Conference Record of the 2004 IEEE International Symposium on Electrical Insulation, Indianapolis, IN USA, 19-22 September 2004

On Line PD Diagnostic on Meduim Voltage Motors and Cable Lines: Useful Tool for the Maintenance Manager

Yuri Aksenov
DIACS, Russia
diacsnew@list.ru

Ignazio Arces
Eni, Italy

Giuseppe Noe
Comelmar, Italy

Abstract: This paper presents the authors practical experience in partial discharges (PD) on line measurements of medium voltage (MV) motors in a complex petroleum refinery.

INTRODUCTION

In most rotating electrical machines, there are numerous potential sites of partial discharge. Machine design, materials of construction, manufacturing methods, operating conditions, and maintenance practices can profoundly affect the quantity, location, characteristics, evolution, and the significance of partial discharges [1]. Now we have technology and condition based asset management for detecting defects in rotating machines before costly failures occur.

THE CONDITION BASED ASSET MANAGEMENT

A "Motor System" (MS) is the entire energy delivery process from electric feed to rotating machinery: the emphasis is on the **system**, not the motor. The authors experience is in a complex refinery where there are plenty of MS's, that can be classified according to the following priority list: problem systems, production-critical systems, large systems, and system with high operating hours. We invoke process screening to select MS's that merit further review.

CLASSIFICATION OF PHYSICAL DISCHARGE EVENTS

PD occurs in insulation laminations, gas bubbles in dielectric materials, etc. PD takes place only when there is an electrical field. From the surge structure we can see that this is the single pulse caused by ionization collision (upper front's length-30nc) and further by recombination, neutralization, etc. (lower front-hundreds of ns).

Sparking is a discharge event with high current between metallic plates. Flow changes in the contact happen not because of ionization (electronic avalanche occurrence), but because of electrolyte, thermal, **fritting** and other mechanisms in contact layer between the two metallic plates.

Arcing events appear when there is a thermo-ionized plasma between contacts, current, more than a couple of amperes and lowering of voltage for the anode and cathode potential sum.

It is should be emphasized that on-line measurements are more important. In this case all phenomena exist [2], stipulated by the presence of:

– an electrical field (only these phenomena can be reproduced by off-line AC HV tests).
– a magnetic field (it is practically impossible to reproduce a working magnetic field in stator winding with testing from another source).
– current system vibrations stipulated by mechanical forces which sometimes lead to sparking.

While making on-line measurements, in the power-changing mode, it is possible to defect several sources of different types of discharges. Existing diagnostics provide the possibility to classify defects and to define the most dangerous of them enabling a machine damage risk assessment. (Table 1):

Table 1
Determined of diagnostic results, maintenance volume and effectiveness

Sorts of defects	Risk of failure	Defects events	Useful or not on-line testing and dischar-ge site location	Useful or not visual inspec-tion	Useful or not AC HV off-line test and PD measurement	Maintenance
Mechanical damages of stator core, arcing, migrating iron particles	High risk	Arcing in soldering contact	Yes	No	No	Unsolder heads and check the insulating condition of elementary conductors near the head, re-solder
		Sparking between plates in core	Yes	Yes	No	Restore an insulating layer between plates, check with thermovision when magnetized
		Arcing between copper conductors in the bar	Yes	No	No	Don't repair
Slot discharges	Risk exists	Vibration between bar and slot and discharge as a results of vibration	Yes	Yes and no	No	Check and restore the packing in the slot
Voids in insulation	Low risk	PD in bar by slot, PD on elbow	Yes	No	Yes	Restore bar insulation
semi-conductive layer damages		Elbow surface discharge	Yes	No	Yes	Restore semi-conductive layer

DISCHARGE DETECTION METHODS

The "Frame sensor" [1] is located on the casing of the motor and the "Radio Frequency current transformer (CT-sensor)" between the bottom of the stator and ground (Figure 1&2). The key-stone of the DIACS ® frame sensors on a magnetic base is the use of a "Sandwich" plate with different electro physical features (DIACS TMP) as outlined below:

– the bottom layer – plate with large value of μ (much more than μ for steel μ_{sensor}>>μ_{steel});
– the middle layer – plate with low resistively (ρ_{sensor} << ρ_{steel}).
– the upper layer – dielectric material.

This "Sandwich" high frequency Sensor (SPHF-measurements method) as mentioned is installed on motor casing.

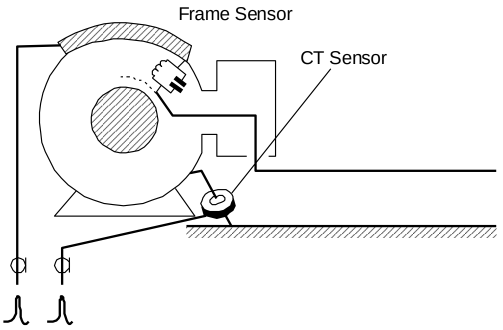


Figure 1 - Discharge pulse detector sites installations.

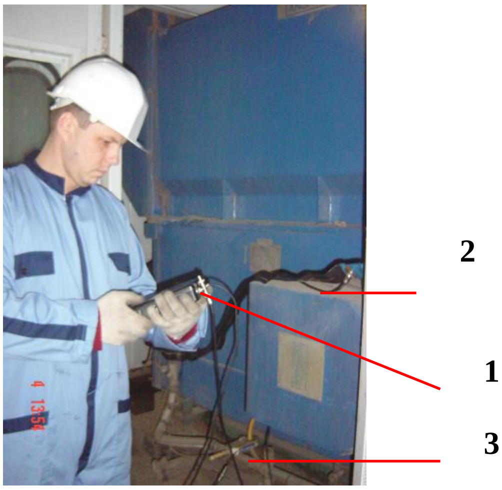


Figure 2 On line PD Detection: 1 – measuring Instrument; 2 – Frame Sensor (DIACS-TMP); 3 – CT Sensor (DIACS CT-68M).

The detected waveform signals are acquired by a preamplifier to the terminal box outside the frame, which is shown in Figure 1. Installation of the "Frame sensor" and the "CT-sensor" are carried out with no effect on the operational condition of motor. On-line PD monitoring technology is used permanently by installing external "Frame sensors".
The front-end PD circuit of the monitor consists of a 2 or 4-channel oscilloscope and PD-analyzer for device control and data processing. The 4 channels are used for big 15 kV motors and "DIACS-TMP" sensors of each phase for gating the sensors. Signals from each "DIACS-TMP" are sent to a computer for analysis. The pulse height is measured, digitized, and then recorded. Table 2 shows a role for defects sites estimation.

Table 2
Typical on-line discharge measurements for medium voltage motors

Defect Site	Signal from CT	Signal from Frame sensor	
Discharge in winding	No signal	Present	PD Pulses reflect from terminal box and don't impregnate in cable
Discharge in terminal box	Present	Present	
Discharge in cable line	Present	No signal	PDs in cable reflect from terminal box and don't impregnate in winding

REVIEW OF DISCHARGE ACTIVITY

Defects are found in specific parts of the core, terminal box, and cable line, while performing on-line motor diagnostics. Typical data from 70 motors is shown in Figure 3. This diagram shows that the quantity of dangerous defects in the winding is bigger than in other parts of the motor. Partial discharge in the insulation is shown by the oscillogramm in Figure 4. Sparking may occur either turn-to-turn between metallic parts or between laminations in magnetic circuits (Fig.5).

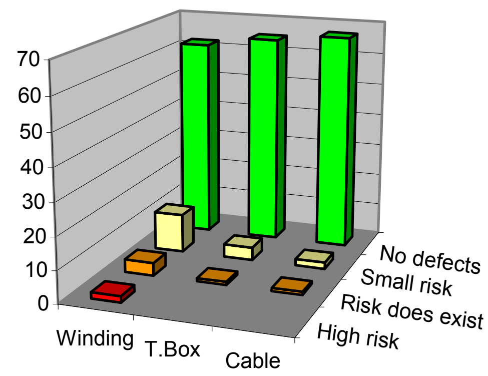


Figure 3 - Typical result (Risk of failure) of discharge screening exercise for 70 motors.

If discharges do exist in the terminal box, then impulses are fixed by the Frame Sensor and the CT-sensor. Figure 6 shows these results: potential defects on this oscillogramm are PD in cable splice.
Discharge activity in Figures 4-6 are at fixed time points although discharge events are not stable themselves all the time. To determine discharge activity changes with respect to time, the system of on-line monitoring is suitable here. Such measurements are made for critical motors. Through comparison of these two diagrams, correlations are well seen in the measurements of discharge activity and motor current (Figure7).

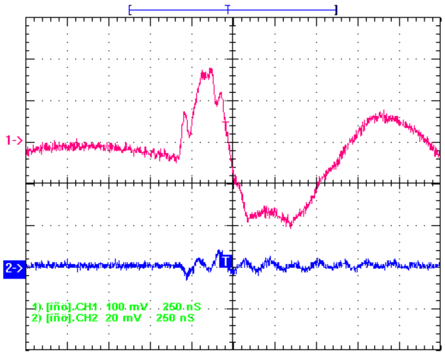


Figure 4 - PD pulses in insulation defects of winding. (Motor: 20 years in operation 6000 V, 400 kW). Ch1 – from DIACS-TMP, Ch2 – from DIACS CT-68M.

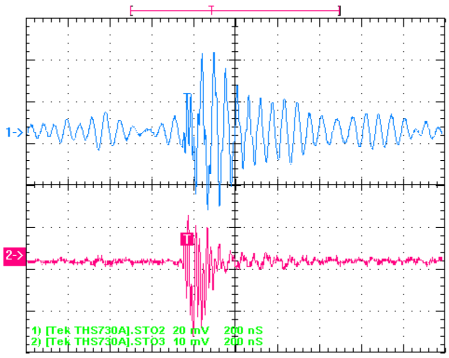


Figure 5 - Sparking pulses in stator defects. (Motor 21 years in operation, 6000 V, 400 kW). Ch1 – from DIACS-TMP, Ch2 – from DIACS CT-68M.

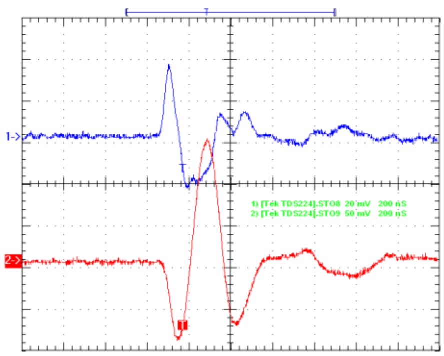
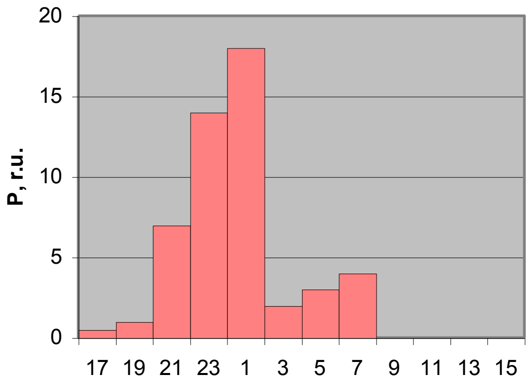


Figure 6 - Discharges in the terminal box. Probable defects in cable splice. Ch1 – from DIACS-TMP, Ch2 – from DIACS CT-68M.

A)



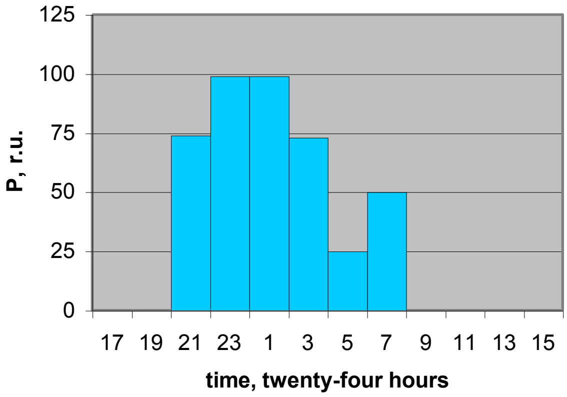


Figure 7 - The result of following monitoring system of power discharge changes on fixed frame sensors applications: A) Discharge activity diagrams with time-control changes; B) Motor regime diagram with time-control changes: Graphic of current changes (full capacity – 100%).

ON-LINE LOCATION RESULTS AND FAILURE SITE ANALYSIS

Diagnostic results indicate maximum discharge activity in “8 hours”. After one month of operation the motor failed. Results of the visual inspection are shown in Figure 8. There is good correlation between the on-line location and the failure site.

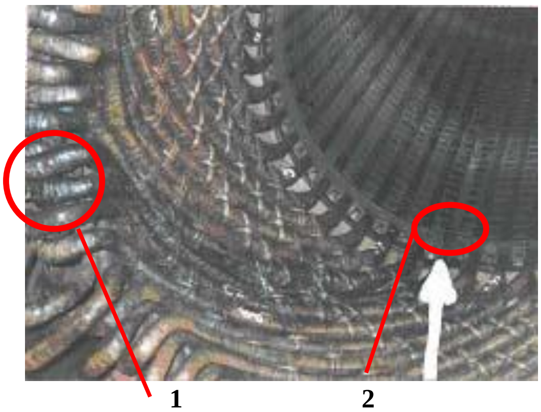


Fig. 8 Motor stator winding pattern analysis: 1 – point with max of signal (on-line PD site location); 2 – failure site.

CONCLUSIONS

The technology of the frame sensors for PD monitoring is a good tool for rotating machines and assist in providing a condition based assessment.

REFERENCES

1. Aksenov, Y.P., et al. In service turbine generators stator windings failure risks minimization on the base of discharge events on-line monitoring. EIC/EMCW’99 Expo, Cincinnati Convention Center Cincinnati, Ohio USA, October 26-28, 1999.
2. Hudon, C., Torres, W., Belec, M., and Contreras, R. "Comparison of Discharges Measured from a Generator's Terminals and from an Antenna in Front of the Slots". EIC/EMCW Conference, Cincinnati, Ohio, October 2001, 01CH37264C.