<u>No Outage Inspection Corner</u> *by: **Don A. Genutis***

*This column focuses on electrical inspection methods and technologies that are performed while the electrical system remains energized. Although no-outage inspections can be very valuable tools, always remember to comply with proper safely guidelines when conducting energized **"On Line"** inspections.*

<u>Partial Discharge Testing of Transformers</u>

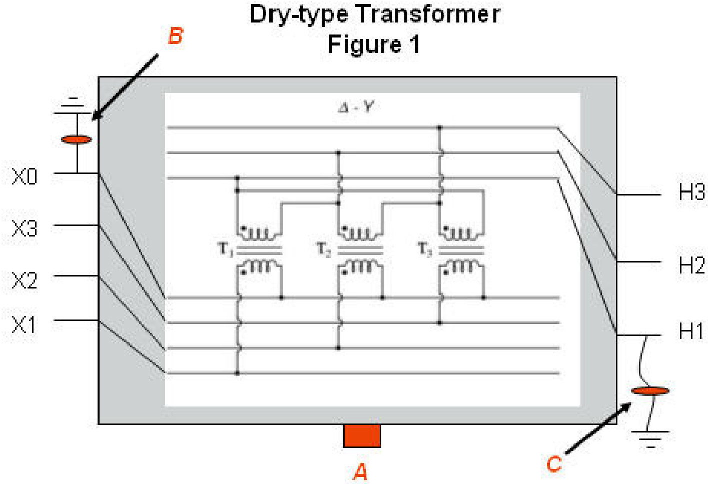
Consistent with the theme of this issue's NETA World, our column will focus on No-Outage testing of transformers. Specifically, we shall explore partial discharge (pd) testing of both dry-type and fluid-filled transformers.

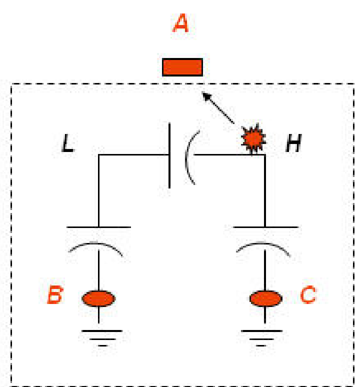
<u>Dry-type transformers</u>

The methods that we will discuss for testing dry-type or non-fluid filled transformers also apply to cast-coil transformers. These types of transformers are primarily used for medium and low-voltage indoor applications, but this column only addresses medium-voltage transformers as low voltage insulation does not typically discharge since the voltage levels used are not great enough to create discharges according to Paschen's law.

Dry-type transformers are typically housed in ventilated enclosures. These vents provide an opportunity to obtain data used to evaluate the condition of the transformer. If an airborne discharge or corona occurs on the surface of the insulation, this "sparking" activity will radiate high frequency pulses that adhere to the inside of the grounded transformer enclosure and will propagate along the inside surface through the vent openings and finally to the outside of the enclosure via the "skin effect". These signals can then can be detected and analyzed by placing a magnetically coupled capacitive sensor on the transformer enclosure as shown as Sensor A in Figures 1 & 2. Alternate sensor arrangements consist of placing split-core high-frequency current transformers (hfct) on the shield of the transformer's primary cables as shown as Sensor C and the point where the low voltage neutral is grounded as shown by Sensor B. Typically, the signals are then recorded by specialized instruments and then analyzed for the presence of damaging PD.

Dry-type Transformer
Figure 1





Insulation Model for Dry-type Transformer

Figure 2

Except for rotating apparatus, insulation systems cannot tolerate PD activity and non-fluid transformers are no exception. Although some types of discharge, such as corona from a conductor in free air, can be benign; it is always best to strive to obtain a “PD-free” system. Therefore, any presence of PD activity should be considered dangerous and at a minimum, should be closely monitored. Under some circumstances, it may be desirable to obtain an outage on the transformer and to conduct service and supplementary off-line tests if pd is detected. Sometimes, cleaning the transformer thoroughly will eliminate or reduce the PD levels and close visual inspections can often locate an external trouble spot that is easily repaired in the field. Performing a “tip-up” test can often provide additional insulation condition information and PD testing can be performed simultaneously in order to obtain the “corona onset” voltage and additional equipment such as the corona camera or the ultrasonic detector can help pinpoint the problem.

By integrating annual PD testing into a facility's no-outage inspection program, insulation failures can be minimized or eliminated completely.

Fluid-filled transformers

The typical fluid-filled transformer insulation system is not too dissimilar from that of the dry-type transformer and PD activity in oil-filled equipment is just as dangerous and perhaps even more dangerous than PD activity in dry-type transformers. Unlike dry-type transformers, discharges in oil-filled transformers are contained within the sealed transformer tank and the associated PD byproducts caused by the sparking activity under oil, are also contained within the sealed tank. PD activity generates hydrogen and regular dissolved gas analysis (dga) sampling and testing can ensure that PD activity is not occurring as long as hydrogen is not present. It is the PD's generation of combustible hydrogen gas that presents additional dangers besides the obvious detrimental affects on the insulation, as possible ignition could cause catastrophic failure to the transformer and possible residual damage to adjacent equipment.

Presently, nearly all large high voltage transformers are filled with mineral oil and this oil offers superior dielectric strength and cooling characteristics in comparison to dry-type transformers. As the primary voltage levels of the transformer increases, much greater care must be taken in regards to the suppression of electrical stresses and the associated prevention of corona. Through various mechanisms, transformer failure related to corona or PD will generate hydrogen. After hydrogen has been detected, the next step usually involves estimating the location of the PD activity in order to determine the likelihood of conducting successful field repairs.

One of most successful methods for PD location involves placing one or more magnetically coupled acoustic sensors at various points on the outside wall of the transformer. Possible locations can then be determined by triangulation or by performing simple calculations. In order to approximate the internal PD source location, success has been made by placing an hfct on the transformers ground to detect the electrical pd pulses. These signals are then used to start a timer or trigger an oscilloscope, the acoustic emission sensor signal is then used to stop the timer. Years of research has accurately determined that sound propagates through oil in a steel tank at a certain rate of speed and the time difference between the electric signal and the acoustic signal is used to calculate the PD source location. Additional detailed information regarding these methods can be found in IEEE Standard C57.127-2007, Guide for the Detection and Location of Acoustic Emissions from Partial Discharges in Oil-Immersed Power Transformers and Reactors.

Figure 3 illustrates a plot of PD signal origination that was performed on a transformer in the field. One of the key findings of this survey was that all PD signals were occurring from the top of the transformer, which lead to the assumption that inspection and possible corrective actions could be conducted from the top inspection plates. This particular transformer was manufactured with the core suspended from the top plate and subsequent internal inspection revealed tracking occurring from the insulating tube surrounding the core bolts which was easily repaired.

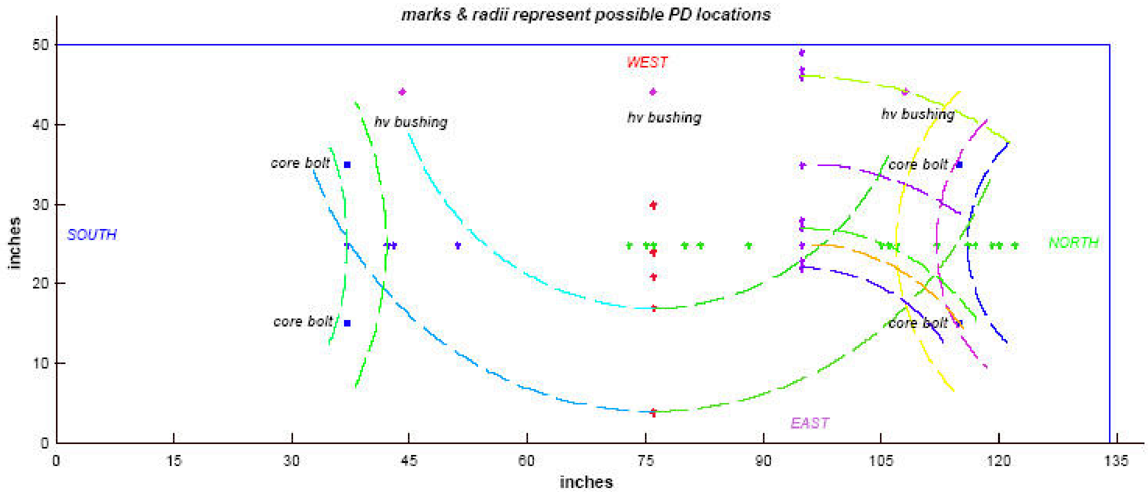


Figure 3

Monitors

Certain types of insulation failures can occur fairly rapidly and regular testing programs may not be able to spot this type of failure quickly enough to save the transformer. Additionally, many transformers may be so critical to the facility that continuous monitoring of the insulation condition is desirable. This is especially true of generating station step-up transformers where replacement costs are in the tens of millions of dollars and replacement units can take 6 months to obtain.

Several different types of monitors are available but those that continuously monitor to transformer fluid for hydrogen seem to be the most popular because of their reliability and relatively low cost. As discussed earlier, hydrogen is generated by partial discharge activity in oil and hydrogen is also generated by other failure modes including arcing, which generates acetylene but also generates hydrogen. Moisture (H2O) in oil also contains hydrogen, so by monitoring hydrogen levels accurately, the health of the transformer can be obtained.

Other types of popular monitors include the Bushing Tan-Delta comparison device that acts like a constant power factor or tan-delta test of the bushings. On large transformers, bushing failures often destroy the associated transformer winding and as bushings deteriorate they usually do not cause a dga problem. So in order to prevent this mode of failure, a connector is placed in each bushing power factor tap. The signals from this tap are then connected to a comparator circuit which monitors any changes in the bushing's insulation system. These taps can also provide a convenient point to conduct periodic or continuous partial discharge tests.

Conclusions

In order the ensure transformer reliability and prevent failures, the following "No-Outage" tests should be performed.

1. Medium voltage dry-type transformers should be tested annually for partial discharge activity using capacitive sensors connected to the outside of the enclosure. An ultrasonic detectors or corona camera may be useful in pinpointing the problem. An off-line "tip-up" test is useful to determine the pd severity.
2. Medium voltage fluid-filled transformers should be tested annually for dga and other fluid characteristics.
3. High voltage fluid-filled transformers should be tested annually for dga and other fluid characteristics at a minimum. Consideration should be given to monitor critical transformers continuously for hydrogen in oil and for bushing tan-delta.

About the author:

Mr. Genutis received his BSEE from Carnegie Mellon University, has been a NETA Certified Technician for 15 years, and is a Certified Corona Technician. Don's technical training & education is complemented by nearly twenty-five years of practical field and laboratory electrical testing experience. He is presently serving as Vice President of the Group CBS Eastern U.S. Operations and acts as Technical Manager for their subsidiary, Circuit Breaker Sales & Service located in Central Florida.