9th National Congress of Electric Rotating Machinery
September 29 to October 2, 1999, Veracruz, Mexico

Partial discharge measurement on rotating machines
Two case studies

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1. Introduction

Measurement of partial discharge activity on rotating machines has been used for many years as a diagnostic tool for monitoring the condition of stator winding insulation. The main purpose of partial discharge testing is to determine whether and to what degree the insulation system is deteriorating during machine life-time. The progressive development of partial discharge activity is an indication of insulation deterioration. To enable in-service (on-line) partial discharge (PD) measurements, capacitive couplers are permanently installed in rotating machines during a short shut-down. On-line PD testing monitors the condition of stator insulation without interrupting normal machine service. In addition, the testing is simple and safe to perform.
The capacitive couplers traditionally used for PD testing on rotating machines have been 80 pF cable type or epoxy mica type. It has been found that higher detection sensitivity can be achieved using couplers with higher capacitance values.
The first case study in this paper describes experience gained comparing 80 pF and 500 pF capacitors.
The second case study deals with one frequently asked question: What is more important, the magnitude of pulses in a single PD reading or the trend of PD activity over a number of PD tests.

2. Comparison of 80 pF and 500 pF capacitor on a 6.9 kV motor

A 6.9 kV, 6000 HP motor was rewound after 14 years of service as a boiler feed pump. After the rewind, three 500 pF epoxy-mica capacitive couplers were installed at the motor terminals. Normally, two or more capacitive couplers per phase are installed in a permanent coupling system on a rotating machine. In such configurations, each coupler pair rejects external noise using the “time-of-flight” method. On rotating machines connected to the power system by sufficient length of shielded power cable, external noise is greatly attenuated and only one coupler per phase is frequently used.
One of the PD tests using the 500 pF is shown in Figure 1.

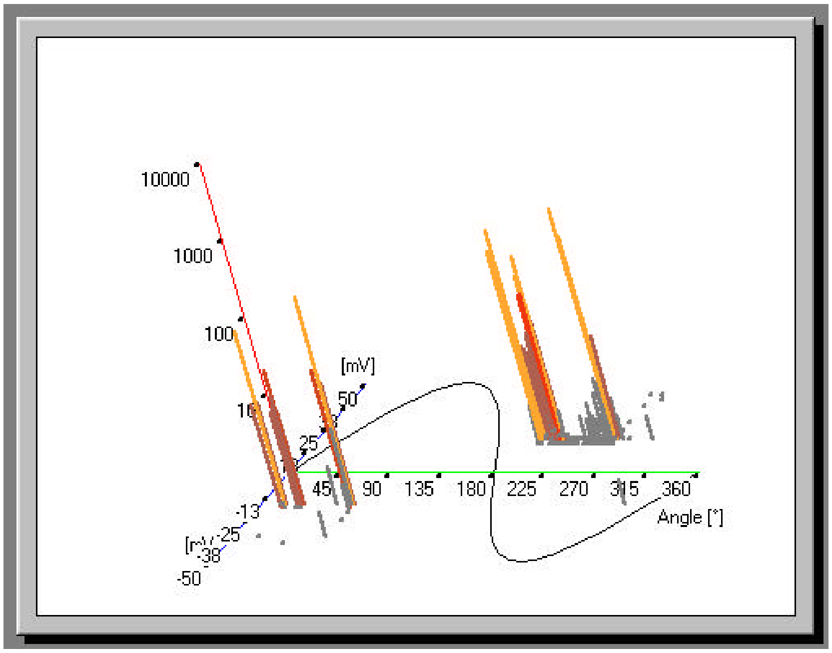

Figure 1. Partial discharge detected from the 500 pF coupler

On this graph, the relationship among the PD pulse magnitude (mV), the number of pulses per second and the phase angle position of the pulse is displayed. PD activity is a voltage related phenomena and PD pulses are normally distributed between 0° - 90° and 180°- 270° of the AC voltage sine wave. Figure 1 indicates a typical, noise free PD test result. Five months later, three 500 pF capacitors were replaced by three 80 pF capacitors. No events or repairs occurred on this machine during this period. New PD tests were made in very similar operating conditions. Using the same PD instrument no partial discharge activity could be recorded (see Figure 2).

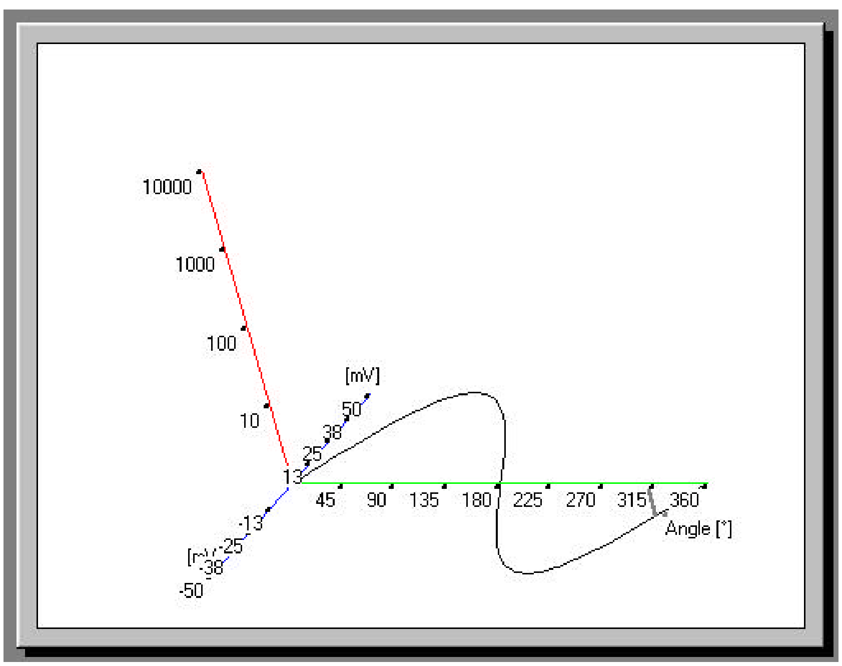

Figure 2. Partial discharge activity detected from 80 pF couplers

Two months after the 500 pF couplers had been replaced by the 80 pF couplers, the 500 pF couplers were put back on the same motor. Subsequent PD tests were taken and the results are shown in Figure 3. This results show the same level of PD activity as was recorded seven months earlier using the same 500 pF epoxy-mica couplers.

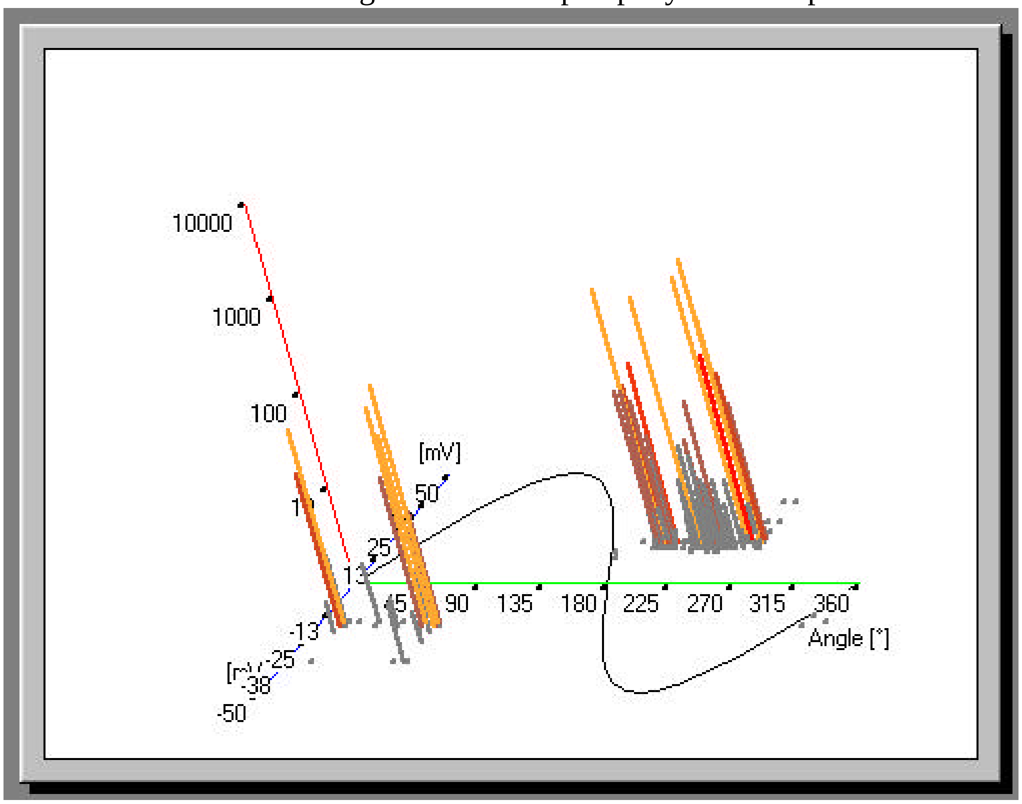

Figure 3. Partial discharge activity detected from 500 pF couplers

During the whole process of changing capacitive couplers from 500 pF to 80 pF and back to 500 pF, no repairs were made on the machine. All of the PD tests were performed under the same voltage and load conditions. Only the stator temperature differed slightly, but that did not cause significant change in PD readings. These PD results clearly indicate that significantly different readings were due to different capacitances of the couplers, not due to the change of the operating or insulation conditions.

Higher capacitance couplers provide many benefits in PD testing. They can make the difference between effectively monitoring the insulation versus waiting for failure to occur. For example, due to low sensitivity of 80 pF couplers it was not possible to establish trending of PD readings. To be detected by 80 pF couplers, much higher PD activity must occur. Therefore, the time between detection of higher PD activity and possible failure is dangerously shortened.

3. Importance of PD trending versus a single PD reading

In PDA technology, a measurement result consists of a number of partial discharge pulses acquired from a capacitive coupler during the test. During the acquisition, pulses are sorted based on their amplitude and phase angle. Different measurement result display modes are available and some are shown in the following figures. Commonly used graphs indicate number of pulses and their amplitude, see Figure 4.

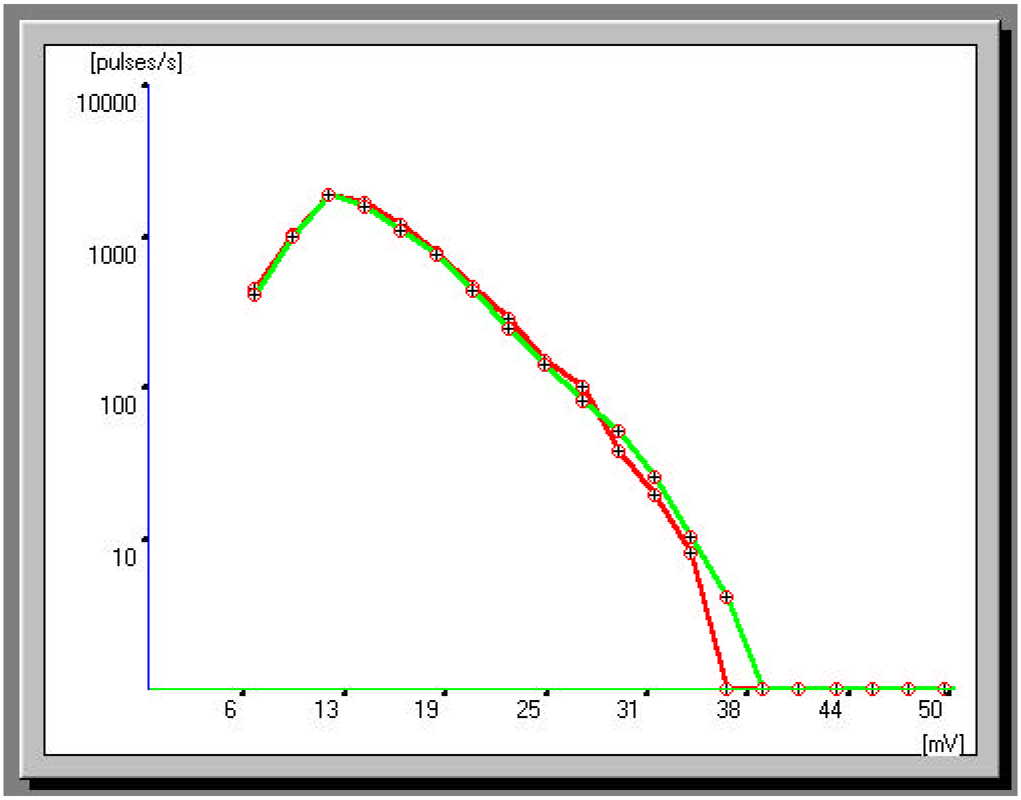

Figure 4. Pulse height graph (two tests, positive pulses only)

In evaluation of PD results, in order to express the PD activity in terms of a single number, two numbers are frequently used, NQN and Qmax. NQN (Normalized Quantity Number) represent approximate area of the triangle whose sides are made up of lines indicating activity (positive or negative), x-axis (pulse amplitude) and y-axis (number of pulses per second). Qmax is the magnitude of the maximum PD pulse (positive or negative) with a repetition rate of 10 pulses per second. While the use of NQN and Qmax numbers has been well utilized, the real benefit of PDA measurements is the effectiveness of trend-analysis. Due to the wide variety of designs, there is no general rule or standard defining acceptable levels of PD activity for a particular machine. Therefore, the users are advised to trend the PD activity comparing results taken in similar load and temperature conditions. It is important to make all tests using the same gain (sensitivity) setting on the PDA instrument, since accuracy of the NQN calculation will depend on this.

While simple analysis of NQN/Qmax numbers as an absolute indicator of winding condition can in some cases be misleading, the comparison of PD measurements under similar operating conditions has been proven to be an effective method for scheduling of maintenance and avoiding unexpected outages.
To effectively use the PDA testing, the user should establish base line PD levels. This is done preferably at the start of a maintenance cycle or six months after commissioning of a new winding. The PD measurements are used thereafter to monitor the gradual deterioration of the stator winding insulation.

Two 6.9 kV motors of the same age and design were being monitored. Motor A had relatively high PD levels compared to motor B, see Figure 5.

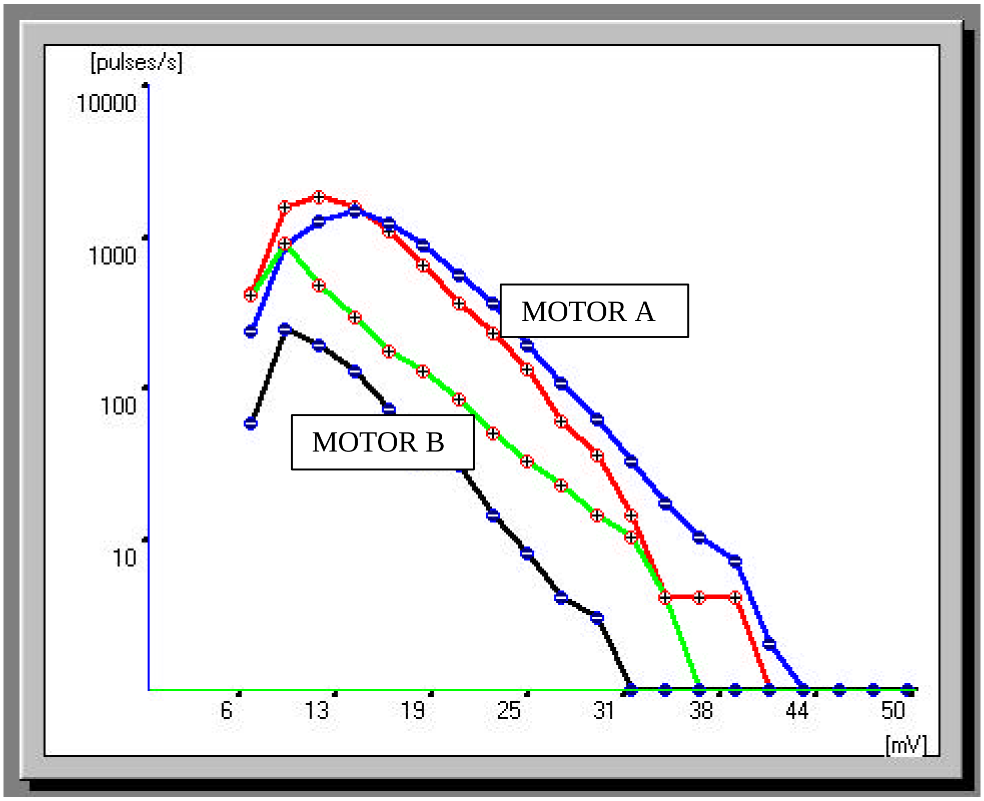

Figure 5. Comparison of PD levels on motor A and motor B

However, Motor A had stable PD readings (Figure 6.), with essentially no change in a one year period while there was a noticeable increase of PD levels on motor B (Figure 7.) in the same time period. In Figures 6 and 7, the height of the stack represents NQN value. Three measurement results are shown in each Figure, with positive and negative NQN values for each coupler.

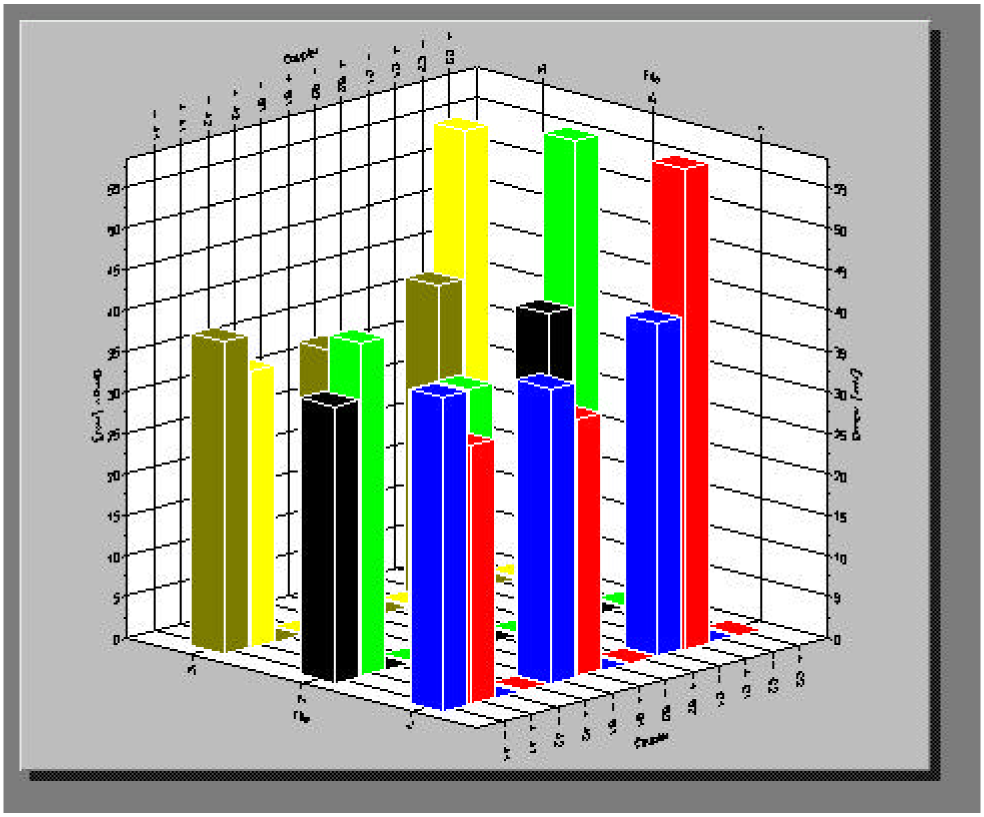

Figure 6. Stable Qmax values on motor A

Comparison of Qmax (positive/negative) values for both motors are given in Table 1.

TABLE 1.

Test Date	October 1998	December 1998	March 1999
MOTOR A	62/45	56/38	65/48
MOTOR B	20/0	36/26	48/30

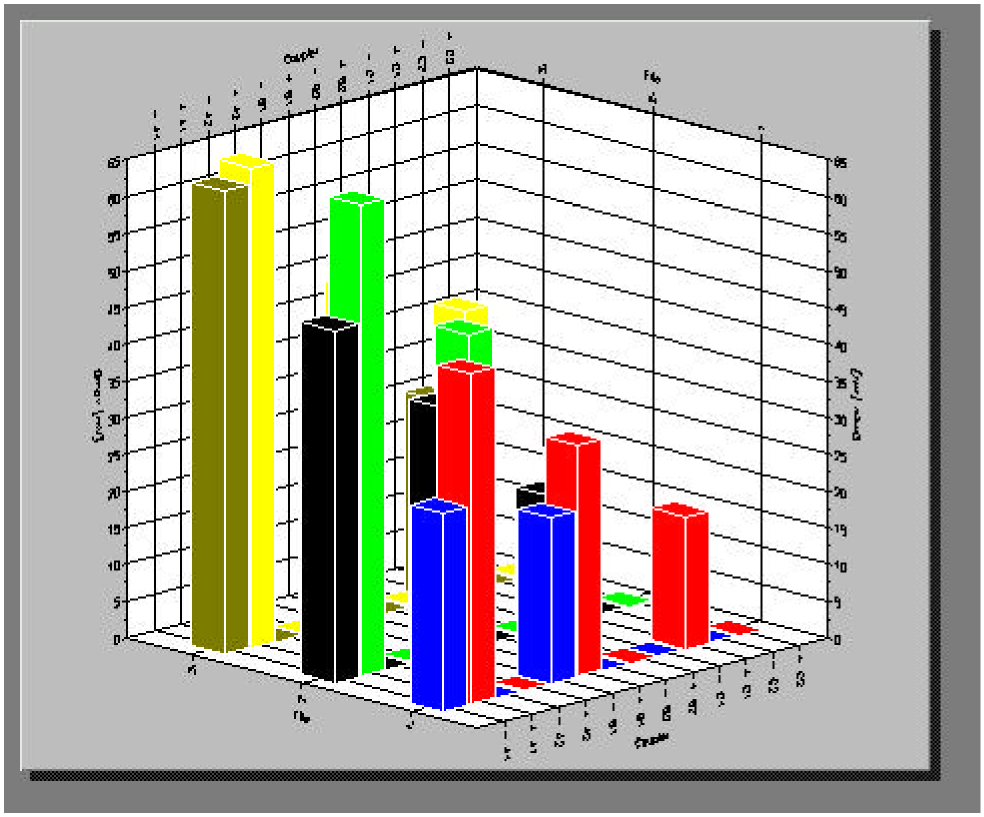

Figure 7. Steady increase over six months in Qmax values on motor B

This rapid increase of PD activity was a strong indicator of rapid insulation deterioration on motor B. Consequently this motor failed, due to a groundwall insulation failure. Motor A, with stable PD trends, is still running.

This case demonstrates the importance of trending PD levels compared to the magnitude of a single PDA reading alone.