December 2012

Partial Discharge Testing of Oil Filled Transformers

What's a partial discharge?

A partial discharge (PD) is an electrical discharge bridging a portion of the insulation between two electrodes. The discharge may occur at any point in the insulation system that the electric field strength exceeds the breakdown strength of that portion of the insulation system. In transformers, the insulation system is comprised of the winding insulation material as well as the dielectric fluid.

IEC Std 60270: "Localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor."

The term "partial discharge "refers to the fact that a complete discharge (breakdown) to ground does not occur, but rather a breakdown between 2 intermediate voltages within the insulation.

PD can be initiated by voids or cracks within a solid dielectric, at interfaces within solid or liquid dielectrics, in bubbles within the dielectric fluid, or along the boundary between different insulation materials as per the following example.

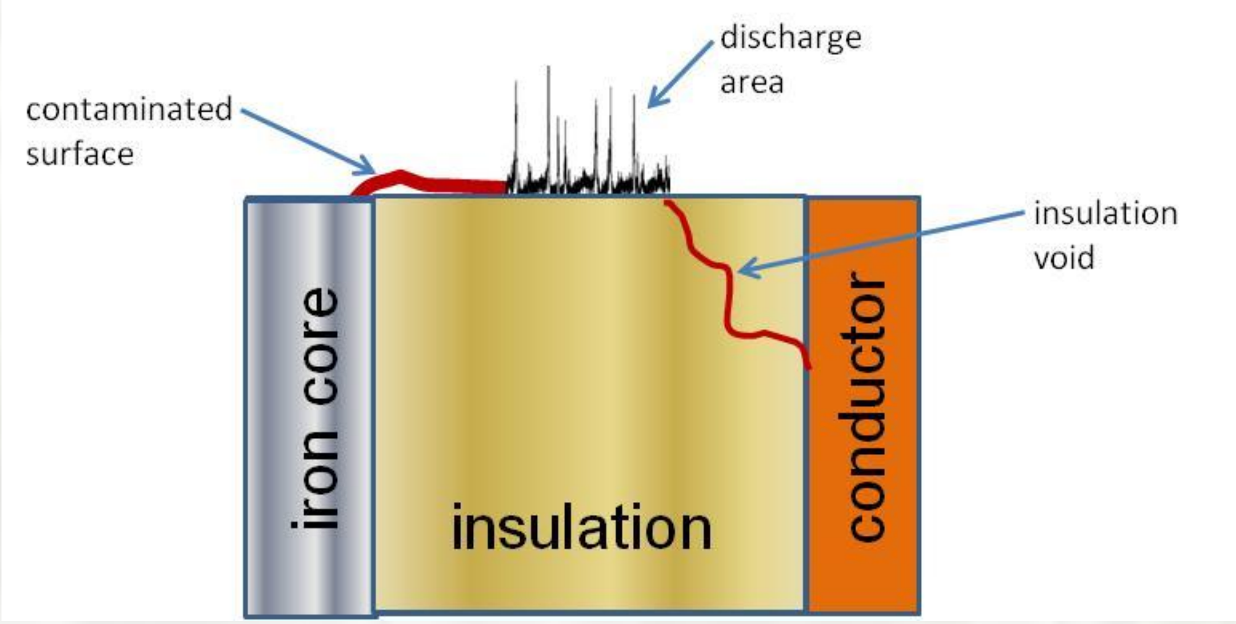

Figure 1

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The main reason why customers should want this test performed is because the partial discharge test is capable of detecting problems before they lead to a complete dielectric breakdown. That is why ***PD testing is described as a non-destructive*** test. Dielectric tests required by ANSI standards such as Impulse, hi-pot, and induced potential, can only detect a failure after the insulation has broken down and a flashover has occurred. PD can, in the extreme, lead to complete dielectric breakdown, but the test does not rely on a complete breakdown to determine the existence of insulation failure.

With partial discharge measuring equipment, the dielectric condition of high voltage insulation can be evaluated, and destructive discharge patterns such as electrical treeing within the insulation can be detected and located before failure. Treeing is one form of electrical pre-breakdown phenomenon caused by discharges in solid insulation. It is a damaging process beginning as partial discharge and progresses through the stressed dielectric insulation in a path resembling the branches of a tree. Figure 2 depicts the dielectric breakdown within a solid insulating plate with extensive tracking during the application of a potential raised slowly to point of flashover.

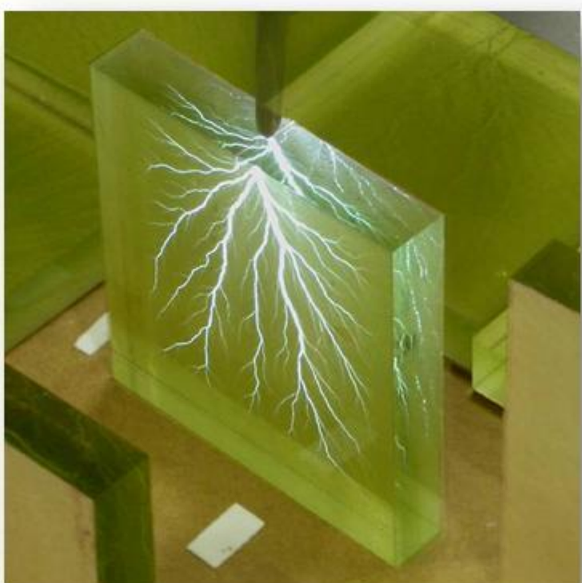

Figure 2

Figure 3

Partial discharges in transformer windings can begin as small voids in the paper insulation. As PD activity progresses, the repetitive discharges eventually cause permanent changes within the affected solid insulation and impregnating dielectric fluid which reduces the insulation qualities of either or both. Over time, partially conducting carbonized trees are formed (figure 3). This places greater stress on the remaining insulation, leading to further growth of the damaged area, resistive heating along the tree, and charring also known as tracking. This eventually culminates in the complete dielectric failure of the transformer.

Several partial discharge detection and measurement methods (optical, acoustic, and electrical) have been developed since the importance of PD was recognized. Partial discharge currents tend to be of short duration and have rise times in mere nanoseconds. On an oscilloscope, the discharges look like randomly occurring 'spikes' or pulses. Due to the short duration and low energy magnitude of these signals, the accepted measurement of partial discharge magnitude is in **picocoulombs**.

The coulomb is the standard unit of electric charge. It is defined as the charge transported by a steady current of one ampere in one second (1C= 1A x 1s). The symbol for the coulomb is an uppercase C. It is a large value. One ampere-hour of current transfers only 3600 coulombs of charge. Therefore values are normally measured in microcoulombs (one thousandth or 10¯6), nanocoulombs (one millionth or 10¯9), and in the case of transformer PD testing, picocoulombs (one billionth or 10¯12) or pC.

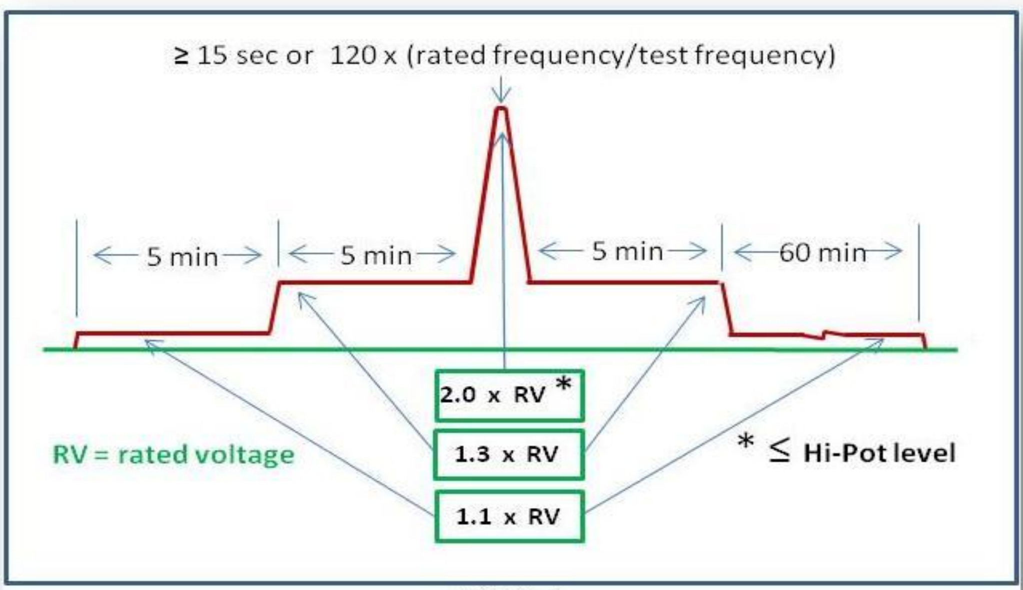

Figure 4

Partial discharge test procedures dictate that measurements are made at various voltage levels as the test voltage is increased to the dielectric test level and then reduced. Figure 4 details the stepped voltage procedure used for transformer PD testing. Since a transformer operates via electromagnetic induction, an AC voltage is applied. However, because the iron core of the transformer is typically designed to operate at 50 or 60 cycles and saturates at approximately 110% of rated voltage, it is necessary to use a test voltage at a higher than rated frequency to avoid core saturation during the test. **For this reason, it is best to test in the lab or manufacturer's facility at the time of factory acceptance testing.**

The test begins with recording the ambient, or background PD level and PD reading instrument is calibrated. The transformer is then energized at 110% of rated voltage for 5 minutes and a calibration is made and discharge rate recorded. The voltage is then raised to 130% for another 5 minutes, another calibration is made and discharge rate recorded. Now the voltage is raised to 200% of rated voltage OR the hi-pot level, whichever is less, another calibration made and PD recorded. The process is repeated 2 more times with the voltage being reduced back to 130%, then 110% of rating (see figure 4). At the 110% level however, the voltage is maintained for a full hour.

If partial discharge levels are present, the inception and extinction discharge levels are to be recorded. The partial discharge inception level is defined as the lowest voltage at which continuous partial discharges above background "noise" occur as the applied voltage is increased. The extinction level is the highest voltage at which partial discharges above background noise no longer occur as the applied voltage is decreased from the inception voltage (figure 5).

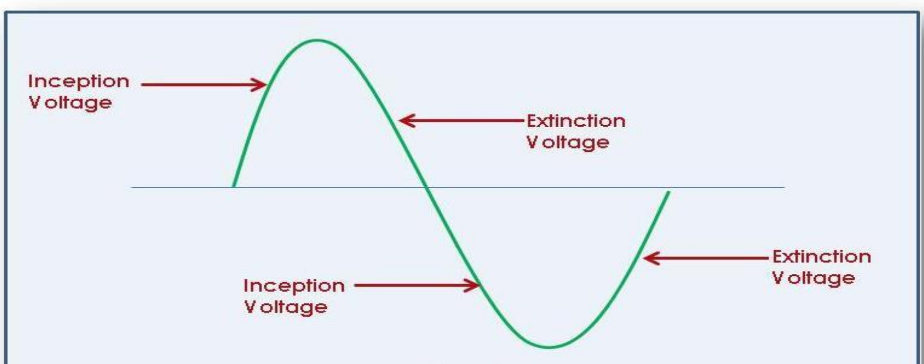

Figure 5

A setting of automatic mode on the oscilloscope enables automated recording of partial discharge locations as well as the inception and extinction levels.

While at first the test results can seem chaotic, expert interpretation of the recorded wave forms can reveal a great deal about the transformer condition. Dry spots in the insulation, insufficient clearances, bad or loose connections are just a few of the problems that can be diagnosed by skillful use of partial discharge testing.