PARTIAL DISCHARGE MEASUREMENT IN OPERATION: PROBLEMS WITH DISTURBANCES AND THEIR REMOVING

L. Beranová, K. Záliš

Department of Electrical Power Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague Technická 2, CZ- 166 27 Praha 6, ČR, tel.: +420 2 2435 2369, mail: zalis@fel.cvut.cz

Summary: Diagnostics by partial discharge measurement is a modern diagnostic method for determination of the state of insulating systems of high voltage machines and equipment. In the High Voltage Laboratory of the Czech Technical University in Prague was developed the complex measuring and evaluating system for partial discharge measurement. Unfortunately, the main problem of discharge activity measurement in practice is in electromagnetic disturbance.

This article is focused on the removing this disturbance from measured data. Great problems in the evaluation of partial discharge data is in various sorts of interferences. The most of disturbing signals was eliminated by using of a suitable circuit modification, but others could be only convert (in the case of partial discharge signals into digital form) by using suitable computing programs for the processing and saving of measured data. In this article two basic algorithms are described for the elimination of main disturbing signals from digitized partial discharge data. At first, the algorithms for the elimination randomize disturbing signals and the second, for the SCR disturbing (from thyristors). Two math theorems were applied to all measured samples by the computing program. In another way for the elimination of disturbances from partial data is the mathematical Wavelet analysis, which makes possible the elimination of more types of disturbance.

1. INTRODUCTION

The majority of diagnostic measurements on the electrical machine's insulating systems and high voltage equipments is made in off-line mode, i.e. on a detached machine during its check-up or repair. Obviously we are using the external adjustable source of a testing voltage. Off course using on-line measurement are more suitable. One of the advantages of an on-line measurement, i.e. when the machine is working, is the possibility of finding the changes of insulation system immediately. This gives enough time for observing a defect progress and repair planning. This is related to partial discharge (PD) measurement. In the transition process from off-line to on-line diagnostics (to monitoring) it is not possible to take over the original methodologies, which could give us the evaluation of diagnostic parameters ‘automatically’.

Some of diagnostic parameters in case of the off-line diagnostics can not be measured in on-line diagnostics. Some of them lose their sense and for this reason it is necessary to develop new on-line diagnostic methodologies, regarding of new conditions. For example, in an off-line PD measurement, the evaluation methodology is based on the relation of basic diagnostic parameters (apparent charge, PD current, PD frequency) and applied testing voltage. In on-line measurement, the value of voltage is constant, but new dependencies appear, e.g. changes of basic diagnostic parameters in operational time.

That is why we have to develop new methodologies, based on the monitoring of diagnostic parameters time shift.

The more important problem in case of on-line PD activity measurement gives different kinds of disturbance and noise.

2. PROBLEMS OF DISTURBANCES

To reach for a high sensitivity of PD measurement we are obligated in interference knowledge and interference elimination. At first we try to find out all kinds of the disturbance, which could affect the PD signal. In a uniform electric field, a gradual increase in voltage across a gap produces a breakdown of the gap in the form of a spark without any preliminary discharges. On the other hand, if the field is non-uniform, an increase in voltage will first cause a localized discharge in the gas to appear at points with the highest electric field intensity, namely at sharp points or where the electrodes are curved or on transmission line conductors. This form of discharge is called a corona discharge and can be observed as a bluish luminance. This phenomenon is always accompanied by a hissing noise, and the air surrounding the corona region becomes converted to ozone. Corona is responsible for considerable power loss in transmission lines and also gives rise to radio interference. The inputs and electrodes could be sources of the corona discharges.

Some of the disturbing signals are processed by thyristor, too. They are used in many different industry sectors. The three-phase six-valve bridge rectifier is almost exclusively used in high voltage direct current applications. The 6-valve bridge connection gives double the direct voltage as output compared to the simple 3-phase rectifier. The convertor transformer may either be wound star-star or as star-delta (or even as delta-star or delta-delta). The ripple of each of these connections is the same, but is phase shifted by 30^o in output with respect to each other. To obtain a smoother output, two bridges (one star-star and the other star-delta) may be connected together to give the twelve pulse connection.

A lot of disturbing signals can be eliminated by using a suitable circuit modification. For example, usually the four-capacity bridge could be used. The PD signal can be also converted into a digital (discrete) form. Any signal processing performed on a computer using real-world data have to be performed on a discrete signal. That is, on a signal that has been measured at discrete time intervals.

3. REMOVING OF DISTURBANCE

The contemporary trend is in the possibility of measured data archive and their further processing. The analogous instruments do not appear this. That is why digital measurement instruments are used often. The biggest problem in this case is in signal digitalizing.

We are interested in the evaluation of PD measurement, especially in cleaning of measured PD data. Two computing algorithms for the elimination of main disturbing signals from digitized PD data were developed and two algorithms were applied through the computing program on measured samples before.

If we want to apply a statistical technique to PD data, we must know the signal character. The most common types of interference are the random noise signals and the semiconductor-controlled rectifier (SCR) signals. In both these cases, we try to find out, if the magnitude of the PD signal data is in interval of tolerance (the amplitude condition). It exist one more additional condition in the case of SCR disturbing signal. We search six (or more) pulses with an invariable period of SCR signal (the time condition). The algorithm is supposed to identify the disturbance and to eliminate the 'bad' signal pulses. However we need data from several periods of supply voltage.

Background noise is eliminated by the software; it is eliminating all peaks of magnitude higher than the required value.

At first we have to find out the noise peak. We compare its value with average value of all peaks and if their quotient is higher than defined constant, the software deletes the peak as product of noise. Minimal value of the quotient is 2, k = 2. The condition is shown in an equation bellow

$$\frac{q_m}{\left(\sum_{i=1}^{p} q_i - q_m\right) \div (p-1)} \geq k\,, \qquad (1)$$

where p is number of peaks in one period, q_m is maximal peak value (charge), k is condition constant <2;10>.

The two conditions used for 3-pulsed SCR signal elimination by software are shown bellow

$$\frac{\sum_{i=1}^{3} q_{mmi} \div 3}{\left|\sum_{i=1}^{p} q_i - \sum_{i=1}^{3} q_{mmi}\right| \div (p-3)} \geq k\,, \qquad (2)$$

where q_{mmi} is i-subscripted peak of three maximal peaks group in one period, q_i is i-subscripted peak of measured period, p is number of peaks and k is constant.

$$\left|\frac{p}{3} - \left|\varphi_{mmi} - \varphi_{mmi-1}\right|\right| \leq k_0\,, \qquad (3)$$

where φ_{mmi} is position of i-subscripted peak of three maximal peaks, φ_{mmi-1} is position of $(i-1)$-subscripted peak of three maximal peaks and k_0 is position tolerance.

Another way for the elimination of disturbing signals from measured data is in the using of mathematical analysis, especially in using the Wavelet analysis. It makes possible the elimination of more types of disturbance. The greatest problem in using wavelet is in the finding the best mother wavelet for these purposes. The Daubechies wavelet (db2) is one of the most useful mother wavelet.

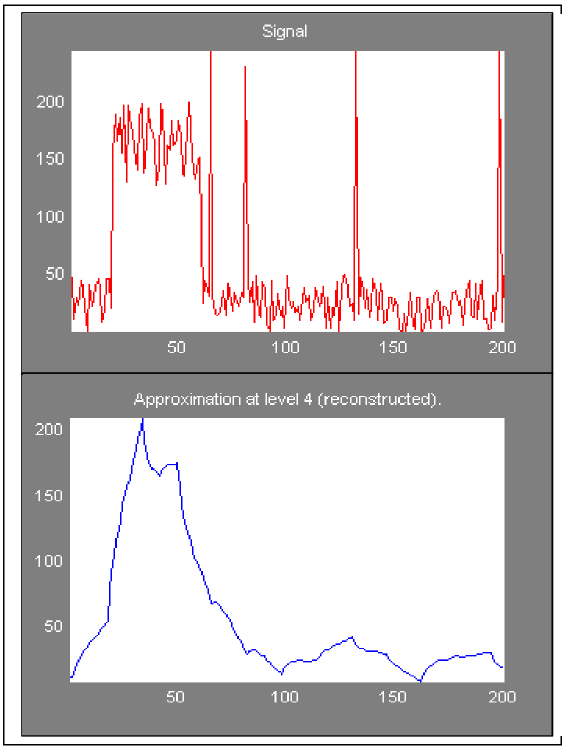

Fig. 1. ***Sample of disturbing signal elimination by DWT***

According to a signal frequency spectrum we can recognize steady signals and unsteady signals. In case of steady signals (stochastic immediate broadband signals) we are interested in the frequency spectrum only. That prefers a Fourier analysis. If a signal does not change much over time, is case of a stationary signal, this drawback is not very important. However, most interesting signals contain numerous non-stationary or transitory characteristics: drift, trends, abrupt changes, and beginnings and ends of events. These characteristics are often the most important part of the signal, and Fourier analysis is not suited to detecting them but the Wavelet analysis can.

For many signals, the low-frequency content is the most important part. It is what gives the signal its identity. The high-frequency content, on the other hand, imparts flavor or nuance. It is for this reason that, in wavelet analysis, we often speak of approximations and details.

4. CONCLUSION

Two computing algorithms for the elimination of main disturbing signals from digitized PD data were developed and two algorithms were applied through the computing program on measured samples.

We have also applied the discrete wavelet transformation to data sets and we can use a wave menu in Matlab environment for it. As mother wavelet we used the wavelet db2 and we performed the decomposition in four levels. At the end we obtained the PD pulses without disturbances. If we use decomposition tree at the last level (number 4 in our example) in detail there is the original disturbing signal an in the approximation there is original signal without any disturbance.

As another way for the elimination of disturbing signals from measured data we used mathematical Wavelet analysis, which makes possible the elimination of more types of disturbance. In both cases we can eliminate pulses of random disturbing signal and SCR disturbing signal. In the first way, using the algorithms, we have to know the character of the disturbing signal. We could eliminate the disturbance by hundred-per-cent effectiveness in this case. In the second case, using discrete wavelet transform, we eliminate the pulses of disturbance, which pulse values are higher then the other pulse values. If we do not know the character of signal disturbance or combined disturbing signal, the discrete wavelet transform is better to use. We need not take interest about the background disturbance because it's low values.

In fact we used some other software for elimination of the disturbing signal. For integration of the discrete wavelet transform into evaluated measuring equipment and its control program we need specific algorithm. This algorithm has to be based on signal filtering.

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