

Ultrasound for Reliable Electrical Assets

by **Allan Rienstra**
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Allan Rienstra Some say I am passionate about ultrasound. They are not wrong, but not right either. I am passionate about helping people get the most from their investment in technologies that create safe workplaces, reduce unplanned downtime, and eliminate waste. Ultrasound just so happens to be that technology. There is so much we can do to create accident free, proactive, environmentally sustainable conditions in manufacturing. All we need to do is care and hear more. If you care like I do, join me and together let's make Earth Great Again!

Ultrasound testing is a powerful solution for assessing the condition of our assets. The technology hears defects in the ultrasonic range and transfers these inaudible faults to low frequency sounds we can hear. Ultrasound signals from failing assets are measured, trended, and analyzed so we can execute an action plan that minimizes the impact.

Reliable plants need FIT assets

Most defects that threaten uptime produce Friction, Impacting, and Turbulence (FIT). These conditions exist silently in the ultrasound region. Find one – or any combination – of these and you now have data to monitor the asset condition at an advanced level.

Why is ultrasound useful?

Ultrasound Owns the Apex of the P-F Curve. Newly formed defects present themselves ultrasonically first, and only become audible once they have advanced closer to the moment of failure. Ultrasound testing is considered one of the earliest indicators that an asset will soon need attention.

Ultrasound instruments are particularly effective in high noise situations. Inspections can be carried out any time of day, regardless of background noise.

Ultrasound is introverted. It prefers to remain isolated to its source. This unique characteristic makes ultrasound extremely effective for distinguishing specific anomalies occurring in close proximity to each other; like finding that one needle in a haystack full of needles.

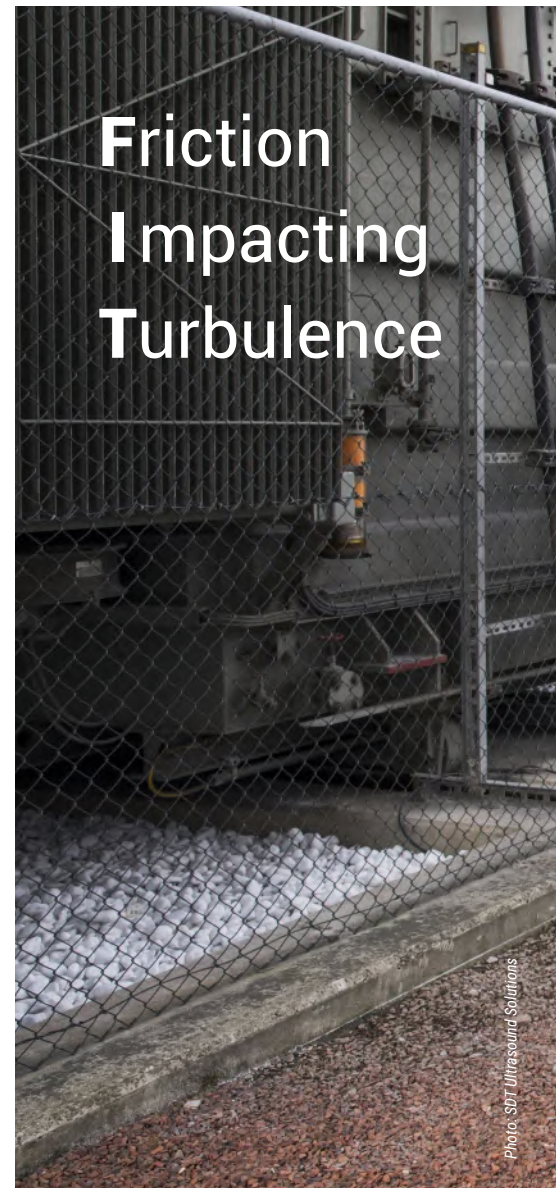
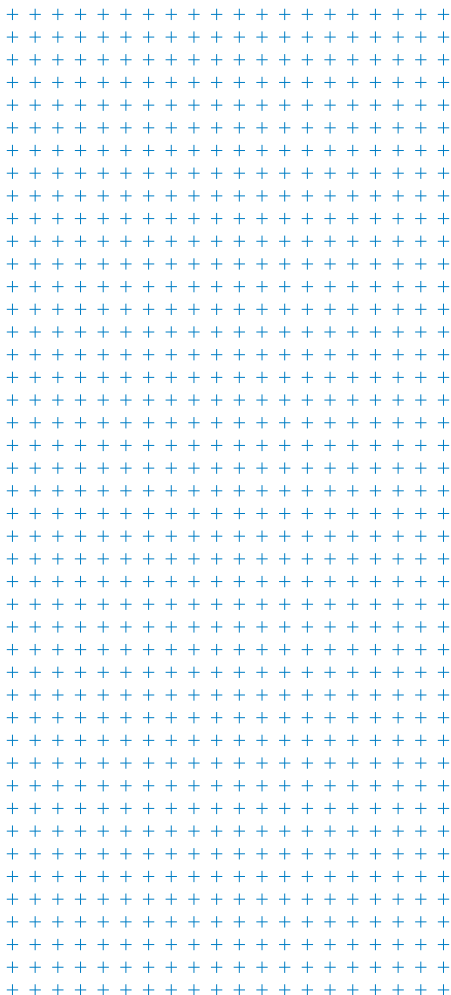
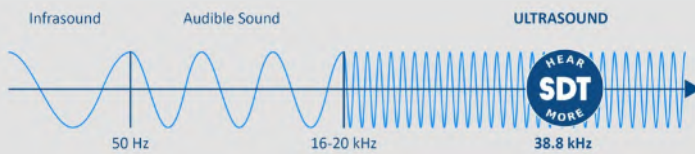
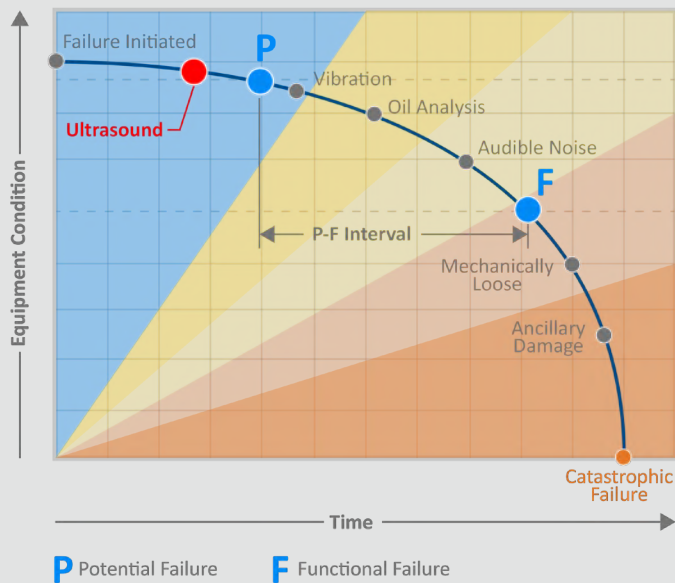


Photo: SPT Ultrasound Solutions



Ultrasound Is The First Line of Defense



Versatility

Ultrasound's versatility is unlike any other condition monitoring technology. SDT identified eight application pillars and within each pillar there are virtually hundreds of ways to increase safety, eliminate unplanned downtime, and reduce energy waste. Ultrasound is the first line of defense for industries seeking higher profits and a sustainable future.

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Ultrasound for reliable electrical assets

The term "Electrical Asset" casts a large net over an important class of systems. Whether it be substations, transmission and distribution lines, transformers, or motor circuit control cabinets, electrical assets play a key role in practically everything we do. Like most things, we take them for granted until they fail to deliver their value. Then we scream.

Energy's journey begins at the point of creation, can include storage, then transmission, distribution, and finally consumption. That journey is full of risk and the most significant risk contributor is partial discharge. Partial discharge happens when insulation material is compromised. One thing we know for certain is that once partial discharge begins, it will only get worse.

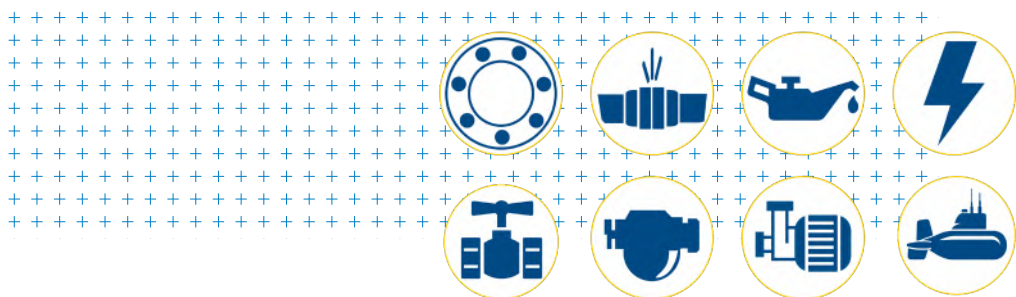
Partial discharge is more common than we would like to believe, even in new installations. Detecting these defects represents a serious challenge. Particularly at an early stage. There is no one perfect inspection technique, or technology, which can, on its own, detect and localize every defect, in every instance on every part of the electrical system.

Selecting the most appropriate method requires that the inspector understand the nature of the defect and the signs and signals available to be detected. The next logical step is to have the right technology available to pinpoint their location. Ultrasound is one technology that is mandatory for all electrical maintenance personnel. To not only reduce the risk of arc flash explosion but also enhance the overall reliability of system components.

When speaking about risk, health and safety should always take center stage. Safety aside, we must consider the risks from unreliable assets and loss of electrical equipment. They are both linked to downtime, costly legal exercises, and ultimately lost profit. Ultrasound is a solution that provides a reduced risk of all three in one go.

Ultrasound helps reduce the risk of arc flash exposure by detecting defects which, when left unattended, will lead to an arc flash event. I am not suggesting for one moment that we should not use PPE and other preventative measures. But I am yet to meet an arc flash suit which can detect an arc flash at its inception. So, the question is this: *If an Arc Flash Suit is the last line of defense, then what is the first?*

Some reliability minds seem obsessed with machines that rotate, while failure modes of non-rotating asset components seldom receive the routine surveillance they need. Pumps and motors receive all the attention while the balance of the system is run-to-failure. Ultrasound testing can change this lackadaisical attitude; especially considering its versatility, ease of use, and applicability to so many non-rotating applications.





What are common failure modes?

Figures produced by the IEEE suggest that electrical defects originating in switchgear were associated with insulation failure 90% of the time. Asset age had very little influence over the cause of failure. This points to the fact that the lion's share of failures are not due to aging and in fact, are mostly associated to poor workmanship, contributing to problems related to the insulation, ingress of water, cracked insulators, and poor installation.

Partial discharge is the symptom, insulation failure is the defect, and the severity is observed as either tracking, arcing, or corona.

How can ultrasound help?

Why ultrasound? Before answering that question, it is helpful to look more closely at types of electrical discharges. What are they; what causes them, and how they behave?

We generally speak of partial discharge and arcing. But they are broken down into further subsets. Partial Discharge (PD) is an atomic reaction which, due to the

movement of electrons, ionizes air molecules and produce locations of high stress. This ionization phenomenon splits the oxygen molecule to form ozone and nitrous oxide which in their normal states are generally harmless. But when mixed with moisture, they become corrosive.

If you have ever walked into a substation and noticed the smell of ozone, then you have witnessed partial discharge firsthand. Ozone odor is quite often the first indicator of the presence of PD.

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PARTIAL DISCHARGE IS DESTRUCTIVE



Corona

Corona is a type of PD. Corona is unique in that the discharge is into air molecules with no insulation present between the conductors. Corona is most commonly found on transmission lines, and sometimes it can be heard in the audible range of frequencies. This is dependent primarily on system voltage.

Corona is influenced by humidity levels; however, it generates a lower discharge in higher humidity areas. This is contrary to what was normally believed. Water in the air captures some of the free electrons which would otherwise initiate the discharge.

Tracking

Tracking is another form of PD. It is the flow of electricity over an interface of different insulation materials and most commonly involves a solid type of insulation. Tracking can present itself on the

surface of an insulator contaminated with hydroscopic dust. Increased moisture or humidity can reduce the insulator's resistance on the surface and enhance the tracking type discharge. By implication then, one distinction between corona and tracking is to check whether there is a positive or negative correlation with absolute moisture content in the air. In any case, an ultrasound inspector must be focused on finding the symptoms of the condition first.

Another fact is that partial discharge – both corona and tracking – do not generate any noticeable change in temperature in electrical systems below 240 kV. One thing we do know with certainty though, is that they are often precursors to fires, explosions, and catastrophic failure of electrical plant systems. Partial discharge only begins to appear acoustically at around 4.4 kV, so any low voltage inspections for PD are a waste of time. Arcing however occurs at even very low voltages.

Arcing

Arcing, and in some instances partial arcing, is the flow of electricity through the air from one conductor to another object which conducts electricity. It is characterized by a rapid expansion of gas, causes fires and explosions, is extremely violent, generates extreme temperatures, and consequently the catastrophic destruction of all equipment connected.

Detection methods

To understand which technology or inspection technique is the best to use on a particular piece of electrical equipment, or in search of a particular defect, we need to know the signs and signals generated and made available for detection by an inspector with the correct tool and appropriate training.

Partial discharge generates ozone, which produces an unmistakable odor. Visual evidence is sometimes available, but it is not a reliable method. PD generates sound throughout the frequency spectrum. However, it presents a particularly clear and unmistakable signal in the ultrasonic range.

Arcing is obvious and visible on external equipment. It also generates ultrasound throughout the spectrum. It also generates electromagnetic radiation, and of course, massive amounts of heat. Both ultrasound and infrared are successful detection methods, however ultrasound wins the initial detection due to its ability to hear through narrow air gaps such as those found on Motor Circuit Control (MCC) panels and doors. Safety for our inspectors must always be our number one priority.

One example of a partial discharge defect saw a cable termination where two phases were crossed too closely together. The ultrasound signal clearly revealed the PD activity while infrared showed nothing. By combining ultrasound with IR, this defect was detected before it had opportunity to advance to a state of flashover.



Photo: SDT Ultrasound Solutions


Electromagnetic Radiation Equipment works well, even if it has its disadvantages. TEV or transient earth voltage detects partial discharge in medium and high voltage equipment which induces a voltage on the inner surface of switch gear cabinets and panels. These transient earth voltages can be measured for amplitude, are comparable, and can be trended. However, TEV detectors have minimal diagnosis capabilities and there are many components nearby which give off transient earth voltages that often lead to misdiagnosis.

Radio frequency devices are great at picking up defects because all defects generate electromagnetic noise. But so are many other components found inside a substation. Electromagnetic noise coming from light ballasts, CPUs, and a several other electronic components interfere with the effectiveness of RF detection. RF devices detect fast transients which can be useful in a substation or on overhead lines. They are a simple indicating tool and can stand in well when other technologies fall short. Always remember that RF technology provides no diagnostic capabilities.



Our eyes are only sensitive to a very narrow band of light. UV Cameras detect ultraviolet light present at the point of discharge. Although a fantastic technology, UV cameras require line of sight and therefore, like Infrared cameras, their usability is too limited to be standalone effective.

Finally, online condition assessment technology, the subject of which is too broad for this paper, is the electrical measurement and analysis of radio frequency cable insulation aging signals which are emitted from the cable whilst in its normal service. It is the most diagnostic and comprehensive tool, however it is not portable and requires a specialist operator.

A technician in a blue uniform and yellow hard hat is using an ultrasound detector on a power transformer. The technician is holding a handheld device with a probe and a display screen. A red laser line is visible, pointing towards the transformer. The background shows a chain-link fence and various electrical components.

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Why ultrasound is so effective

We use the term ultrasound to refer to any sound signal above the range of human hearing. It is generally accepted to be any signal above 20 kHz in the frequency range.

Ultrasound signals can travel through solids, liquids, and gases. That applies nicely to cable termination boxes, transformer oil, and air.

Ultrasound tends to be directional in nature which means their source is easily pinpointed, unlike audible sounds which tends to disperse more freely and widely. Ultrasound is a low energy signal which means it attenuates a short distance from its origin. This further enhances our ability to locate its source without threat of interference from alternate, nearby sources of ultrasound be them defects or otherwise.

With the right ultrasound detector, some basic training and a little experience, inspectors can quickly locate a defect in a high noise environment. The difference between corona discharge, tracking and arcing is obvious, which means the inspector knows exactly which defect is present and how to plan a corrective maintenance strategy.

Advanced ultrasound detectors allow inspectors to record the sound, measure the amplitude, and analyze the signal for diagnosis. Condition indicators are a recent innovation offered only by SDT. These useful tools provide advanced insight about system condition by providing insight that single decibel instruments simply cannot. These detectors allow inspectors to more confidently categorize the defect and present a strategy for repair. Many things are now possible with the right ultrasound detector.

Panels and cabinets

So here we have an easy to use, handheld technology to detect partial discharge and arcing at their inception.

The moment the defect appears it generates ultrasound. For example, in switch gear panels, the presence of an electrical defect floods

the insides of the cabinet with ultrasound. Small in wavelength, ultrasound passes through the tiniest of air gaps making it easy to identify which panels need closer attention, and which to simply leave alone.

Sometimes, rarely even, panels are airtight. Don't be tempted to open them. An ultrasound contact sensor placed on the outer surface of the panel can still detect the presence of electrical defects directly through the metal. The signal is only slightly reduced and is effectively detected.

By listening to, and capturing the ultrasound signal, well-trained inspectors can often categorize the defect on-the-spot. This point emphasizes the need for inspectors to seek training from their ultrasound manufacturer and maintain a mentor relationship with the trainer afterwards.

No single technology solves everything

There is no perfect single technology and ultrasound is no exception. Ultrasound is limited to the ability of the sensor to access the source of the defect through one of the three earlier mentioned media (gas, liquid, or solid). In some installations, no matter which technique or technology you use, you may still come up empty-handed. Reliability leaders should be well-versed in all technology options and be free to choose the one that suits their inspection best. Don't be chided into believing one reigns superior over all others.

Although, without bias or risk of offering advice that could lead to failure, ultrasound is clearly the most versatile, easy-to-use, cost effective technology to begin.

To recap, partial discharge is more common than we like to believe. There are ready technologies available that help to not only reduce the risk of arc flash exposure but also simultaneously enhance the overall

reliability of the electrical system. Ultrasound presents the best win-win scenario for safety and reliability. There are a few technologies available, and some are better than others especially in applications that are suited for a specific purpose.

Comparatively however, ultrasound appears the most practical, simple, comprehensive, and cost-effective. Consider ultrasound as your first line of defense technology to build out your overall electrical condition monitoring and analysis strategy.

