Ultrasound is an effective, low cost method for evaluating the condition of insulation components on high-voltage transmission and distribution equipment. Conventional testing methods require the equipment to be shut down. Ultrasonic testing can locate failing insulation components in live electrical distribution and transmission equipment.

Ultrasonic testing is suitable for outdoor substation and aerial transmission equipment, particularly when coupled with a parabolic concentrator. Enclosed switchgear equipment also can be tested. Spectrum analysis of the ultrasound signal allows tracking to be distinguished from other sources of ultrasound in the gear or adjacent areas. Listening ports permit the safe inspection of any type of switchgear.

**Overhead transmission lines**

The night shift electrical supervisor at a petrochemical refinery received reports of visible arcing at porcelain insulators on a 69 kV power pole. The power line supplied a wastewater treatment facility. If the facility lost power, the refinery would be unable to operate.

From the symptoms described by the supervisor, it was likely that an insulator was failing. The failure of insulators on high-voltage (greater than 4 kV) power transmission and distribution equipment can often result in electrons discharging into the air, a phenomenon known as tracking, corona, or partial discharge. Under the right conditions, the discharge can find a path to ground, resulting in a highly destructive ground fault.

The electrical supervisor wanted to know if a recent infrared test had identified any problems at these insulators. He also wanted to know if the problems had disappeared, because arcing could no longer be seen. The supervisor was told that, except for severe cases where a current path to ground was established, infrared testing would not detect high-voltage insulator failures because the corona or tracking typically produces little or no heat. He also was informed that this situation might be extremely dangerous and that it warranted immediate attention.

A UE Systems Ultraprobe 2000 was used to evaluate the problem. The instrument hears ultrasound (sound above 20,000 Hz) and converts it to audible frequencies. High-voltage discharges that accompany the breakdown of insulation cause ionization of the air and the ionization produces ultrasound. Thus, the presence of tracking or corona can be readily detected by an ultrasonic instrument.

The instrument is simply pointed at the area of concern. If tracking or corona is present, a buzzing noise similar to static on a radio is heard through the instrument headphones. The instrument is directional, allowing the location of the insulation fault to be determined by listening from several locations until the high sound source is pinpointed.

Power pole insulators at the refinery were located about 60 ft above ground. In addition, the area around the pole had discharging steam traps and several compressed air leaks. The traps and air leaks produced high levels of background ultrasound that would ordinarily overpower the ultrasound produced by insulator failure. A parabolic concentrator was used to overcome these problems. This device has a seven element ultrasonic detector array mounted in the center of a parabolic dish. The dish features an optical sight that expedites pinpointing the source of ultrasound.

The concentrator provides two advantages:

- Instrument sensitivity is more than doubled. As a result, even low-level discharges occurring at a substantial distance can be detected.
- The concentrator is extremely directional. Adjacent ultrasound sources are rejected and the precise source of ultrasound is easily determined.

The ultrasound instrument immediately indicated that corona discharge was occurring at each of the insulators. The C phase insulator had a very high level of discharge.

In addition, the insulators were checked with an infrared imager using a 3x telescope. The imager revealed a ring of heat on each insulator. The ring of heat was about 2 deg F above adjacent surfaces and it occurred at a different location on each insulator. There were no connections near any of the rings. It was determined that the heating probably corresponded to the location of the discharge at each insulator. Temperature differences were very small and could be overlooked easily during a typical infrared survey.

When both ultrasound and heat are detected from a failing insulator, the problem has reached a potentially dangerous stage and requires immediate shutdown. The presence of heat indicates a current flow to ground. This flow will precede catastrophic failure.

Although the insulators were subjected to periodic inspections and cleaning, they obviously were failing. Backup generators were brought in to power the facility while the insulators were replaced.

**Enclosed switchgear**

A combination of infrared and ultrasonic testing is often used on high-voltage electrical equipment, particularly enclosed switchgear. Infrared equipment can locate resistive faults such as dirty switch contacts or loose joints. The ultrasonic instrument locates developing insulation faults. In enclosed gear, tracking is a particularly serious problem because the distance from current carrying components to ground is usually small. Failure of insulating components can cause switchgear components to vaporize. Ultrasonic testing in enclosed switchgear may be more important than infrared testing.

At a multi-use 1 million sq ft facility, access doors to a 13 kV switch were locked and no keys were available. The internal current carrying components could not be inspected. This switch was critical; its loss would shut down the entire complex.

Because ultrasonic sound can pass through small cracks at doors or through ventilation openings, an ultrasonic test was performed. The test revealed extremely high internal ionization. Bolt cutters were used to remove the locks. With the lights out, arcing was visible where the bus passed through a supporting barrier board.

Infrared testing also revealed a track of heat leading directly to a support bolt, indicating that current was already flowing to ground. Building tenants were notified and an orderly shutdown was conducted the next evening to correct the problem. The complex was back on line the following morning.

Often, when enclosed high-voltage switchgear or transformers are inspected, it is difficult to distinguish between ultrasound produced by insulation failure and ultrasound produced by vibration of mechanical components. However, spectral analysis of the ultrasound signal can be used to distinguish tracking and corona from mechanically produced ultrasound.

Output from the ultrasound instrument is fed into a spectrum analyzer. The spectrum analyzer can be the same portable data logger used for monitoring vibration in mechanical equipment. Mechanical vibration produces a spectrum in multiples of 60 Hz (electrical field frequency). Tracking and corona ultrasound results from ionization of air. This process produces broadband noise. There may be a 60 Hz component because the arc will rise and collapse with the voltage cycle. However, distinct 60 Hz multiples are not present.

Mechanical vibration produces an easily discerned spectral pattern while tracking or corona produces a noise pattern. Thus, for example, spectral readings can be taken at a dry-type transformer to determine whether an insulation fault is developing. Alternatively, the spectral readings can distinguish between potential transformer or switchgear case vibration and tracking.

On many types of enclosed high-voltage gear, front or rear panels can be removed to provide access for ultrasonic testing. (All appropriate safety procedures must be observed during removal of panels on energized high-voltage switchgear. See National Fire Protection Association 70E, "Standard for Electrical Safety Requirements for Employee Workplaces.")

However, high-voltage switchgear is often totally enclosed. Access is through interlocked doors that cannot be opened when the gear is energized. This type of gear can be easily tested for insulation breakdown through the use of a listening port.

Ultrasound easily passes through an opening but is readily blocked by a solid surface. On switchgear, a listening port can often be provided by removing a few bolts from the housing. The ultrasonic instrument is then held near the open bolt holes to detect the distinctive buzz of internal tracking or corona. On totally sealed gear, a 4 in. dia capped hole can be cut into the switchgear housing during an outage. The port cover can be removed for inspection. The ultrasonic instrument is then positioned at the hole and operated to detect any internal tracking.
**MT**

Information supplied by Mid Atlantic Infrared Services, Inc., Bethesda, MD; (301) 320-2870.