CONCEPT FOR AN ADVANCED PARTIAL DISCHARGE MONITORING SYSTEM LDWD-6

The presented paper deals with an advanced PD monitoring system, developed for insulation condition assessment of high voltage equipment in service such as transformers and rotating machines. The handling as well as the measuring principle of the LDWD-6 is described and the specified parameters are given. In this context it is assumed that the user is in general familiar with both, the physics of PD phenomena and the principle of PD detection. For more information see the relevant IEC publication 270 [1] as well as the references [2; 3; 4; 5]

1. Hardware concept of the LDWD-6

1.1 Block Diagram

The electrical PD detection is an indispensable tool not only for quality inspection tests in laboratory after manufacturing, but also for diagnostic field tests after installation and maintenance. Due to the enormous wide range of applications of PD measuring systems the developed instrumentation arrangement can be flexible composed according to the particular measuring situation. Hence, the PD monitoring system LDWD-6 consists of the following different package modules as evident from Fig. 1.

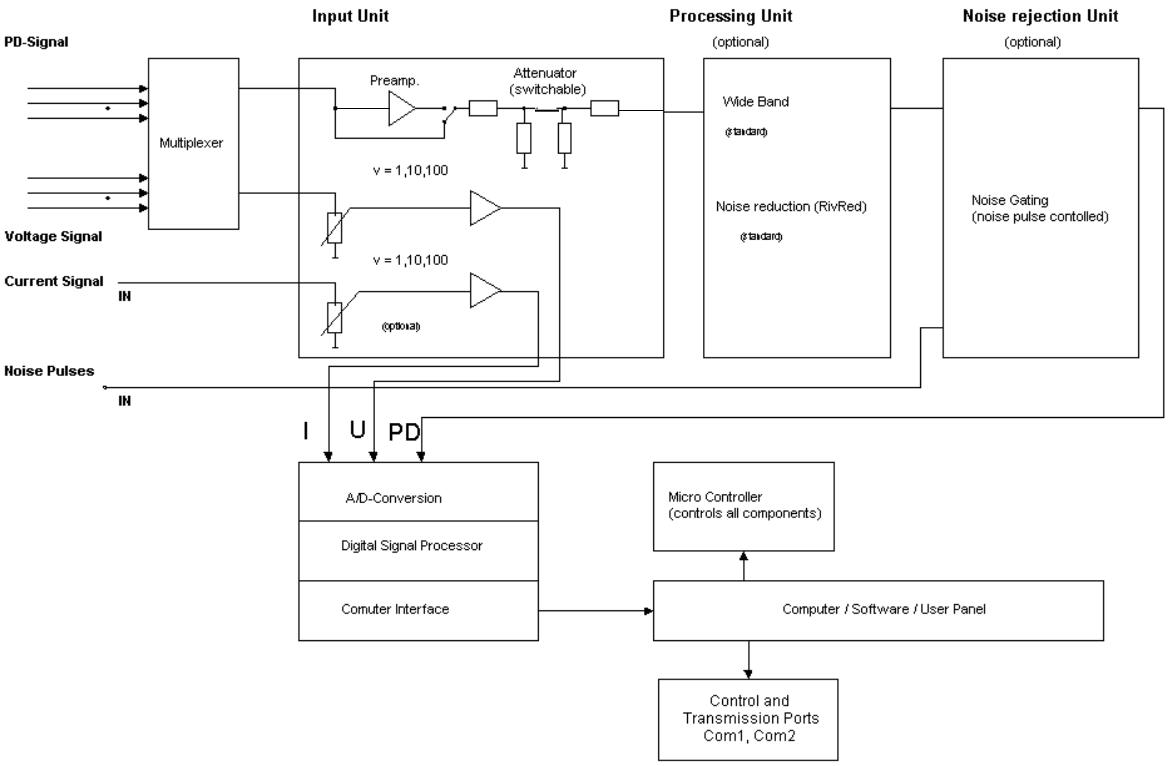

Fig. 1 Basic Schematic Diagram of the LDWD-6

The main functions of the modules can be summarized as follows:

• ***Input Unit***

- Signal attenuation of the PD pulses decoupled from the HV test circuit by either the standardized PD measuring quadripole or inductive / capacitive sensors
- Wide band pre-amplification (selectable gain)
- Pre-attenuator selectable in 3-dB-steps, provides a total attenuation up to 93 dB (provides a comfortable autoranging routine)
- Separate voltage input for acquisition of instanteous values of the applied test voltage, necessary for measurement of the peak value and to display the phase resolved PD pattern
- Additional input for acquisition of the instanteous current values or other relevant magnitudes.

• ***Processing Unit***

Different types of signal processing units can be combined together within the basic device using the versatile plug in technique:

- Wide band processing unit to attain very sensitive PD measurements
- Logarithmic processing unit, provides logarithmic single pulse processing with a high dynamic range and single pulse resolution capability
- Narrow band processing unit for frequency selective PD evaluation, different selectable measuring midband-frequencies

• ***Noise Rejection Unit***

- Windowing method for elimination of phase stable noise pulses (at least for two phase windows selectable)
- Noise pulse gating, controlled by external noise pulses captured via external sensors or antennas

• ***Matching Unit***

- Analog / digital conversion
- High speed programmable gate array pre-processing for recognition of PD, current and voltage amplitude, pulse polarity discrimination, peak detection, single conditioning for further post processing, digital noise rejection, time gating for suppression of not desired signal oscillation and reflections
- Digital Signal Processing (DSP) module for quick data processing and compression, short duration data buffer, time and phase resolution of PD events, conversion of control commands to optional external components such as e.g. external step generator for supply of calibration pulses on line

• ***Control Unit***

- µ-Controller based bus system for controlling the devices and components
- Auxiliary ports for implementation of supplement functions

• ***Internal Multiplex Unit***

- Software controlled multi-channel switch for successive measurements at different measuring points
- Remote controllable

• ***Evaluation Unit***

- Computer workstation performing complex diagnostic tasks
- Real time display of the main PD quantities
- Autorun facility of preselected measuring procedures
- Connection to remote data base via COM (Component Object Model) interface
- High sophisticated analytical and statistical evaluation procedures
- Implemented expert system

1.2 Hardware components

The PD detecting hardware of the LDWD-6 consists of the following main parts: switchable signal attenuator which provides a wide range of measuring sensitivity, the wide band PD processing unit with noise suppression facility and the analog/digital converters for PD and test voltage signal.

Additional it is possible to combine the Basic Device LDWD-6 with the C/tan d measuring system LDV-5. The hardware of the LDV-5 provides the acquisition and evaluation of the data.

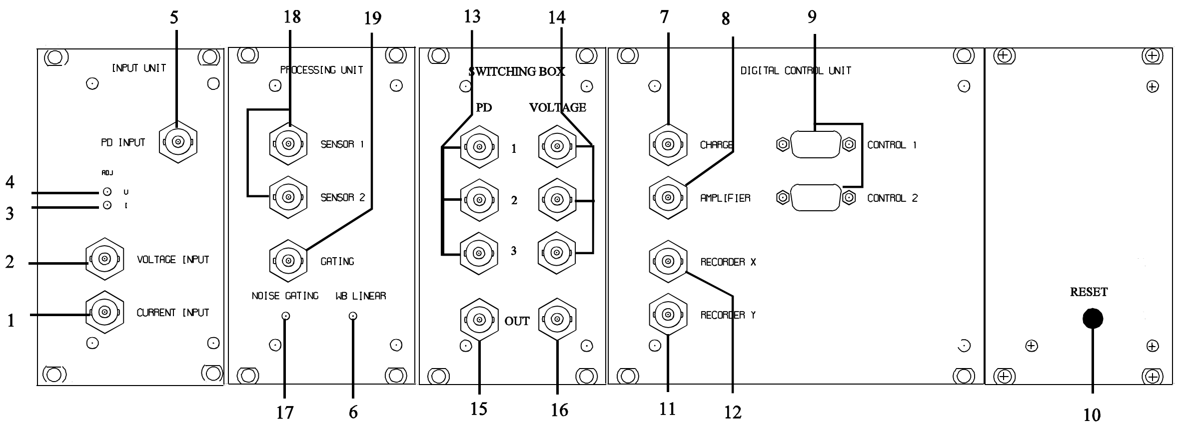

Fig. 2 The Basic Device LDWD-6

1	CURRENT INPUT	11	RECORDER Y
2	VOLTAGE INPUT	12	RECORDER X
3	DIV ADJ I	13	SWITCHING BOX PD INPUT
4	DIV ADJ U	14	SWITCHING BOX TV INPUT
5	PD INPUT	15	SWITCHING BOX PD OUTPUT
6	WB LINEAR	16	SWITCHING BOX TV OUTPUT
7	CHARGE	17	NOISE GATING
8	AMPLIFIER	18	NOISE GATING SENSOR INPUT 1 AND 2
9	CONTROL 1 AND 2	19	CONTROL OUTPUT NOISE GATING
10	ALARM RESET		

2. Software Concept of the LDWD-6

2.1 General

The software concept is characterized by strict partitioning of the numeric data processing into different programmable hardware units.

The first numerical data processing is realized in a field programmable gate array (FPGA). After that, the digital signal processing unit (DSP) is responsible to do the PD pulse to voltage-phase assignment, the control command translation and the precompression for the main processor subsequent treatment. Based on all this progressive software grading the user interface program in the workstation runs exclusively for the front-end application.
Moreover, all control commands for the hardware management are operated by a separate internal µ-controller.

2.2 Analysis and Statistical Features

The front-end software is running under a Windows NT operation system. A comprehensive PD evaluation toolbox [6] is implemented. It serves for all types of analyzing. Typical routines and evaluation processes for quality tests in a production environment, on site tests or even for periodical or continuous monitoring are already realized. Also features for a wide range of scientific PD investigations are available [6].

The analysis and statistical toolbox covers the following functionality:

- replay of all PD quantities in compliance with the specifications of the standards (IEC, VDE, AEIC, IPCEA, ASTM, ANSI) and derived quantities (q, q^2, qxU(t)) using an operation panel similar to an audio or video player
- traditional presentation in time and elliptic mode
- time and voltage dependent presentation of all defined quantities: apparent charge q; pulse repetition rate and frequency n, N; average discharge current I, discharge power P, quadratic charge rate D, etc.
- PD frequency distribution, phase resolved 2D & 3D representation
- PD pulse distribution, segmental or continuous display
- impulse / impulse correlation [7]
- water fall diagrams of the PD-distribution vs. charge
- average PD current vs. phase and time
- all phase and polarity resolved statistical PD parameters (q, H(q)): maximum, minimum, mean value, standard deviation, skewness, kurtosis and cross correlation

2.3 Partial Discharge Expert system

A common mathematical modeling of all occurring PD failures is not available up to now. Only for exceptional cases exists a mathematical model which is suitable to describe a subclass of PD problems. Therefore, an automatized diagnosis system for PD failures is limited to the recognition of specific symptoms in PD measurement data records.

In this connection it must be noted that the characteristic feature extraction of the data record is cut out for the key position [8] in the quality of the diagnosis result. In the scientific field of the PD fault recognition exits a wide range of formulations about the suitability of different features to be extracted. Realized for the presented PD expert system is a combination of two independent feature detectors. The fourier correlation coefficient of the phase resolved charge signal is normalized to the number of the test voltage periods. To describe the phase resolved PD distribution is only a limited number of coefficients of the fourier series necessary [8] and used for the feature extraction array. Additionally, the variation of the coefficients versus the test periods is inserted to the feature pool.

Furthermore, the classical statistical operators [9] of the derived histogram functions of the PD frequency distribution are included in the feature extraction matrix.

After the extraction, the two resulting feature arrays are subjected by a classification schedule. The classification is effected by means of comparison of feature extraction arrays of the actual measured PD data with feature objects of all existing PD failure records stored in a reference database. As the classification result, the qualified probability of the class membership of the classified object array related to identified PD faults is evaluated and after a mutual coincidence check displayed on the computer screen of the PD measuring system. A typical classification result is shown in Fig. 3.

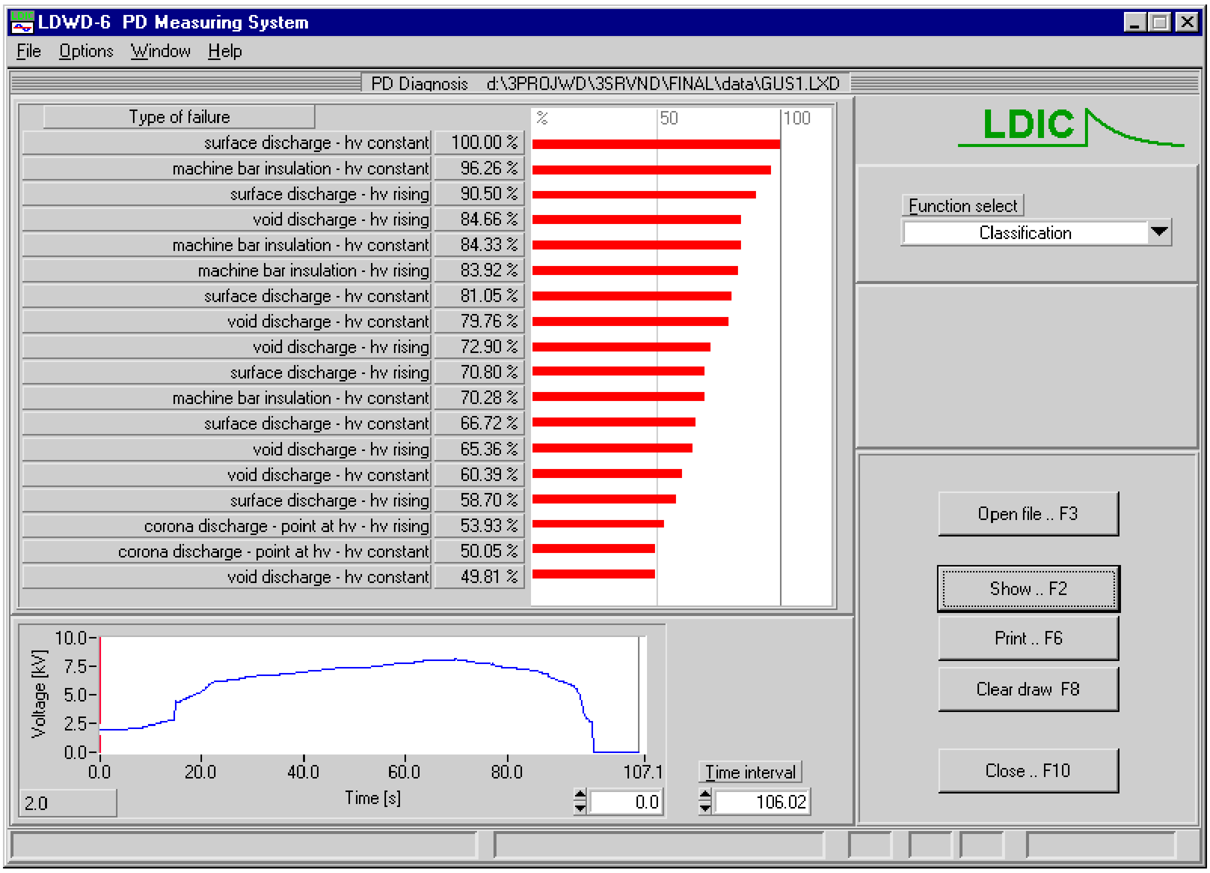

Fig. 3 LDWD-6 Expert System

2.4 Program Overview

The LDWD-6 program consists of the following different sections represented by there windows (panels).

- **Setup** — setup window for default settings of the measuring system
- **Calibration** — mode for displaying the phase resolved PD events, for calibration of the PD measuring system
- **Measurement** — mode for on line measurement and data storage
- **Monitoring** — mode for on line monitoring and history data transfer
- **PD Analysis** — for displaying of the stored data results and their evaluation including graphical presentation by different functions
- **PD Statistics** — for displaying of the stored data results and their evaluation including graphical presentation by different statistical functions
- **PD Diagnosis** — for comparing of the stored data files and their graphical presentation

The functions can be activated from the control panel represented by their buttons in the main panel.

3. Measuring example

The device operates in the monitoring mode full-automatically. The monitoring panel in Fig. 4 is just started. The lower green trace displays the actual course of the PD activity of the monitored test object. The threshold level (upper blue line) is adjusted to 30 pC. The actual PD level is about 12 pC. This value and further setup values are also displayed on this monitoring panel. The alarm function is enabled and the continuously monitoring is running.

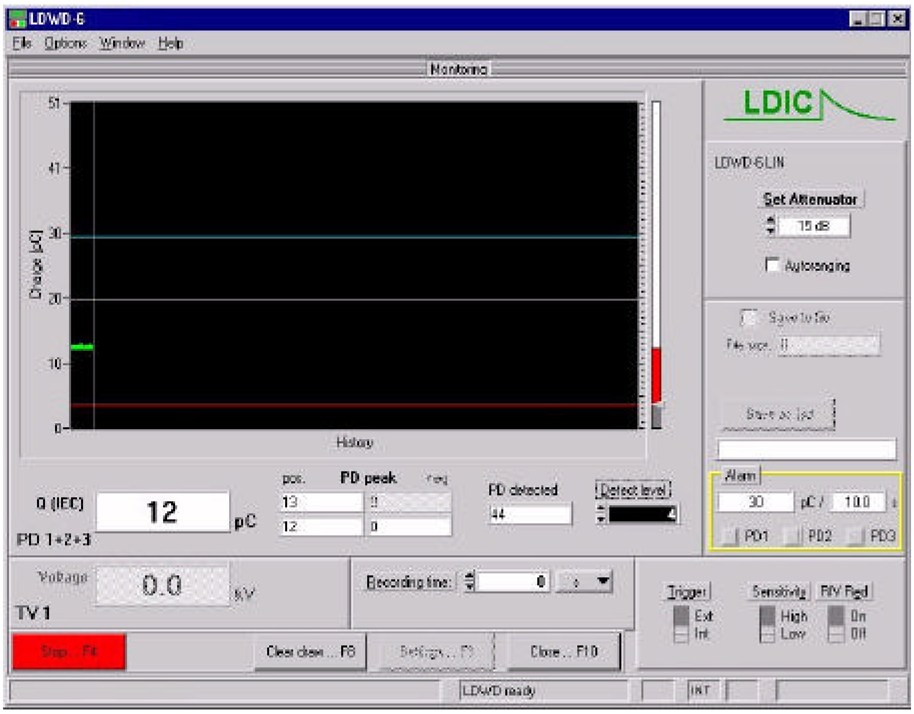

Fig. 4 LDWD-6 software - Monitoring panel

The value for the threshold level can be adjusted as well as the cycle time of the internal multiplexer. The corresponding history files will be storaged on the internal hard disc and can be displayed in order to get a more comprehensive information about the course of the PD activity of the monitored test object. An example of such a history file is shown in Fig. 5. The trigger level was setted to 30 pC, while the PD activity was higher and was released an alarm.

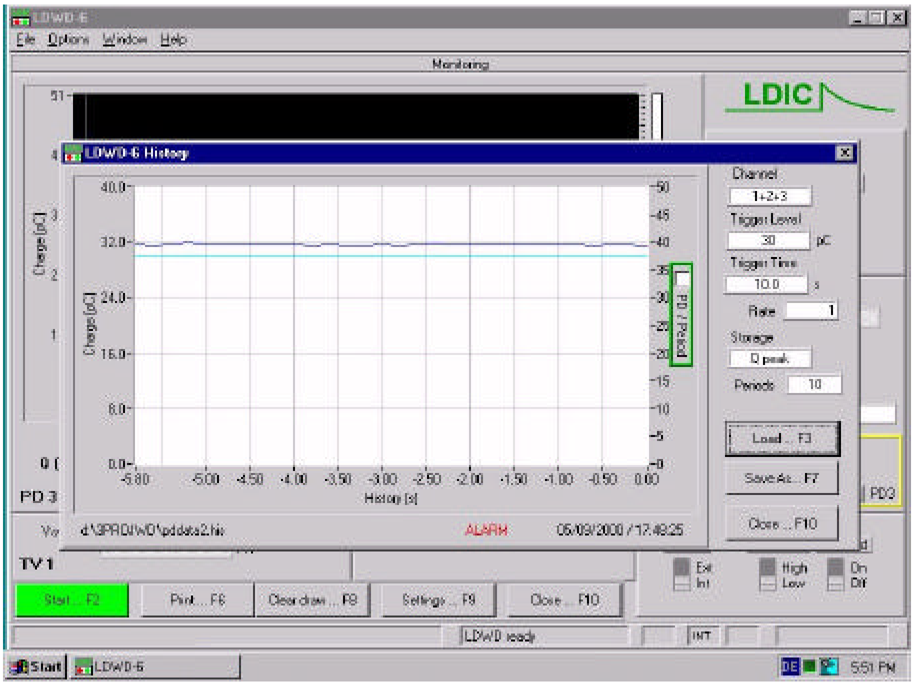

Fig. 5 LDWD-6 software - History panel

But sometimes, the monitoring and history panels are not sufficient, especially, if the operator wants to know more about the PD phenomenon. Therefore, he can use the internal PD measuring facilities and can show the measured files with a lot of information about all PD quantities and derived quantities (q, q^2, qxU(t)). A replay of the measured apparent charge is shown in Fig. 6. The same replay, only in elliptical mode, is shown in Fig. 7. The voltage function for easy determination of inception and exception voltage is shown in Fig. 8. The corresponding pulse number is shown in Fig. 9. The Impulse/impulse-correlation is shown in Fig. 10.

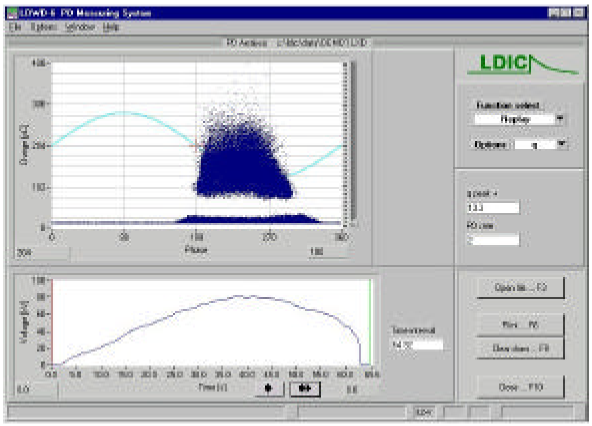

Fig. 6 LDWD-6 software - Apparent charge

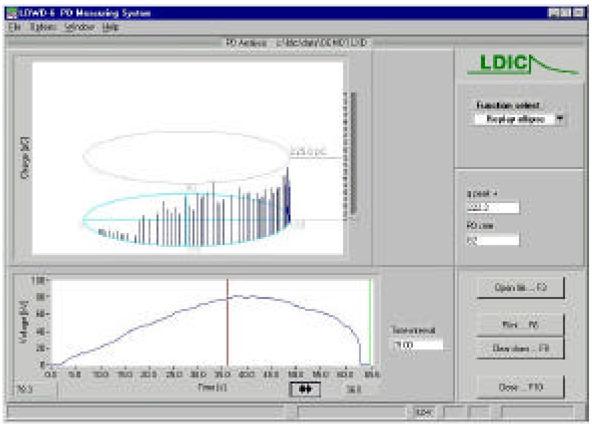

Fig. 7 LDWD-6 software - Elliptical mode

Fig. 8 LDWD-6 software - Voltage function

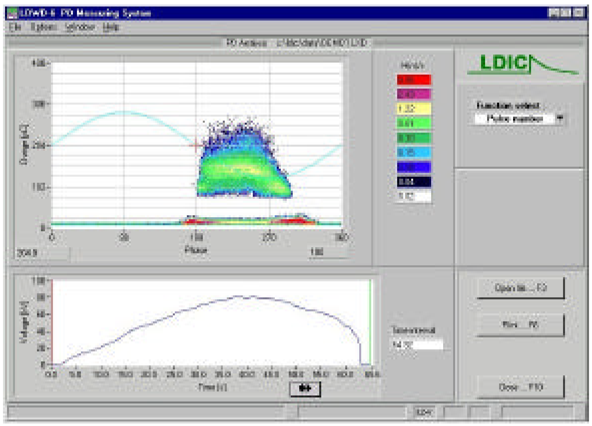

Fig. 9 LDWD-6 software - Pulse number

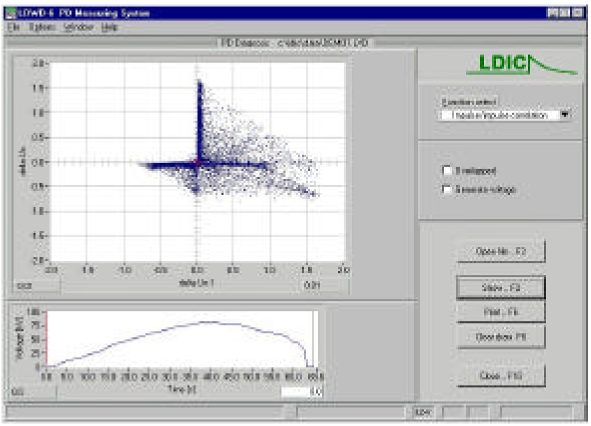

Fig. 10 LDWD-6 software - Impulse/impulse-correlation

4. Literature

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