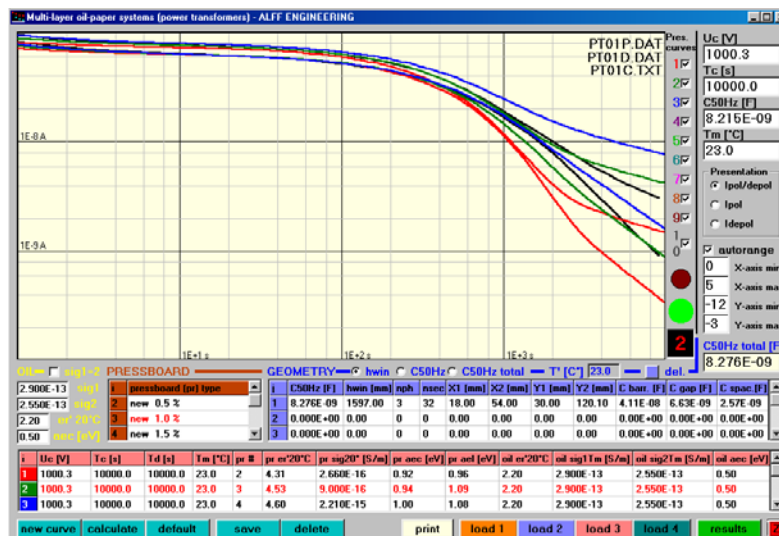


# P D C-Evaluation

## Polarisation and Depolarisation Current Evaluation Program

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### User's Guide

(for the Advanced Evaluation Tools)

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## 1 Introduction

The advanced tools of the *PDC-Evaluation* program permit the quantitative determination of the moisture content in the pressboard (weight %) and the oil conductivity in the homogeneous and multi-layer oil-paper insulation systems.

The determination of the above quantities is based on a graphic comparison between the measured and calculated relaxation currents, which are based on different moisture contents in paper and on different oil conductivities.

## 2 Advanced tools

Two advanced tools are accessible in the *Diagnosis* menu of the *PDC-evaluation* program.

The first tool permits the evaluation of the relaxation currents measured on macroscopically homogeneous insulation systems consisting only of oil impregnated paper. Such homogeneous insulation systems can be found in cables, in bushings, in capacitors and in instrument transformer.

The second tool is conceived to evaluate the relaxation currents measured on macroscopically inhomogeneous insulation systems consisting on a multi-layer arrangement of oil impregnated pressboard and oil ducts in series. A power transformer is a typical electrical apparatus with such an insulation system. Taking the geometrical dimensions and the composition of the investigated insulation into account this tool permits, besides the determination of the moisture content in the pressboard, also the quantitative evaluation of the oil conductivity.

The material characterisation implemented in these two tools is based on investigations performed in the High Voltage Laboratory of the Swiss Federal Institute of Technology on new pressboard material (Transformerboard Type TIV) delivered by Weidmann AG company, Rapperswil [1, 2].

## 3 Evaluation of homogeneous insulation systems

The evaluation of homogeneous oil-paper insulation systems can be performed with the first advanced tool accessible in the *Diagnosis* menu.

The evaluation is based on a graphic comparison between the measured relaxation currents and the calculated ones in function of the moisture content in the pressboard. The calculation is carried out by considering the influence of measuring parameters i.e. the charging voltage "Uc", the charging duration "Tc", the discharging duration "Td" and the measuring temperature "Tm". The geometry (or the dimension) of the test object investigated, which can be expressed in the vacuum capacitance "Co" or in the 50 Hz capacitance "C50Hz" is also taken in consideration [3].

To perform an evaluation, start the program *PDC Evaluation* and load the current data of the test object investigated with the **Load** command from the *File* menu of the *main* window. Now open the advanced evaluation tool from the *Diagnosis* menu. The curves of measured relaxation currents are now displayed in the graphic area. To calculate a first comparison curve push the **new curve** command button and chose a pressboard type from the *pressboard (pr) type* list by clicking on its label. After clicking, the quantities, which characterised the pressboard material (see [1, 2]) i.e.:

- "pr er' 20°C"            the 50Hz relative permittivity at 20°C
- "pr sig 20°C"            the dc conductivity at 20°C
- "pr aec"                the activation energy for the conductivity

- "pr ael"                    the activation energy for the losses

together with measuring parameters "Uc", "Tc", "Td" and "Tm" are displayed in the *working list*.

The information concerning the geometry can be set by choosing the type of the geometry input parameter, with the geometry option buttons *Co* or *C50Hz*, and by typing its value in the corresponding cell of the *working list* [3]. The **PDC-ANALYSER-1MOD** is able to determine the capacitance of the investigated test objects by using a time domain method. This value of capacitance corresponds well to the value of the capacitance measured at 50 Hz with a classic bridge. Therefore, this value can well replace the "real" "C50Hz" capacitance value. All geometry, measuring and material parameters displayed in the *working list* can be varied "manually" by setting new values in the appropriate cells. The variation of the values of measuring parameters ("Uc", "Tc", "Td" and "Tm") in the *working list* has only a "local" effect and is valid only for the actual calculation. For a "global" effect (validity), the values of these parameters must be changed in their own text boxes positioned at the right side of the advanced evaluation window. The default values of the measuring and the material parameters can be recalled in the *working list* with the **default** command. After checking all parameters, the calculation can be started with the **calculate** command.

The advanced Evaluation tool permits the calculation of up to 10 relaxation currents with different moisture content in the pressboard. Each new calculation begins with the **new curve** command. The previously calculated curves can be deleted with the **delete** command.

The moisture content of a test object can be estimated by a graphic comparison between its relaxation currents and a group of calculated relaxation currents with increasing moisture content.

The resulting quantities of the pressboard i.e.:

- "pr er' Tm"                the 50Hz relative permittivity at temperature "Tm"

- "pr sig Tm"                the dc conductivity at Temperature "Tm"

are presented in a separate list, which can be displayed with the **results** command.

The calculated currents chosen from the *working list* can be registered with the **save** command. The advanced tool produces four files. The values of polarisation current are saved in a \*.dat file. The values of depolarisation current are saved in a \*.d.dat file. To permit the reload of the calculated curves in the basic *PDC-Evaluation* program, a comment file \*.c.txt, similar to that generate by the current measuring program in the **PDC-ANALYSER-1MOD**, is also created. Finally, the important parameters of the calculation are saved in a \*.r.txt file.

#### 4 Evaluation of multi-layer insulation systems

The evaluation of the multi-layer oil-paper insulation systems (specially power transformers) can be performed with the second advanced tool accessible in the *Diagnosis* menu.

The principle of the operation in this tool is similar to that described in the previous section.

In the relaxation currents of the multi-layer insulation systems e.g. power transformers, the influence of oil is predominant at short times due to the interfacial polarisation [1, 4]. The influence of pressboard become more visible at long time after saturation of the interfacial polarisation. For calculation of relaxation currents of multi-layer insulation systems the material properties of oil are described in few quantities, which are the relative permittivity at 50 Hz, the conductivity and the activation energy for the conductivity [1, 2].

To estimate the oil conductivity and the moisture content in the pressboard of a power transformer, start the program *PDC Evaluation* and load the current data of the transformer investigated with the **Load** command from the *File* menu of the *main* window. Now the data of measured relaxation currents are also accessible in the advanced evaluation tool. After opening the advanced evaluation tool from the *Diagnosis* menu, click on the **new curve** command and chose the pressboard type with the lowest moisture content from the *pressboard (pr) type* list by clicking on its label. After clicking, the values of measuring parameters i.e. the charging voltage "Uc", the charging duration "Tc", the discharging duration "Td" and the measuring temperature "Tm" are displayed in the *working list*. In the working list are also displayed the values of quantities, which characterised the pressboard material (see [1, 2]) i.e.:

- "pr er' 20°C"            the 50Hz relative permittivity at 20°C
- "pr sig 20°C"            the dc conductivity at 20°C
- "pr aec"                    the activation energy for the conductivity
- "pr ael"                    the activation energy for the losses

and the values of quantities, which characterised the oil (see [1, 2]) i.e.:

- "oil er' 20°C"            the 50Hz relative permittivity at 20°C
- "oil sig1 Tm"            the conductivity of oil for the polarisation current at temperature "Tm"
- "oil sig2 Tm"            the conductivity of oil for the depolarisation current at temperature "Tm"
- "oil aec"                    the activation energy for the conductivity.

In general, the advanced evaluation tool for multi-layer arrangement differences 3 alternative possibilities for input of geometric parameters, depending if the average windings height "hwin" or the 50 Hz capacitance "C50Hz" or the total 50 Hz capacitance "C50Hz total" are known [3]. The information concerning the geometry can be set by choosing the type of geometry input, with the geometry option buttons *hwin*, *C50Hz* or *C50Hz total* and by typing the values of geometry parameters in the *geometry list* [3].

All parameters displayed in the *working list* can be varied "manually" by setting new values in the appropriate cells. The variation of the values of this parameters in the *working list* has only a "local" effect and is valid only for the actual calculation. For a "global" effect (validity), the values of these parameters must be changed in their own text boxes. The default values of the measuring and material parameters can be recalled in the *working list* with the **default** command. After setting of all geometry, measuring and material parameters, the calculation can be started with the **calculate** command.

The two quantities to estimate by multi-layer oil-paper insulation systems are, the oil conductivity and the moisture content in the pressboard.

The amplitudes of relaxation currents at short times are very sensitive to the change of oil conductivity (see figure 1). The value of oil conductivity can be estimated with successive calculation of a first relaxation currents by varying its value of conductivity of oil for the polarisation current "oil sig1 Tm" in the *working list* until a coincidence between measured and calculated polarisation current at short times is reached. For this calculation the moisture content of chosen pressboard must be low (e.g. < 0.2%) .To accelerate the adjusting procedure it is sufficient to calculate only a polarisation current with short duration and to compare it with the measured one. To do this, set a small value for the Tc (e.g. 100 s) and 0 s for the Td in the *working list*.

After this estimation, set the estimate value of the oil conductivity in the text box *sig1*. Now this value of the oil conductivity is accessible for calculation of other relaxation currents with different moisture contents.

The moisture content in the pressboard influences mainly the shape of relaxation currents at long times. To estimate the moisture content in the pressboard, now it is possible to calculate a group of relaxation currents with increasing moisture content in the pressboard and to compare them with the measured currents (see figure 2).

The advanced Evaluation tool permits the calculation of up to 10 relaxation currents with different moisture contents in the pressboard. Each new calculation begins with the **new curve** command. The previously calculated curves can be deleted with the **delete** command.

The high moisture content in the pressboard influence slightly the initial amplitude of relaxation currents. For a better comparison between measured relaxation currents and calculated ones with high moisture contents, it is sometimes necessary to re-estimate (to readjust) again the oil conductivity value.

The advanced tool permits a differentiation between the oil conductivity for the polarisation current and that for the depolarisation one. This differentiation permits the simulation of relaxation currents with a slight non-linear behaviour due to a decrease of oil conductivity at the end of polarisation period. This non-linearity is caused by the application of somewhat too high excitation voltage level and brings about a small amplitude difference between the polarisation and depolarisation currents at short times (see [1, 4]). This small amplitude difference can be simulated by choosing a slightly lower value of oil conductivity for the depolarisation current than that for the polarisation one. To permit the input of different values of oil conductivity for the polarisation and depolarisation currents, the check box *sig1=2* must be unchecked.

The resulting quantities of the pressboard i.e.:

- "pr er' Tm"            the 50Hz relative permittivity at temperature "Tm"
- "pr sig Tm"            the dc conductivity at Temperature "Tm"

and those of the oil i.e.:

- "oil er' Tm"            the 50Hz relative permittivity at temperature "Tm"
- "oil sig1 20°C"        the conductivity of oil for the polarisation current at 20°C
- "oil sig2 20°C"        the conductivity of oil for the depolarisation current at 20°C

are presented in a separate list, which can be displayed with the **results** command.

The calculated currents chosen from the *working list* can be registered with the **save** command. The advanced tool produces four files. The values of polarisation current are saved in a \*.dat file. The values of depolarisation current are saved in a \*.d.dat file. To permit the reload of the calculated curves in the basic *PDC-Evaluation* program, a comment file \*.c.txt, similar to that generate by the current measuring program in the **PDC-ANALYSER-1MOD**, is also created. Finally, the important parameters of the calculation are saved in a \*.r.txt file.

## 5 References

1. Der Houhanessian, V.: *Measurement and Analysis of Dielectric Response in Oil-paper Insulation Systems*. Ph.D. dissertation, ETH No. 12832, Zurich, 1998.
2. Der Houhanessian, V., W. S. Zaengl: *On-site diagnosis of power transformers by means of relaxation current measurements*. Conference Record of the 1998 IEEE International Symposium on Electrical Insulation, IEEE Publication 98CH36239, pp. 28-34.
3. *User's Guide for the Input of Geometry Parameters in the Advanced Evaluation Tools*. ALFF ENGINEERING, 2001.
4. Alff, J.-J., V. Der Houhanessian, W. S. Zaengl, A. J. Kachler: *A Novel, Compact Instrument for the Measurement and Evaluation of Relaxation Currents conceived for On-Site Diagnosis of Electric Power Apparatus*. Conference Record of the 2000 IEEE International Symposium on Electrical Insulation, IEEE Publication 00CH37075, pp. 161-167.

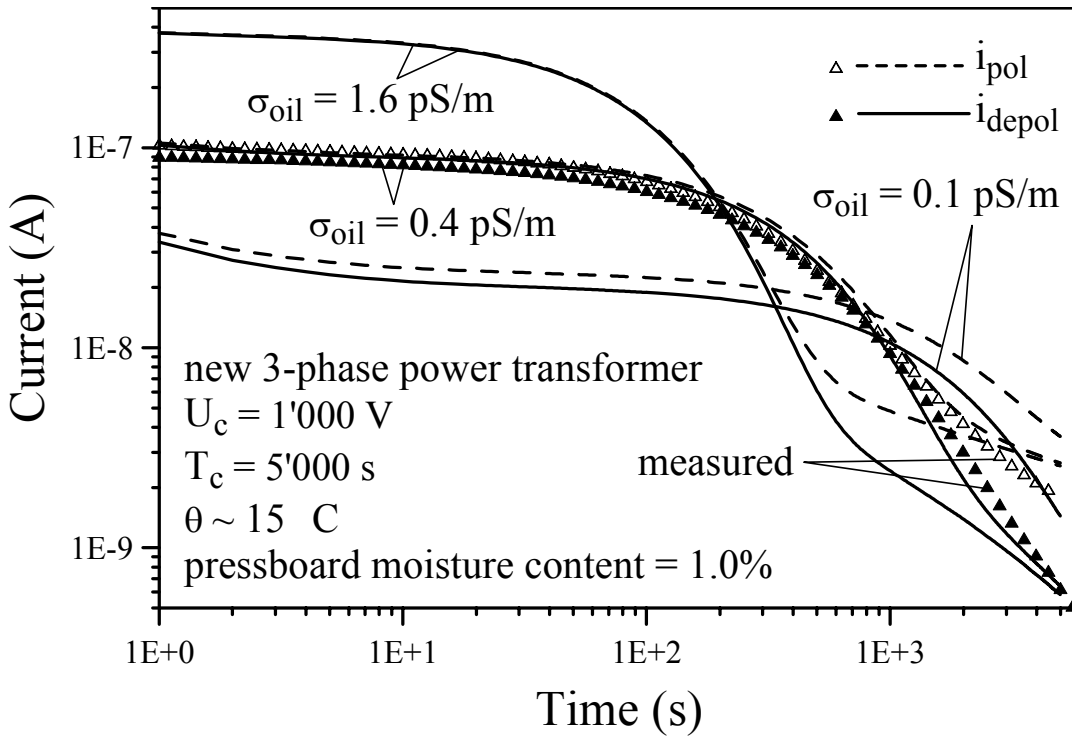


Figure 1: Measured and calculated relaxation currents as a function of oil conductivity  $\sigma_{oil}$  of a new power transformer.

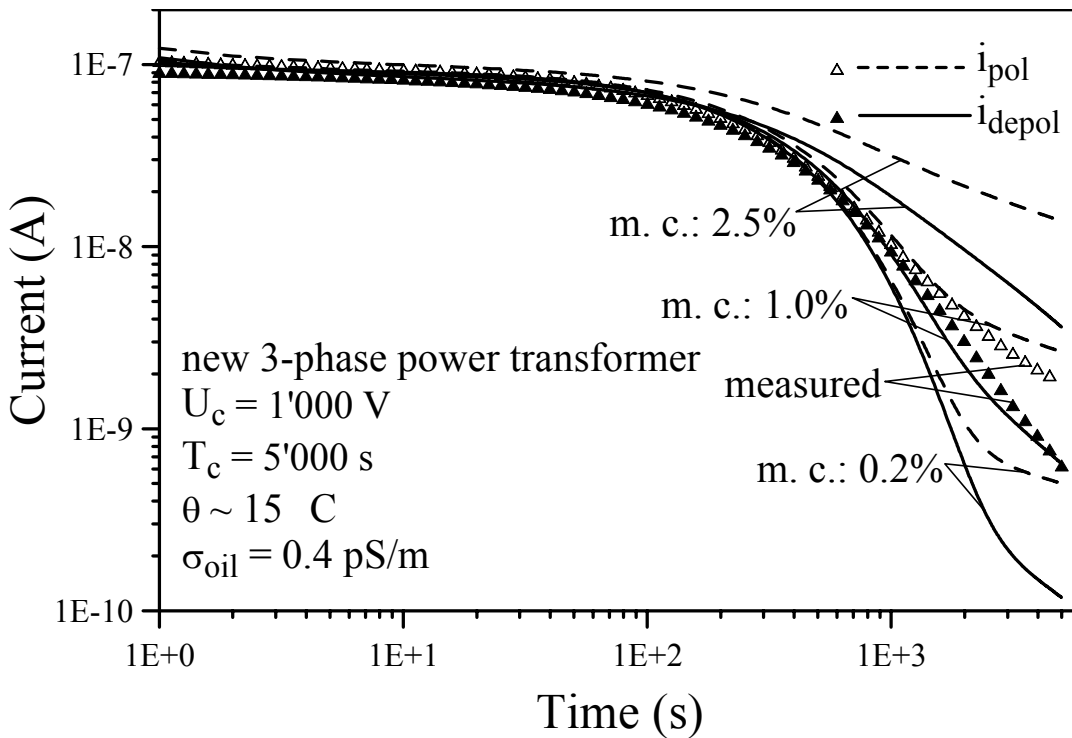


Figure 2: Comparison between measured and calculated relaxation currents as a function of moisture content (m. c.) in the pressboard barriers and spacers of a power transformer.