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The Dynamic Duo

Ultrasound & Infrared Team Up to Prevent Transformer Outages

by Allan Rienstra

Processing steel requires big energy and heavy duty electrical systems. But just one electrical component failure can grind steel production to a halt, costing manufacturers huge losses in time and money. The more severe the failure, the longer it takes for systems to be restored. Maintenance crews rely on condition monitoring technologies like ultrasound inspection and infrared imaging to predict electrical component failures in all systems including substations, MCC gear, transformers, and the like.

The earlier a problem is spotted, the larger the window for scheduling maintenance. Electrical repair crews prefer to make repairs on their terms, rather than on the terms of the machine because it is far less expensive and a much better option for everyone. Being alerted early that a system needs attention also means that the maintenance required is "simple maintenance" as opposed to costly overhaul, total repair, and/or replacement. By simple maintenance I mean just that – simple cleaning, dusting, and minor parts replacement using spares already stocked in stores.

Most electrical faults are the result of partial discharge. Partial discharge is defined as "a localized electrical discharge in an insulation system that does not completely bridge the electrodes"[1]. A discharge is described as either an "arc" or a "spark" and can either be phase to phase or phase to ground. Partial discharge is destructive to the conductor or insulator, and over time, will cause the component to fail. Corrosive gases like nitrous oxide negatively impact the integrity of insulators. Partial discharge is influenced by the system voltage, the shape of the void from phase to phase, ambient temperature, the condition of the insulation material, and environmental conditions such as pollution and humidity. The combination of these factors have an impact on the time it takes for the system component to fail. Partial discharge is a common problem in high voltages, but it can also be problematic in low voltage switch gear. Since voltage is an influencing factor, the higher the voltage the more destructive partial discharge becomes.

One stage of partial discharge is termed "Tracking." Tracking is difficult to detect since it doesn't demonstrate any heat build-up. In its early stages, it can be considered arcing. Like corona discharge and arcing, tracking exists only to seek a path to ground. Dirt, dust and moisture help tracking follow this path, which is why simple maintenance like cleaning is effective in prolonging the service life of electrical systems diagnosed with tracking. Tracking begins with a low buzzing and crackling, and builds in intensity until it reaches the point of flashover. After flashover occurs it becomes quiet again. It is this constant build up in intensity and discharge that leads to insulator breakdown and graduation to more destructive arcing.

Headquartered in Brazil, Gerdau is one of the world's leading steel producers and trades under the symbol GNA on the NYSE. Gerdau Ameristeel is the American arm of Gerdau Brazil, and there are 19 mills in North America under this umbrella. Most, if not all, of Gerdau's mills employ various predictive technologies to ensure that electrical outages are few and far between. A good example of how combined predictive inspections prevented a transformer outage was provided for this article by Skip Young, certified infrared and ultrasound technician with Gerdau Ameristeel in Calvert City, KY.

Typically, electrical faults only generate heat once they've reached an advanced stage. Relying solely on IR may result in a missed diagnosis, but not for Skip Young. While conducting all scheduled IR scans, Young also brings his ultrasound detector. He knows that acoustic energy is generated at any stage of discharge, and that by combining ultrasound and infrared scans, he is assured to find virtually all faults.

The insulator shown in Figure 1 was damaged by tracking, and eventually, arcing. The problem was detected early with an ultrasound inspection system. One of SDT's Certification Instructors, Debra Smith, reminds us that electricity will always follow the easiest path to ground. She teaches ultrasound inspectors how dirt, dust, and moisture enhance the opportunity for tracking to establish this path to ground. Debra also reminds us that tracking indicates the presence of an equipment fault, but when caught at an early stage, it can often be fixed with simple maintenance procedures. There are serious safety consequences to be considered by all inspectors carrying out this work.

Thermal images from several 161kV to 13.8kV step down transformers were provided to us by Young. As

Figure 1 - The insulator shown here was damaged by tracking and eventually arcing.

shown in Figure 2, there were no apparent hot spots visible on the A, B, and C phases but a vigilant ultrasound scan produced a sound file[2] with obvious indication of early tracking.

Figure 2 - Thermal images of A-phase bushing and incoming connection on this 161Kv to 13.8Kv step down transformer showed no apparent hot spots.

We can have a good look at Young's ultrasonic data using SDT's Ultranalysis software. This program looks at captured ultrasound files in the time and spectrum domain as shown in Figure 3. The top image illustrates the time domain showing the build up and release of the ionization discharge as it finds a path to ground. Ultrasonically we hear the build up, and then an interruption or neutralization of the air surrounding the problem. Heat does not build up here until the situation progresses and there is sufficient flow or current to produce heat along the discharge path.

The bottom image illustrates the spectrum domain from Young's ultrasonic data. There are two things to note here. First, the obvious repetition of 60 Hz events clearly tells us that, in addition to tracking, nuisance corona is present. Secondly, the noise level between the 60 Hz peaks confirms there is tracking activity.

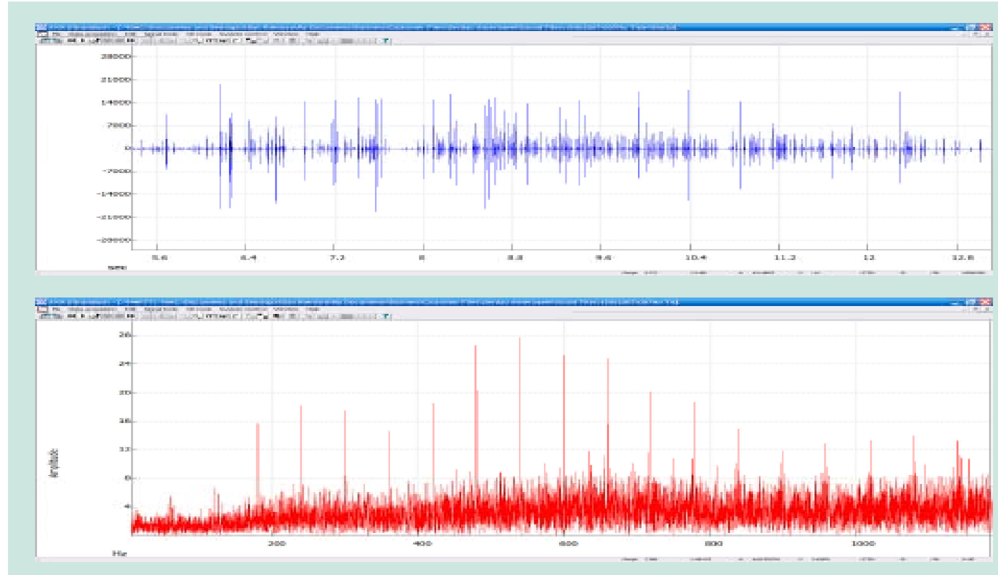

Figure 3 – The demodulated sound file can be viewed in both the time (top image) and spectrum (bottom image) domain. The top shows tracking picked up in the ultrasound range from the A-Phase bushing of the transformer.

We also listened to sound files taken from the B and C Phase bushings. Neither showed any signs of heat when scanned with Young's infrared camera. However, both projected signs of tracking when scanned with the ultrasound collector.

Once a diagnosis was made on the suspect transformers, the decision to perform simple maintenance during the next planned outage was made. Infrared scans showed no signs of heat so we felt confident that the discharges discovered during ultrasound scanning was, indeed, tracking in its early stages. The problem was discovered at an early enough stage that simple maintenance could be done on human terms, not terms dictated by a failure.

According to Young, their simple maintenance merely included cleaning and tightening all connections on A, B, and C phase. Looking at the time signal in Figure 5, we

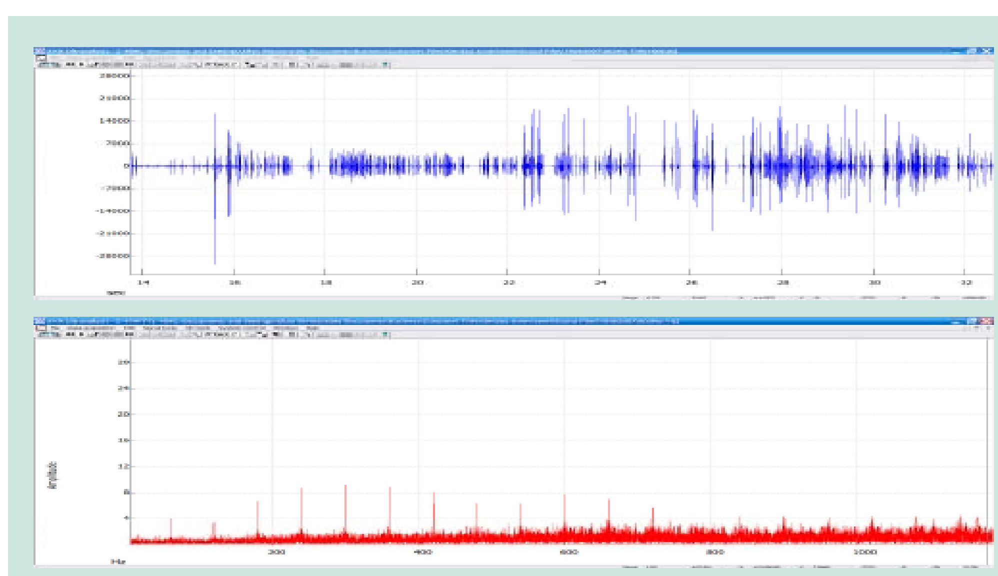

Figure 4 - B-Phase Bushing prior to cleaning. Note in the time signal the short but violent bursts at the 22 second mark and again at the 28 second mark. These are clear signs of tracking without heat build up. In the spectrum domain there are clear 60hz peaks once again but nowhere near as strong as in image 3.

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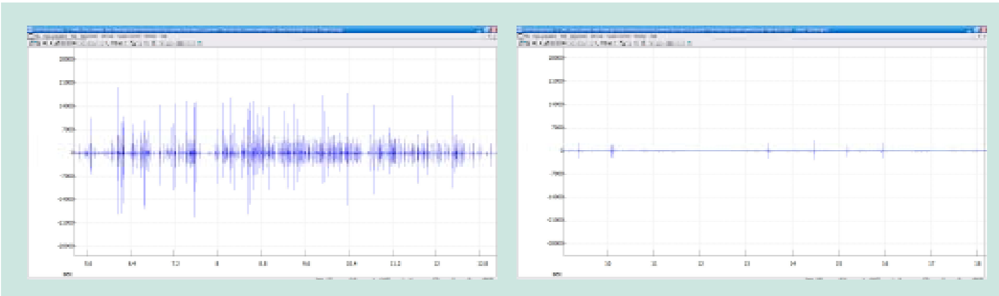


Figure 5 – Time signal of ultrasonically detected tracking on A-Phase bushing before (left) and after (right) simple maintenance of cleaning and tightening of connections.

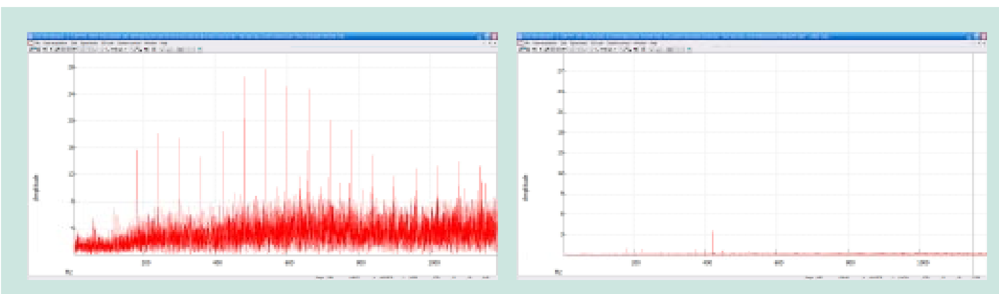


Figure 6 – Frequency signal of ultrasonically detected tracking on A-Phase bushing before (left) and after (right) simple maintenance of cleaning and tightening of connections. Dominant 60hz peaks are gone as is the tracking noise between peaks.

can see that simple maintenance definitely improved the condition. Since tracking is a stage of partial discharge that does cause damage to connectors and insulators, it will be necessary for Young to continue vigilant ultrasound scans on the transformers.

Gerdau's case study is a perfect field example of how combining two predictive technologies ensures that eminent problems are detected at the earliest possible stage of failure. By detecting the presence of early tracking with ultrasound, Gerdau was able to avoid excessive damage to the transformer. They were able to schedule planned maintenance and fix the problem on their terms. Best of all, the required maintenance was simple cleaning and re-tightening of connections. No costly parts were required and the effects of the maintenance were obvious and positive. Finally, having found the problem early, electrical maintenance crews are now aware of a possible weak link in the transformer. Vigilance will be stepped up, and both infrared and ultrasound scans will be more frequent so as to avoid a more catastrophic outage.

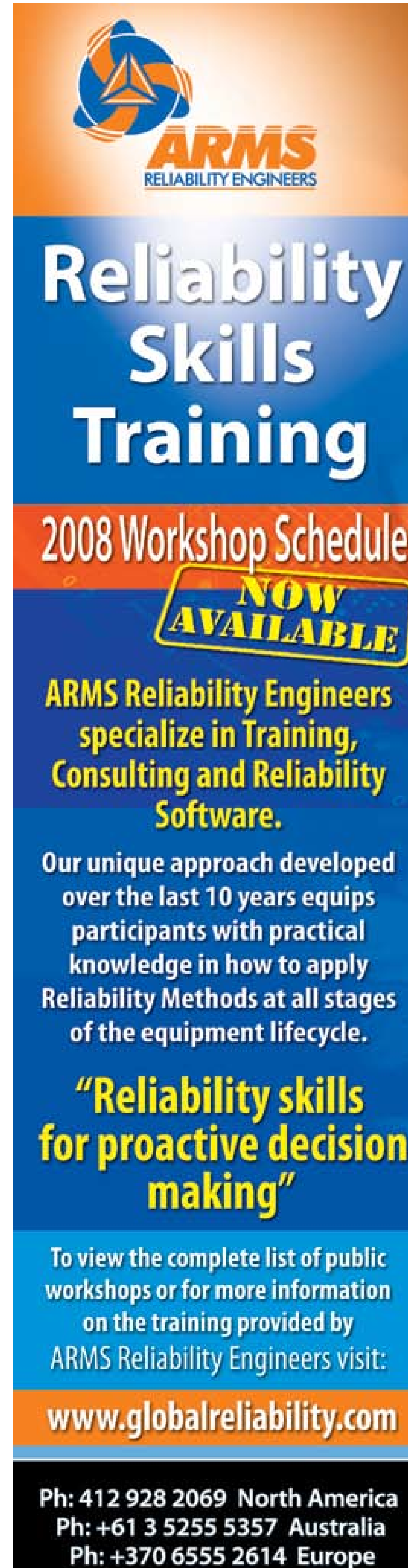
Ultrasonic and infrared inspections performed well together on Gerdau's transformer issue, and there is no reason why the pairing should not be considered a winner for observing partial discharge on insulators, MCC panels, and high voltage transmission and distribution lines.

References

1 - Martec and SDT North America, Level 1 Certification Training Syllabus Version 2.2

2 - The accompanying sound files for this paper are available at www.sdtnorthamerica.com

Allan Rienstra is the General Manager of SDT North America providing ultrasound solutions to maintenance professionals since 1991. Allan has written countless articles on practical applications for ultrasound inspections including "Strategies for an Effective Airborne Ultrasound Program". These published works are considered the standard by companies implementing inspections programs. As a co-author of SDT's Level 1 Ultrasound Certification Program, Allan is recognized as a leader in his field. He is a graduate of Simon Fraser University, Vancouver, British Columbia, Canada and resides in Cobourg, Ontario with his wife and two children.



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