Processing steel requires big energy and heavy-duty electrical systems. But just one electrical component failure will grind steel production to a halt costing manufacturers with 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 the terms of the machine. That is the cheapest and best 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 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.” 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. These factors have an impact on the time
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Partial Discharge: “A localized electrical discharge in an insulation system that does not completely bridge the electrodes.”

before failure for the system component. Partial discharge is a problem common to high voltages but it can be problematic in low voltage switch gear too. Since voltage is an influencing fact, the higher the voltage the more destructive PD becomes.

One stage of partial discharge is termed “Tracking.” Tracking is difficult to detect since it doesn’t demonstrate any heat build-up. It can be considered arcing in its early stages. Like corona discharge and arcing, tracking exists only to seek a path to ground. Dirt, dust, and moisture help tracking follow the path which is why simple maintenance like cleaning can prolong 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 the constant build up in intensity and discharge that lead to insulator breakdown and graduation to more destructive arcing.

Gerdau is one of the world’s leading steel producers and trades under the symbol GNA on the NYSE. Headquartered in Brazil, 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 electrical outages are few. A good example of how combined predictive inspections prevented a transformer outage was provided to me for this paper by Skip Young, certified infrared and ultrasound technician with Gerdau Ameristeel in Calvert City, Kentucky.

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 scheduled IR scans Young also brings his SDT ultrasound detector. He knows that acoustic energy is generated at any stage of discharge. By combining ultrasound and infrared scans he is assured to find all faults.

The insulator shown in Figure 1 was damaged by tracking and eventually arcing. The problem was detected early with an SDT170 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 about how dirt, dust, and moisture enhance the opportunity for tracking to establish this path to ground. Debra reminds us that tracking indicates the presence of an equipment fault. 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. There were no apparent hot spots visible on the A, B, and C phases but a vigilant ultrasound scan produced a sound file with obvious indication of early tracking.

We can have a good look at Young’s ultrasonic data using SDT’s Ultranalysis software. This easy-to-use program looks at captured ultrasound files in the time and...
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Image 3 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 nuisance corona is present in addition to tracking. Second is the noise level between the 60 Hz peaks which are a confirmation of tracking activity.

We also have 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 a 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.

Image 3 – The demodulated sound file recorded by the SDT170 can be viewed in both the time and spectrum domain using AVM Ultranalysis software or even your vibration data collector. The top picture shows tracking picked up in the ultrasound range from the A-Phase bushing of the transformer.

Image 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.
According to Young, simple maintenance included cleaning and tightening all connections on A, B, and C phase. Looking at the time signal in Image 5 (next page) 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 imminent 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, as well as high voltage transmission and distribution lines.

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

Image 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.