Noise and On-Line Partial Discharge Detection

Introduction

The use of power electronics has spawned many electrical advancements. Their widespread usage today includes variable speed drives, motor soft-start acceleration, UPS systems, and other applications. However, this equipment can create difficulties when attempting to detect electromagnetic signals associated with partial discharge activity.

Consistent with this NETA World issue’s theme, the following No-Outage Corner shall focus on power electronics including the disturbances they cause and how these disturbances can be dealt with during on-line partial discharge (PD) testing.

Signals

When performing on-line partial discharge testing, sensors are coupled to medium- and high-voltage equipment in order to detect synchronous, high-frequency electromagnetic pulses which are characteristic of insulation breakdown. Depending upon the type of equipment that is being analyzed and location of the discharge, signals typically in the frequency range of one half to several tens of megahertz are common. However, this frequency range may also encompass a wealth of signals caused by power electronic or other equipment. Therefore, discerning the partial discharge signals from this electrical noise can be very important for making the correct analysis and subsequent insulation condition diagnosis.

Types of Noise

There are generally two main types of noise, impulse and continuous. Impulse noise may be random such as pops and crackle or steady, precisely timed noise such as SCR firing. The amplitude of this type of noise may vary greatly. Continuous noise such as AM broadcast, 60 Hz power noise, or background white noise (see Fig. 1) tends to maintain fairly consistent magnitudes. Noise removal techniques will differ depending upon what type of noise is present.

Often, continuous noise is not of sufficient magnitude to present a problem. In these cases, any partial discharge signal will exceed this small background noise level and can be seen clearly without any corrective action. When the noise level is excessive, steps must be taken to remove the noise while not affecting the partial discharge signal itself. The use of hardware or software filters are perhaps the easiest and most effective way to deal with this type of noise.

Filters

Filters can be either passive or active. Passive filters usually consist of resistive, capacitive, or inductive components that can be packaged into a small enclosure that is placed in line with the signal input. Active filters consist of electronic
components and may require an external power supply. Active filters can pack many more stages of filtering and provide much more precise filtering parameters into a much smaller package compared to passive devices.

Due to the high magnitude of 60 Hz interference present during any on-line PD testing, a 60 Hz high pass filter is routinely used. Eliminating the 60 Hz signals has no affect on PD measurements since PD occurs at much higher frequencies.

AM broadcast signals can present a much greater problem for on-line PD detection. In the U.S., AM signals are in the 515 kHz to 1715 kHz range and can be of sufficient strength to hide or mask PD signals. For cable PD testing, signals in the lower regions of this band would correspond to distant PD sources. At its source, the PD signal typically consists of broadband high frequency pulses up to hundreds of megahertz. The cable itself acts electrically as a low-pass filter, so that the higher frequency pulses related to PD activity will only be detectable near the PD source. This aids in detecting PD origination. The unwanted AM broadcast signals can be removed using a two megahertz high pass filter, but this also eliminates any PD signals in the lower bandwidth, thus eliminating the detection of distant PD. When performing on-line cable PD testing, this may require testing the cable at multiple points, such as at all the splices and terminations, to ensure that a distant PD signal is not missed.

Other Methods

When the cable system construction does not allow for multiple test point access, other noise reduction methods must be used. One such method involves recording the original analog signal digitally and then applying mathematical formulas to eliminate the unwanted noise. Before and after waveforms, using this noise elimination method, are shown in Figure 2.

Impulse noise can also cause problems during PD measurements. Fortunately, this type of noise often occurs at the exact same phase angles over the power cycle and can be easily distinguished from PD activity. Figure 3 shows partial discharge from a generator which is easily distinguishable from the exciter pulses. Impulse noise can also be eliminated from the power cycle by gating which involves completely removing all signals contained within the narrow sectors associated with the impulses by subtracting those sectors from the power cycle.

While typical PD measurements are best made in the time domain using oscilloscope-based instruments, taking measurements in the frequency domain using instruments such as the spectrum analyzer may sometimes be useful for noise removal when other methods may not work as well as desired. When using spectrum analyzers, the signal frequency is observed to identify potential PD activity. A suspect frequency of interest is chosen as the center frequency and the instrument is then switched to zero-span mode which only displays a few cycles in the time domain mode. These cycles, however, are only associated with the narrow center frequency band chosen, thus effectively creating an adjustable narrow band pass filter. As with all noise removal methods, there are compromises to be made in the use of spectrum analyzers as well. The instrument does not perform well in the AM broadcast region, so detection of distant PD sources cannot be made due to high frequency attenuation as explained earlier.
VFD Caused Insulation Problems

Variable frequency drives (VFDs) are commonly used to precisely control motor speed in order improve efficiency. However these devices create high magnitude pulses that can create partial discharge damage to feeder cables or the motor itself. These discharges can even occur on low voltage motors (<600 volts) and have led to many cable and winding failures. A factor that causes motor insulation breakdown is the motor lead length. This is a potential problem if the impedance of the motor is much larger than the impedance of the wiring and a reflected wave is established which is added to the VFDs original transmitted wave, thus creating a doubled magnitude voltage spike which exceeds the motor or cable insulation capability and results in eventual breakdown. Because the impedance of motors is larger in smaller motors, this problem is more likely to occur in smaller motors. Steps have been taken to decrease VFD to motor cable length during installation and to utilize higher rated cable and motor insulation in order to reduce this problem.

Conclusion

Power electronics are here to stay as is the need to assess medium-voltage equipment condition. By using a variety of techniques, an experienced technician can greatly improve the signal to noise ratio when performing on-line PD testing and effectively detect insulation problems before complete failure occurs.

Mr. Genutis received his BSEE from Carnegie Mellon University. He has been a NETA Certified Technician for 15 years and is a Certified Corona Technician. Don’s technical training and education are complemented by twenty-five years of practical field and laboratory electrical testing experience. Don serves as President of No-Outage Electrical Testing, Inc., a Group CBS affiliate that focuses on new inspection technologies performed while the equipment remains in service.