWD-6 was developed. With its weatherproof housing it is especially suited for permanent outdoor installation.

Its main task is to monitor the PD on several locations, be it different phases or more than one transformer. If the PD level is above a given threshold for a predefined amount of time, an alarm will be generated. A relay output will switch to signal the alarm. The built-in modem can also perform an alarm action, e.g. call a pager.

The LDWD-6 has also all the analysis functions available for the LDS-6. The function principle is quite the same. All PD events will be saved on the hard disk. Newer events will overwrite older. This allows analyzing the conditions even some time before the alarm and recognizing a trend. The modem or a network connection can be used to remote operate the LDWD-6.

8. Summary

It is shown that the partial discharge testing of power transformers has its own unique requirements for the test equipment.
Therefore the partial discharge detector LDS-6 was adapted to meet these special needs. Also a new device for permanent monitoring on-site was developed.
The new components of the LDS-6 required for these specialized tests were introduced.

9. References

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