Integrating infrared and airborne ultrasound

SDT North America

ABSTRACT

The use of airborne ultrasonic translators to detect corona, tracking and arcing has gained in favor and popularity over the past two or three years. Airborne ultrasound generated by electric faults can be detected through small openings of door seals on switchgear cabinetry, through the outer shell of an oil filled transformer, and in the switchyard emitting from bushings, buss bars, and insulators. Using highly sensitive airborne sensors these ultrasonic detectors can even isolate electric faults on high tension transmission and distribution lines at distances of over 150 feet.

Ultrasonic detection is able to find electric faults that do not generate heat, yet little has been done to integrate the use of Infrared Thermography and Airborne Ultrasound. Informed inspectors who recognize the value of combining the two technologies are providing more accurate and complete reports, and are finding potentially catastrophic electrical faults that used to be missed altogether. Today, with very simple software technology, an inspector can employ the use of sound wave files to visualize reports for the customer or his/her employer. Imagine taking a wave file of arcing, then using the wave file together with an infrared image to write a report. The result adds clarity and understanding of review at every level.

Typically, corona and tracking do not show up with an infrared scan in electrical systems below 240 kV. This point alone demonstrates the need for the inspection industry to marry temperature imaging and ultrasound scanning techniques. This paper will discuss the many uses of airborne ultrasound to record wave files and use an infrared system with real time photo and/or IR images to aid the inspector in his/her reports.

A southeastern chemical plant used airborne ultrasound and an infrared camera to inspect several 13.8 kv rectifier panels with the panels closed. No significant temperature variations could be detected through the closed panels. There was however significant levels of airborne ultrasound detected at the lower right corner of one of the fifteen panels. Ultrasound detectors transform ultrasound to audible sound while maintaining the tonal characteristics of the source. Therefore several qualified electrical technicians were able to safely listen to the signal and make a definitive action. The “vacuum breaker” was removed, and by applying a DC current to this breaker a failure was revealed.

Finding this fault averted the loss of electrical power, a shutdown of the plants compressed air system, and possible injury to personnel from fire or shock. This random ultrasound inspection revealed a potential fault that would have been missed during the company’s regular inspection. Since then airborne ultrasound inspection of all switchgear has been added as part of the regular scheduled infrared PM.

1. STRENGTH IN NUMBERS

The use of airborne ultrasonic translators as a predictive technology for maintenance and reliability professionals has gained in favor and popularity in recent years. For many, ultrasound plays a major role in determining the relative health of rotating machinery and electrical systems all the while providing a first defense against inefficiencies in compressed air and steam delivery systems. For others just discovering the versatilities of airborne ultrasound this technology may play a moderate role in favor of infrared inspections, oil analysis, or vibration analysis.

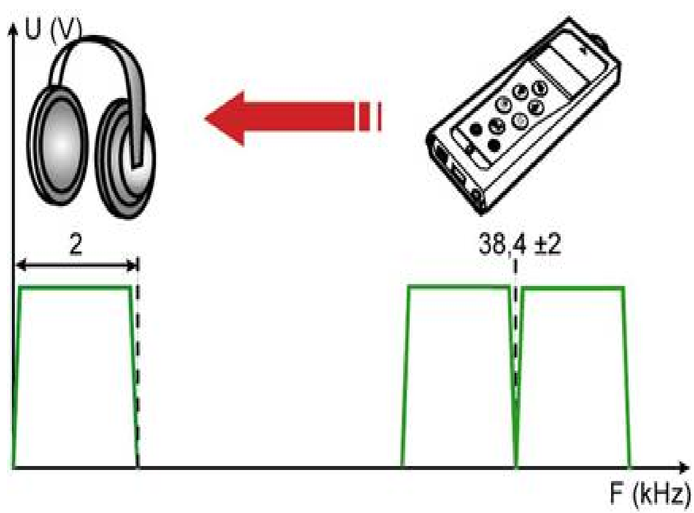
We believed for a long time that no single predictive technology can serve as master to all. Each has strong suites and each has limitations. But when two versatile technologies like ultrasound and infrared are integrated the old adage "there is strength in numbers" becomes particularly valid.

Infrared Thermographic Scanning and Airborne Ultrasound Detection are two powerful predictive maintenance technologies on their own. We first learned the phrase "Hear what you can't see and see what you can't hear" uttered by a thermographer who had just used ultrasound to detect a fault on a high voltage transformer. An earlier scan with his infrared camera had failed to detect the tracking condition. At that point it was clear that integrating the complimentary nature of these two technologies was logical, and to ignore one over the other made little sense. We try not to do things that don't make sense.

Ultrasonic inspection and infrared scanning are well respected for their broad range of usefulness throughout a plant. Since the purpose of this topic is to discuss the integration of these two technologies we will cite case studies relevant to fault detection in electrical systems. For it is here that the need to marry ultrasound and infrared is demonstrated with clarity.

2. BACKGROUND

How Ultrasonic Detectors Work



Ultrasonic translators detect sounds produced at frequencies which are not perceivable by the human ear. They reconstruct those sounds at lower frequencies within the range of human hearing without compromising their quality and characteristics. This allows a person to hear and interpret sounds which would normally go unheard. Ultrasonic frequencies are easy to locate because they travel more directionally through air than lower audible frequencies. Depending on the quality of the detector and the ability of the user, ultrasounds can be detected, measured, recorded, stored, and analyzed in areas with extremely high levels of ambient noise.

Electrical Faults

In industry ultrasonic phenomena is produced by any number of sources. One contributor of ultrasound is electrical faults commonly known as arcing, tracking, and nuisance or destructive corona discharge. At the site of an electrical fault air molecules are disturbed as electrons jump across a failing insulator in search of ground. The result is an ultrasonic "crackling" phenomenon. The type of fault (arcing, tracking, nuisance corona, or destructive corona) can be determined by subtle characteristics which set them apart from one another.

Airborne ultrasound generated by electric faults can be detected through small openings around door seals on switchgear cabinetry, through the outer shell of an oil filled transformer, and in the switchyard emitting from bushings, buss bars, and insulators. Using highly sensitive airborne sensors these detectors can even isolate electric faults on high tension transmission and distribution lines at distances of over 150 feet.

Ultrasonic detection can pinpoint electric faults that might not generate any heat supporting the argument to combine heat and sound based inspection technologies. Experienced inspectors who recognize this are providing more accurate and complete reports, and are finding potentially catastrophic electrical faults that could be missed using only a single inspection method. Today, with very simple software technology, an inspector can employ ultrasound wave files to visualize reports. Imagine taking a wave file of an arcing connector on a transformer, then using the wave file together with an infrared image to illustrate the report. The combined results add clarity, confidence and understanding of review at every level.

Over the years we've seen countless applications where a singular detection technology did not always find the source of a perceived problem. But once a complimentary technology was introduced, such as combining ultrasound and infrared, or ultrasound and vibration analysis, a more educated and confident assessment was made. For example you can listen with an ultrasonic detector to a gearbox with a worn or broken gear whereas a low frequency vibration might miss the rubbing sound of bad gear mesh or the non-cyclical spike of random tooth damage. But by linking the ultrasonic detector and the vibration meter together the CRT on the vibration meter can easily display and identify the problem.

Not all electrical faults generate heat. Some do, but the heat can be masked by ambient temperatures or other heat sources. Not all electrical faults produce ultrasound either. Allow me to illustrate these points with some real life examples I've encountered over my career as an ultrasound specialist.

Case 1; Provided by Jim Hall:

A southeastern utility had gathered seven work trucks to find and remove a 13kv polymer insulator, thought to be creating TV and Radio interference within a community. A utility's worse nightmare is to have a retired electrical engineer and a HAM radio operator sending certified letters to the FCC complaining about the situation in their community. So a decision was quickly made to have the necessary parts pulled from supply and loaded onto one truck and have a work crew, a lift truck, a field supervisor, an electrical engineer, and two Radio and TV interference troubleshooting teams onsite to find the problem and fix it.

All these men and supplies were in place to find and remedy this problem. The troubleshooters using special antennae's and infrared imaging found what they thought to be the problem. The infrared image was showing very little heat just 10° F above ambient. The special antennae's heard a great deal of noise along the ¼ mile area.

However the field supervisor had just received a new ultrasonic device that could hear corona, tracking and arcing. The new ultrasonic device could only register very little sound emitting from the 13kv polymer insulator. Surely he thought this could not be the source of the R/TV interference. Upon further scanning in the area the field supervisor came upon a cut-out switch of the local 14.4kv service making a great deal of ultrasonic noise. The infrared image showed a hot spot worthy of repair. The cut-out switch was within 35 ft. of the electrical engineers home TV antennae and was in line-of-sight of the HAM operator's antennae.

The lift truck readied a crew to clean and replace the switch. Afterwards the field supervisor proceeded to the electrical engineers house to view his television screen. Sure enough the picture was clean. No more interference. The HAM Operator as well was pleased.

Case 1 is a fine example of what can happen by employing the use of both the ultrasound, special antennae's (radio waves both low and high frequencies) and the use of infrared imaging.

Case 2, Provided by Jim Hall:

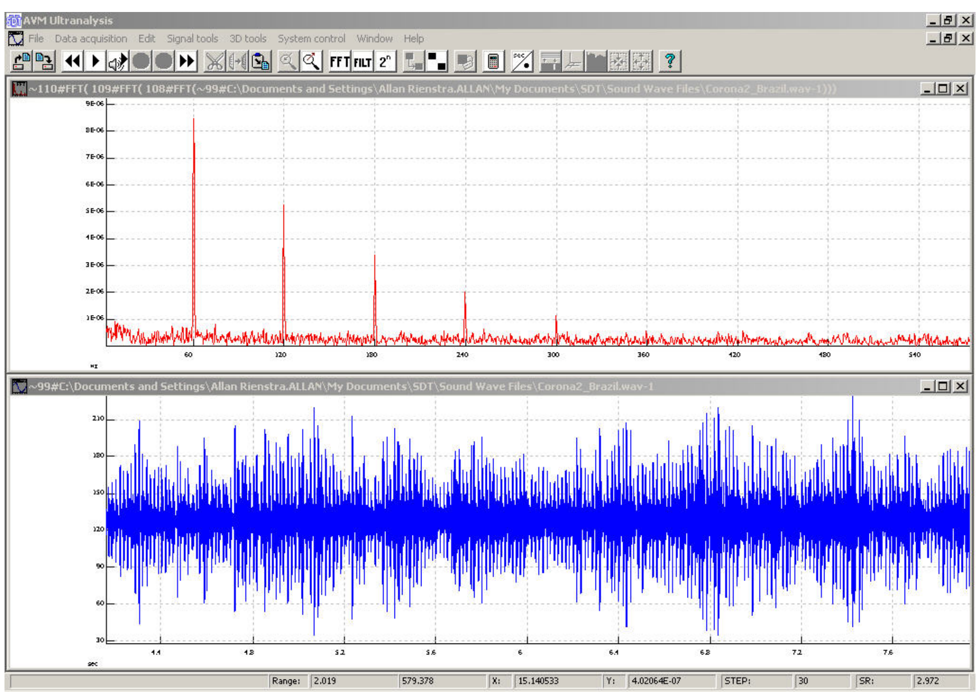
Another southern utility was using infrared to scan a switchyard for hot spots upon breakers, insulators, bushings, etc… There were many complaints of local town's people complaining about the AM radio reception being almost completely blocked out for several blocks. An infrared scan showed limited amount of arcing but not enough to justify a repair in the area. Review of the area using an ultrasound device and employing the use of a parabolic reflector revealed with "directionality" corona discharge from a 13kv brake switch. At a distance of 30 feet a decibel level of 58 dBµV was detected emitting from several places on the switch.

Corona discharge is invisible to the IR under 240kv. It is however visible in the ultraviolet range and some corona cameras (a new emerging technology) can see corona.

Ultrasound however can hear corona at great distances. Airborne ultrasound having a wavelength of 1/8th to 5/16th of an inch makes the corona sound naturally, very directional. A photo in non-infrared was made with the IR camera and an arrow was brought onto the picture to display the multiple locations of corona activity.

A ".wav file" of the ultrasonic signal was made as well. This wave file accompanied the real-time photo to the technicians. The wave file served two purposes here. One to give the technician an idea of what the corona sounded like to compare after the repair, and two, to provide the technicians a recording for their library for which to train new personnel on what to listen for.

The picture here illustrates corona signal in real time waveform and spectrum. When viewed in spectral mode clear modulations can be seen every 60 Hz indicating the nature of this electrical fault.



There are four primary conditions that are typically listened for using airborne ultrasound; Arcing, tracking, corona and destructive corona.

- Arcing; an abrupt stop and start.
- Tracking; a build-up of intensity, discharge and starts over.
- Corona; a steady frying or buzzing sound. Destructive Corona is a steady frying buzzing sound and is usually accompanied by a popping sound or arcing sound.

When to take action? Arcing and tracking requires a need to investigate and repair. Corona, typically heard on overhead utility lines, high moisture areas (tropical climates) depending upon the amount of decibels heard (high or low) and the actual equipment being investigated, the technician may investigate but not repair. Radio and television interference for instance may be coming from an insulator, very low decibel (dBµV) signal may or may not be repaired at the time heard.

However, “destructive corona” should be investigated by a professional, properly attired and familiar with the consequences of dealing with a possible volatile activity.

Case 3, Provided by Jim Hall:

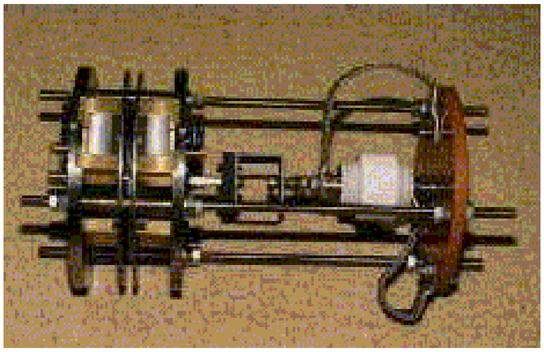
This particular incident happened while demonstrating the ultrasonic device for a southern chemical company. The electrical engineers had just purchased a new $45k Infrared Imaging System. The approving officer thought this camera and system was the last piece of equipment he would have to approve for his electrical shop.

The technicians upon completing certification as Level I and II for Infrared Thermography came back to the plant and placed an order for an ultrasonic detector. The request was not approved. But, hearing about how ultrasound and infrared work together in the classroom the technicians were convinced they needed to bring in someone to sell their supervisor on the idea of ultrasound.

Upon entering the plant and walking to the rear of the plant I noticed several new overhead switches and transformers. Wanting the technician to listen for any “abnormalities”, I immediately placed the headphones on my head and a second pair on the technicians head so that as we walked he and I could listen for anomalies such as corona or arcing or tracking. He assured me that the service company used a plastic explosive to swage the fitting and terminal ends and that we most likely would not hear any corona.

Unfortunately, that was not the case. A fair amount of “nuisance corona” was being heard from the swaged fittings and some terminal ends. Not all but some had electrical leakage.

Upon entering the switchgear room I saw a row of 15, 13kv Rectifier Panels. All the panels incorporated a vacuum breaker in the lower right side of the cabinet. The technician assured me that he had already come through with Infrared Imaging and saw nothing of interest. I also explained to him that he would have had to perform the inspection “with the cabinet doors closed and locked” and there was every chance he would not have seen any problems. With the 13kv Rectifier Panels closed and locked, I started scanning from right to left, every panel. It wasn’t until panel number “13” (of all panels) that we heard what I thought to be “arcing, tracking and corona discharge” all at onetime.



Fortunately I had ready a recorder to save a wave file if I came across an anomaly such as this. After recording the wave file I immediately turned to the technician and told him the “demonstration is over”.

That evening I took the wave file and attached it as an email to an engineer of a central Florida utility. He suggested that the technician remove and apply DC power to the breaker to see if it would fail. After passing along the suggestion the technician applied DC power and the breaker failed. Most important for that technician was the avoidance of a failure on a breaker that supplied a large amount of the plant’s compressed air.

Case 4; Provided by Jim Hall:

Another utility was asked to investigate a series of 13kv dry switch transformer one hot summer day. His customer was complaining about low power readings during the day and fearing a loss of power asked the local utility to investigate his “power in”. The engineer using both IR imaging and Ultrasound came upon one of several dry switches that had no significant IR temperature but he heard what he thought to be corona and arcing. After being properly attired with the necessary protective clothing and safety gear the engineer opened the transformers doors. High humidity (moisture) and possible carbon build-up on the switch were on the engineers mind as he slowly opened the doors. Sure enough flashover did occur but he was not injured. A visual of the transformer showed holes in the two adjoining Baker Boards. One “L” shaped. Discoloration of the paint inside (inside only) and the condition of the Baker Boards revealed a faulty transformer.

3. SUMMARY

We have talked about the various case studies and field evaluations that have occurred in the past. Every utility and electrical repair shop should employ ultrasound for inspecting, switchgear, sub-stations, transformers (both wet & dry), and overhead distribution and supply.

An ultrasound device that is repeatable is the key to successful integration of the two technologies. A device must be able to repeat a reading when the technician returns to a site that is unchanged physically. Some things that can change the reading: Distance from the source or anomaly, typically the same time of day, load factors the same, humidity relatively the same. All being equal, we want your unit to be “Repeatable”. Only a unit that measures a true “dBµV” decibel and a unit that utilizes True RMS conversion techniques can give repeatable information.

Datalogging the decibel range and the capabilities to record a wave file from the detector are also important.

Some of today’s ultrasonic systems will allow the end user to not only trend the Ultrasonic information with an internal datalogger but also link various sensors to the datalogger such as; store infrared temperature using a pyrometer, a parabolic dish to the datalogger to store dBµV (decibels), a thermocouple (non-infrared) when needed, a DBA sensor to store outside sound levels, a magnetic contact sensor (for structure borne ultrasonic sounds, i.e…bearings, arcing, tracking or corona inside an oil filled transformer) and or a Laser Sighted Optical Tachometer (contact or non-contact) for RPM measurements.

For more information about integrating airborne ultrasound with an infrared temperature scanning program please contact:

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