UHF System for Detection and Spatial Localization of Partial Discharge in High Voltage Power Transformers

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Abstract. *The article presents a new approach to the detection of a very weak electromagnetic (EM) signal, which is generated by partial discharge (PD) in a high-voltage, oil-filled power transformer. The new technique is based on the discrimination of signals with origin in outside of the transformer which are detected by external sensing head. Performed measurement process contains several different measurement modes with corresponding arrangement of sensing heads. The time-shifts of the waveforms related to transient process occurrence in the signals are the main input parameters for localization methods. In order to estimate the position of the signal source in the 3D space a minimum of four antennas has to be used, since the time of the PD is unknown.*

Keywords: Partial Discharge, UHF, Antenna, Detection, Spatial Localization.

1. Introduction

Security of the power transformers is an issue which is closely related to the stability of whole electric power distribution system. High power transformers in nuclear power plant reach power up to hundreds of MVA and any damage or destruction cause big technical problems and financial losses. Various diagnostic methods for transformer condition determination have been developed. Each of these suffers from some disadvantages. The recent technology development and the availability of hi-tech instrumentation have opened new opportunities to employment of advanced diagnostic methods, as the radiofrequency (RF) method is [1]. RF method is based on the sensing, evaluation and source localization of the EM signal in UHF range. Therefore, it is frequently called the UHF method. Our group has developed an UHF method based diagnostic system for detection and localization of partial discharge activity, as described in [2].

2. Subject and Methods

PD signal is detected by the special measuring system. Whole system contains 4 specially designed sensing heads central unit (Fig. 1), and software for PD analysis and

Fig. 1. Left - sensing head, middle - sensing heads mounted on the transformer, right – assembly of the diagnostic system in shielded box.

localization (Fig. 2). Sensing heads are mounted in to the front wall of the transformer. Heads are connected by triaxial cables for simultaneous RF signal transmission and DC powering. Signal preprocessing part of each head includes conical antenna, controllable attenuators, amplifiers, high pass filter and RF limiter. Data are acquired by Agilent data acquisition system which uses a four-channel, 10 bit high speed cPCI digitizer.

Detection methods

Expected duration of signal caused by partial discharge inside of the transformer is under 150ns and is characterized by short rising time. Detection of the partial discharge is based on setting of special antenna setup and trigger conditions. Acquisition system can use four antennas inside of the transformer and one external antenna which can be positioned in dependence on expected location of noise signals. If external antenna is used only three channels are free for acquisition, fourth channel is used as information on signal presence outside of the transformer. Trigger is set on all channels simultaneously to ensure the best trigger condition for signals coming from all parts of transformer. Partial discharge signal level depends on strength of the discharge and its distance to the antenna. This level can vary and to ensure the best trigger conditions different setting of variable attenuators needs to be tested. EM signal of the partial discharge can be distinguish from signal from other types of discharge by its shape and duration time. Ideal signal contain higher frequencies and has a short rising and duration time. Long distance signal propagation attenuate high frequencies and cause extension of those times. Signal changes in dependency on signal origin allow to create specific settings and separate desired signal.

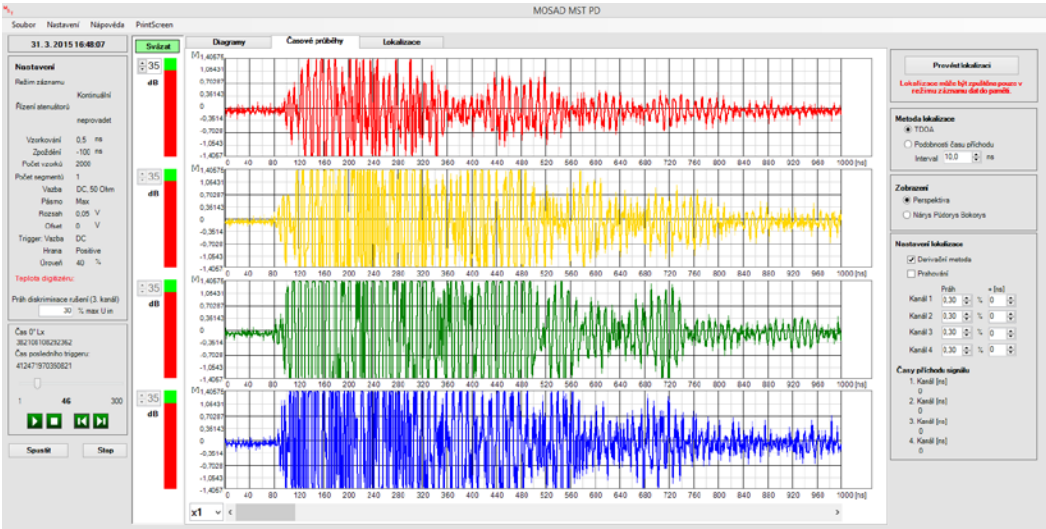

Fig.2. Software for partial discharge analysis and localization

Detecting presence of partial discharge inside of the transformer is several step procedure. First step is analyzing of signals in continual measurement mode where signal can be examined by its shape and position in 20ms of voltage period. If amount of other signals or higher noise level is in comparison to the desired signal high, is necessary to acquire signals into the memory and provide offline analysis. Memory mode is designed to acquire 300 data sets with minimal death time after downloading one data set.

Spatial localization

Accuracy of the spatial localization is determined by accuracy of detection signal arrival time. Localization algorithm is based on Time Difference of Arrival (TDOA) method where position of the signal source is calculated from difference of times of signal arrival in each channel. Time of arrival is determined from energy accumulation curve EAC given by equation [1][2]

$$w_i = \frac{t_s}{Z_0} \sum_{k=0}^{i} u_k^{\ 2},\ k = 1 \dots N \qquad (1)$$

Point in data vector could be marked as the time of arrival when EAC or its firs derivation

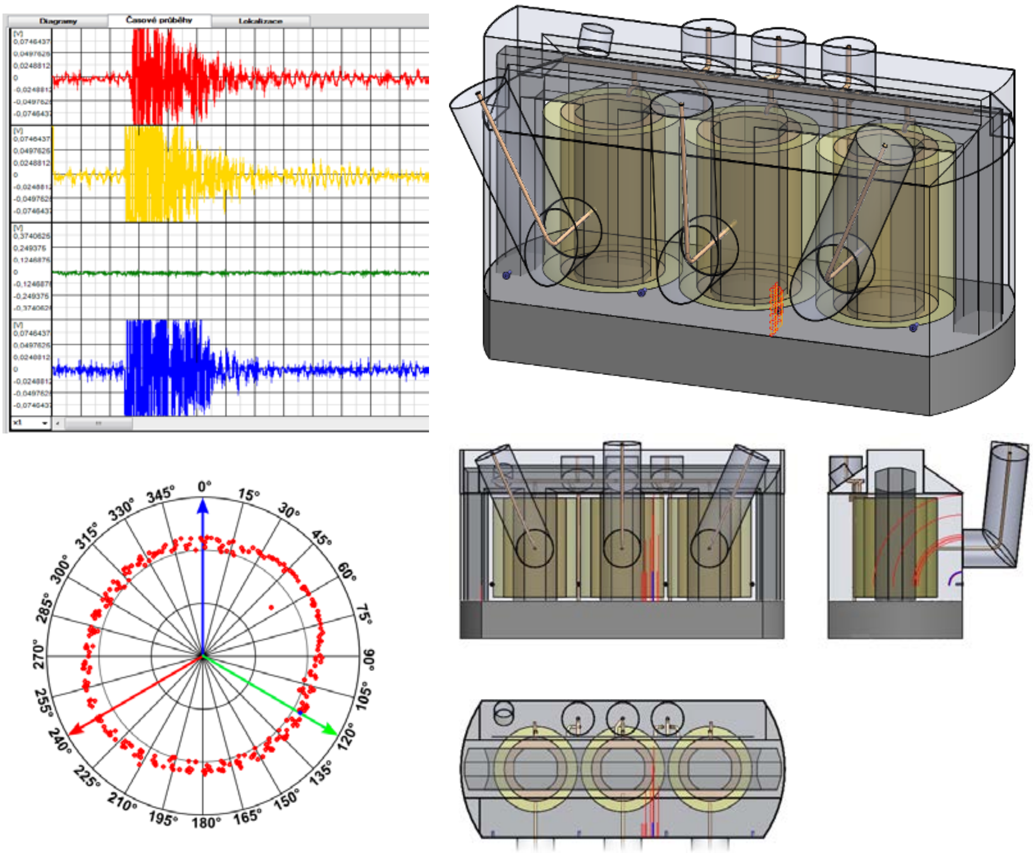

Fig.3. Result of the system calibration. Top left detected signal, down left position of data sets in phase chart, top right – results of localization for matrix method, down right – results of localization for TDOA method.

reach threshold value. Partial discharge can be then localized by two methods. First method use for given antenna arrangement derived equations and calculate position for each data set separately. This is very useful in case where is necessary to localize small amount of data sets manually. Due to high sensitivity of the TDOA method to the precision of the time of the arrival is feasible to use results accumulation. Second method for spatial localization use 4D matrix of signal arriving times. Comparing of the calculated time with the matrix could be area surrounding points which fit to defined interval marked as a potential origin of the partial discharge. In case of periodical presence of the same discharge in 300 data sets is area if its origin contains this area higher values then rest of the space. Localization results are then defined as points where value is higher than 50% of maximal value.

System calibration

Measurement system contains several specially designed devices which need to work properly to give correct measurement output [4]. For this purpose was designed special sensing head containing source of testing discharge [5]. Calibration procedure include definition of specific trigger condition to ensure detection of injected pulse, visual check of the signal shape and its positioning on phase chart and spatial localization of the signal source in third vessel, Fig 3.

Signal discrimination

Settings of the system can be considered as optimal, provided that detected signals has origin only in transformer volume. Even if system uses optimal setting, there is still high number of signal coming from outer space. Determination of which data will be used and what is the noise is based on use of external antenna. Simultaneous detection inside and outside of transformer volume allow us to mark data with signal on external antenna as a noise and delete this data. Assuming the presence of PD only inside of the transformer, then can be data with no signal on external antenna marked as wanted signal an used for analysis and spatial localization. Correct function of this method requires placing antenna in to position where is possible to detect signal from feeding and output bushing simultaneously.

3. Conclusion

Detection system is used for monitoring of presence of partial discharge in power transformers in nuclear power plant Dukovany, Czech Republic. Presence of partial discharge in this transformers is in regard to technological age of transformers not expected. However, number of signals per second detected inside of the transformer is large. Detected signal are caused by other types of discharges coming mostly from feeding and output bushing. Shape of those signals is influenced by propagation process. Long duration discharges are then discriminated by use of external antenna placed close to the feeding and output bushing and by detection of the signal level in range 400-1000ns. In this interval is expected only noise level therefore are all data with higher signal level discriminated. Discrimination efficiency has a strong influence on results of spatial localization and resulting analysis of the transformer.

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