TLM

On-site PD Measurements on Power and Distribution Transformers

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Brief Career Summary

My professional career directly started after completing my theoretical and practical thesis concerning high voltage testing on rotating machines at the company Maintenance Partners Belgium, a group company of Mitsubishi heavy Industries Ltd. With this company, I started as application engineer for partial discharge and loss factor testing of new designed VPI and Resin rich insulation systems, as well on rewound and repaired high motors and generators in the workshop. Later on, in 2010, I became Reliability Engineer at the same company. At that time the focus was mainly on on-site partial discharge testing (off-line & on-line) of rotating machinery, approximately 400 machines per year. Beside the partial discharge testing on machines, several other predictive tests as well on transformers belonged to the daily tasks such as:

- Load measurements/monitoring
- Winding resistance and inductance measurements
- Various DC-insulation resistances tests
- Dielectric loss analysis
- Recurrent surge oscillation measurements
- Surge testing
- Ring flux tests and Elcid core tests
- Hi-pot testing
- Basic Vibration analysis
- Ultrasound measurements
- Sleeve Bearing examination and Basic Shaft Alignments
- No load/load loss measurements
- Transformer turns ratio and winding resistance testing
- Polarity and phase displacement testing

In August 2012, I followed my passion for Partial Discharge analysis and started as Application/Service Engineer at Power Diagnostix Systems GmbH. Here, I'm mainly active with service related jobs such as on-site Partial Discharge Diagnosis and Fault Location on distribution and power transformers, MV and HV cables and rotating machines worldwide. Beside the consulting jobs, I take care of various training sessions concerning different high voltage applications and commissioning of PD-equipment and monitoring installations worldwide.

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On-site Partial Discharge Testing on Transformers

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Abstract – A different asset management approach based on detailed condition assessments resulted in changing maintenance strategies in order to improve the reliability of power apparatus such as transformers. Following these strategies, transformers are nowadays more frequently repaired on-site. Consequently there is currently and increasing demand for on-site re-acceptance testing, re-commissioning and localization of partial discharge activities within power and distribution transformers. Lightweight modernized converter based mobile test systems have simplified performing applied and induced voltage tests for on-site PD diagnosis. In case that partial discharge activity is found, several measurement and analysis techniques can be applied in order to locate the defect position and to perform a root cause analysis on this partial dielectric imperfection within the transformer winding. The acoustic PD localization method has been proven to be very effective for pinpointing partial discharge with more than hundred different cases.

Keywords: New maintenance strategies; condition assessment; on-site repair; on-site partial discharge testing; mobile test systems; partial discharge troubleshooting methods

1 Introduction

Unexpected maintenance outages are usually a disaster for grid companies and utilities as the unavailability of power and distribution transformers represents tremendous costs and affects the efficiency of the power network and the aspect of safety. Ideal would be the implementation of a predictive maintenance strategy from the early beginning after the first on-site commissioning. With this strategy, required outages can be scheduled based on the condition of grid equipment. Sadly to say, this method has not been applied in the past, as transformers were considered as static grid assets having no need for maintenance until they start to behave different from their normal operational condition. Hence, it will take a while to fully implement the CBM as the number of aged and maintenance requiring transformers worldwide already represents a serious number. As a consequence of this increasing quantity of aged units, the failure rate will inevitably increase. Some of the existing units already require a complete overhaul or already need to be replaced before they can even undergo a first attempt for a dedicated condition assessment. However, trends are changing and on-site maintenance becomes more and more implemented, based on detailed condition and risk assessments, in order to improve the reliability and reduce the down times, transportation time and associated high transportation costs. Based on available figures [10], a few hundred on-site refurbishments and partial repairs have been accomplished successfully worldwide. As a consequence of the need for dedicated condition assessments and on-site repairs, both site acceptance (SAT) and diagnostic on-site testing show an increasing demand. Beside the standard oil and dissolved gas analysis, partial discharge measurements are an important part of the available tools and methods to predict the status of a transformer winding.

2 On-site Repair and Testing

After partial repairs or even a complete refurbishment is completed on-site, transformers need to be fully re-commissioned and tested according to relevant standards such as the IEC 60076 [1] and IEEE C57.113 [2]. Passing the site acceptance test is of course a must before re-energization by the grid. The preparation for such on-site repairs and testing to standards is a demanding task. Besides having a well-acquainted staff, creating a clean and sealed environment, providing lifting facilities, advanced drying processes and special tools, in other words, moving the factory to the site, a mobile test setup that covers the power requirement and approaches the shielded lab environment conditions from the factory should be moved to the site as well. In the past, mostly motor-generator sets with step-up transformers were used as a power supply. One of the disadvantages of such units is the size, as multiple bulky containers need to be moved to the site. Moreover, from technical point of view, not all required tests can be carried out as often desired. With

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the current compact electronic based mobile systems [3] on-site testing has been seriously simplified. The step-up transformer for the induced voltage test and the reactor for the applied voltage test are assembled within one 40ft standard container. Besides that, the variable frequency range of the power converter offers performing induced voltage tests at a self-compensating frequency. Thus, the power consumption required for such tests can be limited to the active losses only.

Fig. 1: Mobile transformer test system, 1.3MW

3 Partial Discharge Measurements

Standards such as the IEC 60076 specify the partial discharge measurement as routine or special test to be performed on units from specific voltage classes. While in the past PD testing had to be carried out on power transformers with a rated voltage above 72.5 kV, the focus is now on the lower rated units as well. Even if it is not a standard test, it is a recommended special test, which transformer manufactures have to perform as part of tenders. This is a logical result of the developments made with the partial discharge measurement technique and standardization the past 20 years. Since many years the PD measurement is a method that has proven to be very effective to unveil ongoing dielectric problems or design failures within various insulation systems. Testing according to standards [1, 2] requires defined criteria and rules to be strictly followed, while diagnostic testing has more an approach of predictive testing and localization, regardless the methods and techniques used. However, one thing they have in common, i. e. mapping of phase resolved partial discharge patterns. Analysis of the pattern properties by studying dominant half cycles, typical shapes, clustered pulses, and respectively the phase position of the PD events can offer some important information about the nature of typical insulation failures. Not only the statistical data behind the pattern are of importance, but as well having an understanding of the winding design, properties of insulation materials used, as well as the distribution of the high frequency PD pulses within the active part and the bushings to locate certain faults.

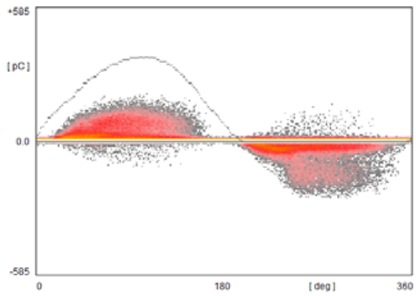

Fig. 2: Pattern of multiple gas bubbles trapped in glue

As an example, figure 2 shows a PRPD pattern of multiple flat air pockets trapped within glued wooden spacer blocks recorded just after the inception. The symmetrical pattern indicates that there is no physical contact to an electrode. In this case, the statistical time delay for the PD inception indicates initially a low availability of a starting electron.

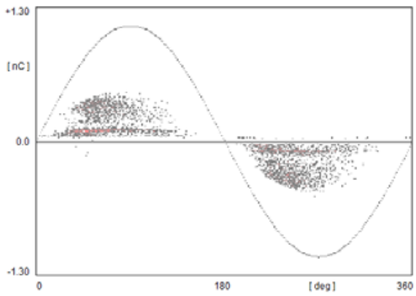

Fig. 3: Pattern of gas inclusions just before the PDEV

Figure 3, instead, reflects the PRPD pattern of a similar activity as found with figure 2, just before reaching its partial discharge extinction voltage (PDEV). Here, the pattern still shows a similar distribution, but with a reduced repetition rate. The typical sine shaped clusters indicate more prominently the individual cavities compared to the pattern of figure 2. Typically, the ratio between inception-extinction for such flat cavities is in range of two.

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4 On-site Partial Discharge Testing

4.1 Site Acceptance Test

After on-site repairs or rating upgrades of existing units, a partial discharge measurement should be performed with a three phases induced voltage (IVPD), according to the procedures and evaluation criteria defined by the IEC 60076-3. As stated above, with today's compact inverter based test systems, the induced voltage test can be easily performed at a self-compensating frequency. Hence, there is no need for a large diesel generator and reactive power compensation. Moreover, such test systems can be automatically tuned into the self-compensating stage without the need for a dedicated power factor measurement prior to actual test. Besides the limited power required, setting up such modern mobile test sets requires a couple of hours only. In order to meet the criteria of the applicable standards, the measurement setup should be well optimized [9]. Measuring in the low frequency range as defined, offers mostly the best coverage for partial discharge sources that are deeply buried within transformer coils. Moreover, the impulse properties of the HFPD pulses shall be less affected and hampered by HF effects such as attenuation, reflections, dispersion, and resonances [7]. However, the frequency range from 30–500 kHz is very often exposed to strong background noise sources, acting within the same frequency range. Firstly, the output of the power source should be well noise-controlled.

Fig. 4: HV filters with embedded current transformer and capacitive voltage divider

With electronic based systems, the IGBT switching often hampers sensitivity readings in the low frequency range. In order to meet the defined noise criteria of <50pC [1], adequate and advanced filtering is a must. Figure 4 shows such high voltage filter with embedded voltage divider and current transformer. Besides filtering the output of the step-up transformer, they directly provide the data required for the load and no load losses measurements. Secondly, site conditions cannot be compared with the well-controlled atmosphere of the shielded test room. Usually, the transformer tank offers sufficient shielding for the active part. However, open air bushings may then act as antennas for ambient noise such as AM broadcasting stations. Therefore, with on-site tests, a digital PD detector with embedded spectrum analyzer and gating function is a handy tool in order to investigate the present signal to noise ratio and modify the center frequency accordingly. Figure 5 shows such an example of a spectrum of a PD signal (blue trace) overlapped with the spectrum of the diesel-generators noise (red trace). In this case, it's clear that measuring that measuring at CF2 shall offer the better sensitivity.

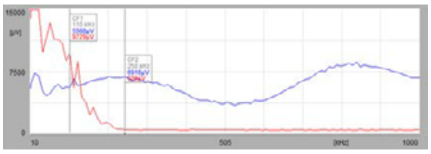

Fig. 5: Signal to noise ratio investigation

For transformers in the medium voltage class range external corona on top of the bushings might become critical as well. Hence, fitting of corona electrodes (spheres) is strongly recommended to avoid such external disturbances with typically a high repetition rate and widely distributed spectrum.

Fig. 6: Preparation for an induced voltage test

Finally, the feeding cables to the low voltage winding or tertiary winding are recommended to be flexible shielded cables, which are of course PD-free. The combination of extended high voltage filtering, noise gating, spectrum analysis, and PD free setup makes it possible to perform on-site PD measurements according to standards. Sometimes minor modifications on the setup, such as separating groundings, are more

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efficient than simply increasing the center frequency with the risk of exceeding the IEC 60270's frequency boundaries [6]. In worst case, when criteria can just not be met, a compromise on minor deviations from the procedure can be found with the owner of the transformer or witnesses of the tests, as they are aware of firstly, the non-shielded conditions, and, secondly of excessive transportation costs, which can be avoided by performing the site acceptance test. The actual PD measurement setup is identical to setups used with regular factory acceptance tests. Usually, the condenser bushings of the high voltage windings provide a test tap where quadrupoles can be fitted. When the low voltage and even the tertiary winding do not provide such test taps, coupling capacitors can be used instead.

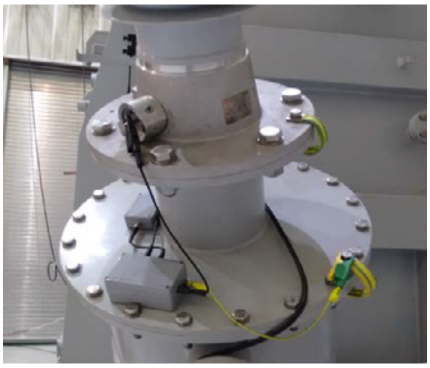

Fig. 7: Quadrupole and preamplifier fitted to the tap

4.2 Diagnostic Testing

Diagnostic testing has a slightly different approach than site acceptance testing. With such kind of tests, all alternative decoupling methods can be used and the strict rules and criteria do not apply. The aim of such kind of periodical tests is gaining more information regarding the transformers winding condition for trending purposes or even an attempt to perform a PD localization. The test can be performed offline, using an external high voltage supply, or online, using the grid to energize the transformer. With an offline test, the measurement setup will be similar to the acceptance test setup, maybe with additional sensors or antennas besides the quadrupoles fitted to the capacitive test tap (Fig. 7). In case of online testing, it's possible to de-energize the transformer for a short time in order to install various sensors and for calibrations and sensitivity checks, followed by re-energizing by the grid. If the transformer must stay in operation, alternative decoupling methods should be considered.

When oil drain valves are available that provide UHF signal access by means of a direct oil path into the main tank, UHF sensors can be fitted. Figure 8 shows a transformer valve UHF sensor (TVS2) installed on a DN50 standard flange. The sensor measures the internal PD-activity in a frequency range from 300 MHz up to 1 GHz. At the place of origin, the electron avalanche under nitrogen condition might reach rise times below the nano second range, causing a frequency response of the PD in the UHF range. However, the bigger the distance of the signal's origin to the drain valve (sensor position), the more such signals can be hampered, reflected, and/or attenuated by transformer winding components such as spacers and pressboards and the support structure. Depending on the properties of the travel path of UHF-signals by internal failures to the sensor, it can happen that the original signal loses its ultra-high frequency contents. Hence, in such a case, it can become difficult to detect the defect in the UHF range [3].

Fig. 8: Transformer valve sensor (TVS2)

Measuring in the UHF range generally limits the coverage to the vicinity of the sensor position only, while the noise conditions are much better compared to the low frequency range. The TVS2 can be installed under both online and offline conditions. Consulting the design drawings beforehand is recommended in order to make sure what is behind the tank wall and, hence to avoid dangerous situations. Moreover, it should be ensured that the UHF signals can really reach the antenna which is usually 2–4 cm inside the main tank.

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Fig. 9: Clamp-on HFCT fitted to a cable bushing

In cases where oil and air or insulated cable boxes are used and where the transformer cannot be switched off and no permanent sensors are installed to the test tap, high frequency current transformer can be used instead. Such clamp on HFCTs generally measure the PD-activity in a low to medium frequency range. Often, sensitive readings can be obtained even by indirect decoupling. Important is that the power cables provide access to the ground sheath and that the shield is effectively grounded at the transformer's side. Otherwise the important return path for the high frequency PD-pulses is missing, and, hence, no useful signals might be found. Alternatively, coupler capacitors can be considered. Besides clamping the CT on the HV and LV power cables, the ground connection, if available, is often a good candidate for measuring excellent internal signals. Synchronization can be done using the instrument´s line frequency. Figure 9 shows such temporary installation of split core HFCTs fitted with a wideband preamplifier.

Besides the electrical decoupling methods in the low, medium, and UHF range, partial discharge can be captured using its ultrasonic signal emission by installing piezo electrical acoustic sensors to suspicious area on the tank wall or bushings. The output signal of the sensors can be used to map a phase resolved pattern or can be processed on a time basis for acoustic PD location measurements. However, for pinpointing a useful electrical trigger provided by an HF or UHF sensors is required firstly, in order to make sure the acoustic signals are correlated to the dominant electrical signal [4]. Figure 10 shows three acoustic sensors (AS75I) fitted to the wall of a power transformer's OLTC tank compartment.

Fig. 10: Acoustic sensors mounted on a tank wall

Finally, for periodical online measurements, a part of the continuous monitoring setup (Fig. 11) can be used. In this case, bushing adapters (BAs) and busing coupling units (BCUs) can be fitted to the capacitive test setup and connected to a coupler termination box (CTB) in the vicinity of the transformer by using outdoor coax cables. Once this setup is commissioned, the calibration files can be loaded as reference file for consecutive online partial discharge tests.

Fig. 11: Permanently installed BA and BCU

For both acceptance and diagnostic on-site testing on power and distribution transformers, a versatile multi-channel PD detector is required, which combines the conventional measurement according to the IEC 60270 with all available non-conventional decoupling techniques and important features such as spectrum analysis and extended noise discrimination. Figure 12 shows such an on-site setup with the ICM*sys8*. Besides the functions and features mentioned above, the instrument can be used to process acoustic signals as well.

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Fig. 12: On-site test setup with the ICM*sys8*

With the new version of the ICM*sys8* the instrument comes with an embedded 100Msample digital storage oscilloscope (DSO) to process electrical and acoustic signals in time domain.

4.3 On-site Consulting

In case a permanently installed dissolved gas analysis monitor (DGA) indicates an increasing presence of hydrogen or acetylene for instance, a PD monitor exceeds predefined PD alarm thresholds, or even by a trip of the Bucholz relay, on-site consulting might be required. Power Diagnostix Service GmbH offers such on-site consulting services using one of the mobile test systems for offline in-depth verification measurements or the decoupling methods as explained above for online investigations.

5 Troubleshooting Methods

When PD localization is the aim of a diagnostic test or consulting measurement, the key point is the strategy to be used. In such case, it doesn't matter which measurement techniques shall be used, it's rather a matter of combining different methods in order to gain as much information as possible to the PD origin. PD troubleshooting on-site is usually less evident compared to the well-controlled conditions of shielded test rooms in the factory, as site conditions may limit the sensitivity.

The first step with any PD location attempt is an advanced electrical measurement. Unfortunately, signal decoupling for electrical measurements is limited to the bushings taps, grounded neutral, and, when available, the core and frame bushing. Prior to energization in three phase configuration, the characterization of the transformer during the PD calibration is most important. By completing a so-called calibration matrix, the signal distribution or cross coupling to all connected measurement points can be studied and characterizes mostly the windings configuration. A delta connected winding usually results in cross coupling factors of 20–30%, for instance. Figure 13 on the next page shows an example of such cross coupling matrix of a YN,a0,d1 auto transformer.

	1R	1S	1T	2R	2S	2T
1R	100.0 %	7.0 %	2.2 %	34.6 %	3.9 %	2.3 %
1S	4.8 %	100.0 %	5.2 %	3.1 %	25.4 %	3.4 %
1T	1.5 %	6.9 %	100.0 %	1.9 %	2.9 %	27.0 %
2R	47.7 %	9.5 %	5.7 %	100.0 %	9.5 %	6.4 %
2S	2.8 %	32.6 %	3.7 %	6.3 %	100.0 %	4.6 %
2T	10.4 %	10.4 %	56.5 %	10.0 %	9.5 %	100.0 %

Fig. 13: Matrix of an auto transformer (YN,a0,d1)

With these cross coupling factors in mind, the next step is energizing the winding stepwise until the partial discharge incepts. A statistical delay with the inception can give a rough indication of the size of such typical gas inclusions, for instance. As a second measure after reaching the inception voltage, the ratios of the signals obtained from the different measurement positions should be compared with the characterization factors. In case there is match between the ratios, this can be an indication of a partial discharge source that is not too far away from the measurement position. During on-site testing, moisty conditions may require noise gating sensors, such as disturbance antennas and/or HFCT´s to cope with low external corona.

Fig. 14: Disturbance antenna DA1

Installing spheres helps to avoid heavy corona and can significantly improve the general sensitivity. Neglecting external noise is important when comparing the cross coupling ratios as a misleading indication may be obtained by comparing the levels of an internal source that is superimposed with external disturbances. Figure 14 shows such disturbance antenna in order

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to pick-up external corona signals. In third place, the phase resolved partial discharge patterns shall be analyzed. It is important to start recording patterns as soon the inception has been reached. Since patterns may change over time under influence of the applied field and the formation of by-products such as gasses, the original PD source might stay hidden. Therefore, it is important to focus on the pattern as found with the inception voltage and on the development of the pattern in function of the voltage appliance sequence. Except comparing the cross coupling factors, studying the pattern symmetry and distribution, the phase resolved patterns offer more information concerning the defect type, geometry, and possible contact to electrodes and surfaces involved.

Sometimes a partial discharge measurement performed in three phase induced mode might result into partial discharge pulses showing rare phase positions. In such case, single phase excitation may be considered on the phase showing the dominant magnitude and most correct phase position. Studying the inception voltages of the different energization configurations can indicate whether the partial discharge activity is a phase-to-ground or inter-phase related defect mechanism and, hence, simplifies locating failures between mutual HV phases. Single phase applied voltage tests can simplify discovering activities in stacks of insulation barriers between the HV and LV winding for instance [5].

In addition to the phase domain analysis, partial discharge activity can be analyzed in both time and frequency domain as well. Partial discharge sources located closer to the bushings tend to show a similar frequency spectrum and time domain signal as provided by the calibrator during injection into the bushing or test tap. Signals travelling the winding will be exposed to an increasing attenuation and/or defined resonances due to the transformers complex RLC circuit. Frequency spectra might then show a different response with additional resonance frequencies, while in time domain an often delayed signal is found showing strong ringing [7].

Figure 15 shows an example of a time domain measurement. The signals from top to bottom represent the PD activity measured on terminals 2R, 2S and 2T of a star connected low voltage layer winding of a distribution transformer. The purple trace, i. e. the signal measured on the 2T terminal, shows the strongest magnitude compared to the others. Moreover, the signal of 2T has the shortest rise time and, hence, reflects the highest bandwidth. Finally, the identical polarities indicate that the PD is not occurring between the mutual LV coils, but, that the PD activity originates on the T-coil itself. The signals on 2R and 2S are mere cross coupling.

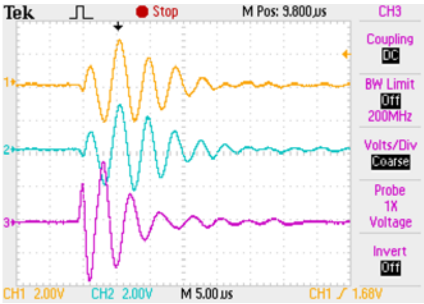

Fig. 15: Example of time domain signals

Besides studying the electrical signal response in phase, frequency, and time domain, a partial discharge source can also be identified by measuring its acoustic emission. Although the acoustic response detectable at the tank wall strongly depends on the properties of the signal transmission path to the tank wall, homogeneity of the transmission medium, the transformers winding construction, and, respectively, the properties of the tank wall, it is an effective method for partial discharge localization.

In order to locate the partial discharge source, it's necessary to find acoustic signals that can be certainly correlated to the electrical partial discharge signal, and, hence, acoustic signals emitted by vibrations and magnetostriction, for instance, are neglected [8]. Therefore, the acoustic signals are studied on a digital oscilloscope by triggering the acoustic waves on the dominant electrical PD signal derived from the capacitive test tap, for instance [4].

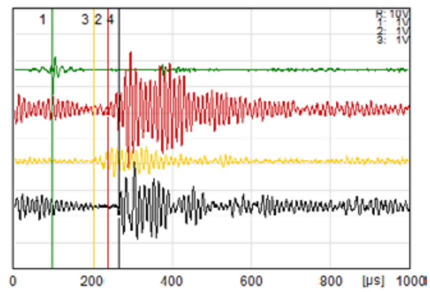

Fig. 16: Acoustic signals triggered on an electrical signal (green trace)

Using triangulation methods on three planes of a cubicle tank or three reference points on the circumference of a cylindrical tank compartment or bushing can indicate the exact position of the partial discharge source within the insulating medium. However, due to the complex network of transformer windings, the acoustic signal

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tend to travel into various directions and get distorted, attenuated, or reflected. In this case, it is important to optimize the positions of the piezo electric sensors so that the signal path of the acoustic waves to the sensor is as short as possible. Having a straight oil path to the tank wall is the ideal situation but cannot always be achieved. The typical propagation speed of pulses travelling a direct oil path is about 1400 ms^{-1}. However, with non-ideal conditions where no direct acoustic waves can be detected, a good understanding of the transmission path is required to prevent a misleading PD fault location. Acoustic signals travelling the tank wall, for instance, propagate with a pulse velocity that is much faster compared to a direct oil path, respectively 5200 ms^{-1}.

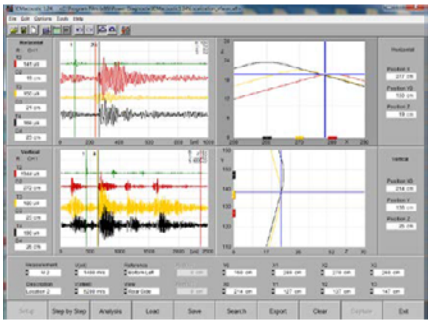

Fig. 17: ICM*acoustic* software

Figure 17 shows the interface of a special software package developed for triangulation of acoustic signals. Here, the resulting scope waveforms of the acoustic signals provided by acoustic sensors in horizontal and vertical direction can be imported. With the new version of the ICM*sys8*, even an external oscilloscope is not required anymore thanks to the embedded DSO. Moreover, the software offers a convenient link to the ICM*acoustic* software to directly analyze DSO data of the acoustic measurement. Based on this, the triangulation software computes automatically the fault position with respect to the sensor positions measured from a certain reference point on the tank. However, apart from the available tools which simplify the analysis, the main competence is still with the operator.

6 Summary

Currently, asset managements have to deal with a growing population of aged power and distribution transformers. Maintenance strategies are slightly changing into a condition based maintenance structure. As a result, the condition of transformers becomes more frequently assessed on-site using compact mobile test systems and various PD measurement techniques.

Due to detailed condition assessments including PD location coordinates by triangulation of acoustic signals, the root cause can be unveiled in an early stage, and required corrective actions can be scheduled and even completed on-site so that further investigation in the factory test lab might not be required anymore.

Although test conditions cannot be compared with the shielded test room from the factory, acceptance testing can be successfully performed on-site using lightweight three-phase converter based test sets. Advanced filtering techniques, noise cancellation methods, and spectrum analysis tools make on-site acceptance testing possible, even with respecting the defined criteria by the relevant standards. Different non-conventional methods are available for diagnostic testing purposes.

Characterization or taking fingerprints of the transformer by injecting calibrator signals at the relevant measurements point is essential in case of a dedicated PD localization. Phase, frequency, and time domain measurement are interesting methods to be combined with the acoustic technique, which has proven to be very effective in more than hundred cases with newly built and/or repaired units.

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References

[1] IEC 60076-3 ed 2013, "Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air"

[2] IEEE C57.113, "IEEE Recommended Practice for Partial Discharge Measurement in Liquid-Filled Power Transformers and Shunt Reactors"

[3] Soeller M., Gross. D., "Teilenladungsmonitoring und -ortung an Transformatoren vor Ort", 5th Transformer Life Management Conference, Hannover, Germany, June 2011

[4] Gross D., Soeller M., "On-site Transformer Partial Discharge Diagnosis", IEEE International Symposium, San Juan, Puerto Rico, June 2012

[5] Gross, D., Soeller M., "Strategies to Locate Partial Discharge in Large Power Transformers", INSUCON 2006, Birmingham, UK, May 24–26, 2006

[6] IEC 60270, "High-voltage test techniques – Partial discharge measurements", CEI/IEC 60270-2000

[7] Gross, D., "Signal Transmission and Calibration of on-line Partial Discharge Measurements", ICPADM 2003, Nagoya, Japan, June 2003

[8] Gross, D., "Acoustic Location of Transformer PD under non-ideal Conditions", ISH, Pilsen, Czech Republic, August 2015

[9] Goedertier J., Gross. D., "On-site services on Power and Distribution Transformers", 8th Transformer Life Management Conference, Neuss, Germany, September 2015

*[10] Werle P., Lorin P., Zeitz E., Eklund L., "Increase transformer reliability and availability from condition assessment to site repair", ABB, TechCon Asia-Pacfic, 2009*Contact information:

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