Partial Discharge Analysis

Ultrasonic Techniques to Evaluate Partial Discharge in Electrical Machinery

Summary

Partial discharges are small electrical sparks that occur within the electric insulation of switchgear, cables, transformers, and windings in large motors and generators. Partial Discharge Analysis is a proactive diagnostic approach that uses Partial Discharge (PD) measurements to evaluate the integrity of this equipment. This article describes how instruments that detect airborne ultrasound can be used to detect and evaluate partial discharge in electrical equipment.

MB04025

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4 pages
September 2004

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Partial Discharge

Partial discharges are small electrical sparks that occur within the electric insulation of switchgear, cables, transformers, and windings in large motors and generators. Partial Discharge Analysis is a proactive diagnostic approach that uses partial discharge (PD) measurements to evaluate the integrity of this equipment. Each discrete PD is a result of the electrical breakdown of an air pocket within the insulation. PD measurements can be taken continuously or intermittently and detected on-line or off-line. PD results are used to reliably predict which electrical equipment is in need of maintenance.

Just as every material has a characteristic tensile strength, each material also has an electrical breakdown (dielectric) strength that represents the electrical intensity necessary for current to flow and an electrical discharge to take place. Common insulating materials such as epoxy, polyester, and polyethylene have very high dielectric strengths. Conversely, air has a relatively low dielectric strength. Electrical breakdown in air causes an extremely brief (lasting only fractions of a nanosecond) electric current to flow through the air pocket. The measurement of partial discharge is, in fact, the measurement of these breakdown currents.

Electric equipment can suffer from a variety of manufacturing defects or operating problems that impair its mechanical reliability. The electrical insulation of motors and generators is susceptible to:

- Thermal stresses
- Chemical attack
- Abrasion due to excessive coil movement

In all cases, these stresses will weaken the bonding properties of the epoxy or polyester resins that coat and insulate the windings. As a result, an air pocket develops in the windings. Not only do partial discharge levels provide early warning of imminent equipment failure, but partial discharge also accelerates the breakdown process. The excessive arcing between ground and conductor within the insulation will, in time, compromise the dielectric strength and mechanical integrity of the winding insulation. Once this happens, a ground fault or a phase-to-phase fault is inevitable.

Ultrasonic / Acoustic Emission

All operating equipment produces a broad range of sound. The high frequency ultrasonic components of these sounds are extremely short wave in nature, and a short wave signal tends to be fairly directional. It is therefore relatively straightforward to isolate these signals from background noises and detect their exact location. In addition, as subtle changes begin to occur in electrical and mechanical equipment, the nature of ultrasound allows these potential warning signals to be detected early, before actual failure.

Figure 1 An airborne ultrasound instrument.

Airborne ultrasound instruments, often referred to as "ultrasonic translators", provide information two ways: qualitatively, due to the ability to "hear' ultrasounds through a noise isolating headphone, and quantitatively, via incremental readings on a meter. This is accomplished in most ultrasonic translators by an electronic process called "heterodyning", which accurately converts the ultrasounds sensed by the instrument into the audible range where users can hear and recognize them through headphones.

Although the ability to gauge intensity and view sonic patterns is important, it is equally important to be able to "hear" the ultrasounds produced by various equipment. That is precisely what makes these instruments so useful; they allow analysts to confirm a diagnosis on the spot by being able to discriminate among various equipment sounds.

The reason users can accurately pinpoint the location of a particular ultrasonic signal in a machine is due to its high frequency / short wavelength. Most of the sounds sensed by humans range between 20 Hz and 20 kHz (20 cycles per second to 20,000 cycles per second). They tend to be relatively gross when compared with the sound waves sensed by ultrasonic translators. Low frequency sounds in the audible range are approximately 1.9 cm. to 17 meters in length, whereas ultrasounds sensed by ultrasonic translators are only 0.3 - 1.6 cm long. Since ultrasound wavelengths are magnitudes smaller, the ultrasonic environment is much more conducive to locating and isolating the source of problems in loud plant environments.

Using Ultrasonic / Acoustic Emission for Partial Discharge

Ultrasonic testing is often used for evaluation at voltages exceeding 1,000 volts, especially in enclosed switchgear. This is especially useful in identifying tracking problems. In enclosed switchgear, the frequency of tracking greatly exceeds the frequency of serious faults, which can be identified using techniques such as infrared thermography.

When electricity escapes in high voltage lines or when it jumps across a gap in an electrical connection, it disturbs the air molecules around it and generates ultrasound. Often this sound will be perceived as a crackling or frying sound; in other situations it will be heard as a buzzing sound.

There are three basic electrical problems that can be detected using ultrasound:

- Corona: When voltage on an electrical conductor, such as an antenna or high voltage transmission line exceeds threshold value, the air around it begins to ionize to form a blue or purple glow.
- Tracking: Often referred to as "baby arcing", follows the path of damaged insulation.
- Arcing: An arc occurs when electricity flows through space. Lightning is a good example.

The process can be used to detect both end winding (Phase to Phase) and slot section (Phase to Earth) discharge.

High voltage applications include: insulators, cable, switchgear, buss bars, relays, contactors, and junction boxes. In substations, components such as insulators, transformers and bushings may be tested.

The method for detecting electric arc and corona leakage is similar to the procedure used to detect acoustic emissions from mechanical sources. Instead of listening for a rushing or rubbing sound, a user listens for a crackling or buzzing sound. In some instances, as in trying to locate the source of radio/TV interference or in substations, the general area of disturbance may be located with a gross detector such as a transistor radio or a wide-band interference locator. Once the general area has been located, the scanning module is utilized with a general scan of the area. The sensitivity is reduced if the signal is too strong to follow on the meter until the loudest point is located.

Determining whether a problem exists or not is relatively simple. By comparing sound quality and sound levels among similar equipment, the problem sound will tend to be quite different. Alternatively trending the signal amplitudes over an extended period of time may give early indication of developing faults.

Further Reading

Alan Bandas, Ultrasonic Inspection, UESystems_03002. http://www.aptitudeXchange.com

SKF, Connecting the Inspector 400 Ultrasonic Probe to the Microlog CMVA, CM3053. http://www.aptitudeXchange.com

About DEI

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While DEI's activities extend to one-off consultancy exercises, our core services are delivered via on going, day-to-day involvement with the client throughout the life of an installation. Whether a new facility or an existing operation, DEI has the capabilities and expertise to assist clients to maximize the effectiveness of their maintenance effort.

Formed in 1981 to provide engineering solutions for the challenges of the North Sea Oil and Gas Industry, DEI now has extensive activities throughout the power and process industries world-wide. The company has active bases in Aberdeen, Abu Dhabi, Stavanger, Perth (Australia) and Kuala Lumpur.

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