CONTINUOUS MONITORING IS ON THE RISE: CAN YOU ADAPT?

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Electrical testing companies have traditionally built their businesses by periodically running tests on electrical assets. This reassures the end user that their equipment is in good working order and hopefully will remain that way until the next scheduled test.

However, that isn't always the case, and failures can occur between tests. Given the high impact of failures and aging of medium-voltage assets, as well as the growing number of options in cost-effective monitoring solutions, a change is taking place: End users are increasingly installing 24/7 monitoring on their medium- and high-voltage assets. Potential problems are spotted when they start and are more likely rectified before failure occurs.

Cost-effective monitoring systems and services for thermal increase and partial discharge (PD) are readily available. Thermal monitoring checks the health of your conductors and can replace periodic infrared scans while reducing the need for visual inspections. PD monitoring checks the health of your insulation and can replace periodic PD surveys.

Test companies that rely on thermographic and PD surveying of MV and HV equipment but do not adapt to this change may suffer in the coming years. An end user who buys a 24/7 monitoring system needs less periodic testing, thereby reducing the business available to testing companies. Testing companies that adapt and offer to install and maintain monitoring systems as well as react to monitor-generated alarms could see their business increase. It is important to understand this paradigm shift and plan accordingly to ensure the success of your testing company.

WHY ISN'T PERIODIC TESTING ADEQUATE?

Periodic testing is certainly better than no testing, but it isn't perfect. Serious loss can occur if an undetected problem reaches catastrophic failure in the period between surveys. Obviously, if you test more frequently, the chance of failure goes down. However, at some point, that becomes too labor intensive and financially onerous.

The obvious analogy is the increasing use of 24/7 wearable EKG monitors for heart patients. Having an EKG at your annual physical is great, but you can still have an issue between visits. For most people, the inconvenience and cost of such a device makes it not worth the benefit, but as cost goes down and convenience goes up, who knows? For high-risk patients, it can be a lifesaver.

On assets above 2.5 kV, partial discharge (PD) testing is typically done annually or bi-annually because the general belief is that PD takes at least that long to lead to failure. That is sometimes — or even often — true, but it is not always the case. Take the following incidents as examples.

Example 1: Distribution Utility

In November 2014, a UK utility installed a full-time only partial discharge monitor at one of their high-risk substations. The site was judged high risk due to its location near a river's edge combined with the type of switchgear operated at the location. Tragically, there was no remote communication channel available, and the system data was not reviewed during the testing period. On July 28, 2015, the switchgear failed catastrophically (Figure 1).

Figure 1: *Result of Inaction — Catastrophic Failure*

Experts reviewed the recorded data and found that the substation had read little to no activity from installation in November 2014 until March 2015. However, from March 2015 on, there was a marked increase in PD activity. Over a week-long period, PD rose to a level that — had the alarm system been installed — would have triggered an alarm (Figure 2). This spike continued to exist until July 28, 2015, when the switchgear suffered a catastrophic failure. Although a periodic survey in early March would have found no issues, a catastrophic failure still occurred four months later. This would have been easily detected with continuous monitoring. As a direct result of downtime, the utility received Customer Minutes Lost (CML) and Customer Interruption (CI) fines totaling $700,000.

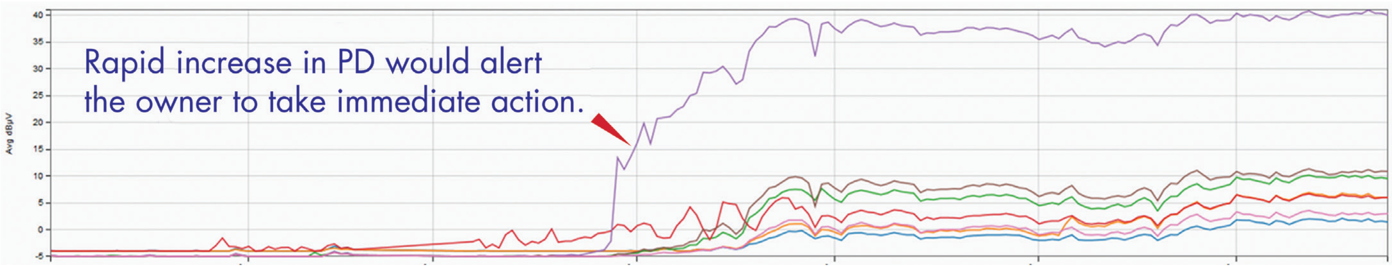

Figure 2: *Dramatic Rise in PD Reading*

Example 2: Petro-Chemical Plant

A large manufacturing site that is home to an olefin and polymers business and a crude oil refinery operates a combined heat and power plant that supplies electricity to the site through two separate 1km-long, XLPE cable circuits known as CHP1 and CHP2. Following the detection of partial discharge in three relatively new joint pairs during routine conventional offline very- low-frequency (VLF) testing, an on-line permanent cable monitoring system was installed.

Following installation, the PD activity identified during the VLF testing was confirmed in all three cables and located to the vicinity of the suspect joint pairs. This removed the need to take the CHP plant off line again to perform further periodic VLF testing to determine the severity of the problem. Avoiding just a single CHP outage in this way saved more money in terms of lost production than the entire cost of installation.

The onset of PD can be seen in Figure 3 for cable CHP2-R2 over a one-month period when levels rose from 100 pC to 1,000 pC. Figure 4 shows the very clean PD pulse that enabled location of the PD. This highlights the benefit of continuous monitoring whereby trends in activity can be seen that would have been missed with spot measurements alone.

All three cables where PD was identified were successfully managed until their joint pairs were replaced during the planned outage 10 months later. The suspect joint pairs were sent for forensic examination.

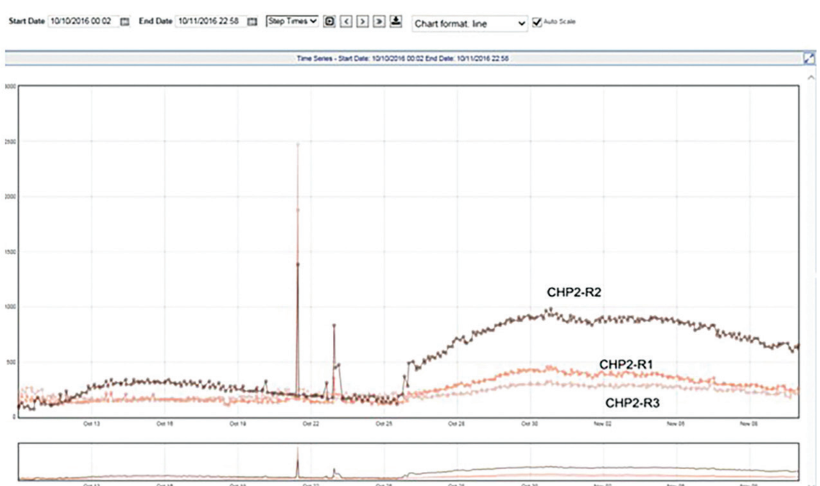

Figure 3: *Rapid Increase in PD in CHP2-R2*

Figure 4: *PD Current Pulse Recorded on CHP-R2*

Figure 5: *Partial Discharge Location*

During the forensic investigation, evidence of PD was found in one joint of the joint pairs when the outer heatshrink cover was removed from the cable stress control sleeve (Figure 5). The root cause was identified as an incorrect gap — only 1 mm instead of the recommended 5 mm— between the XLPE insulation and the connector. This prevented the yellow mastic from filling the gap properly, leaving a void that led to the elevated electrical stress responsible for the detected PD.

Example 3: Critical Infrastructure Building in Virginia

A large office building had full-time partial discharge monitoring installed due to the critical nature of its operations. Ultrasonic and TEV detection were provided for all cable termination compartments. An installation mistake common to all the potential transformer cables (Figure 6) caused partial discharge to be present almost immediately upon energization.

As seen in Figure 7, the cable was energized in early March 2017, and within a month, the ultrasonic level was already four times higher than other identical cabinets where the problem was previously corrected. During the next three months, the level increased to over 100 times that of the good cabinets.

Figure 6: *Improperly Installed PT Cables*

The cable was denergized after a few months, and the damage was similar to that shown in Figure 8. This image is from another cable that was previously damaged and replaced.

Figure 8: *PD Damage to PT Cable*

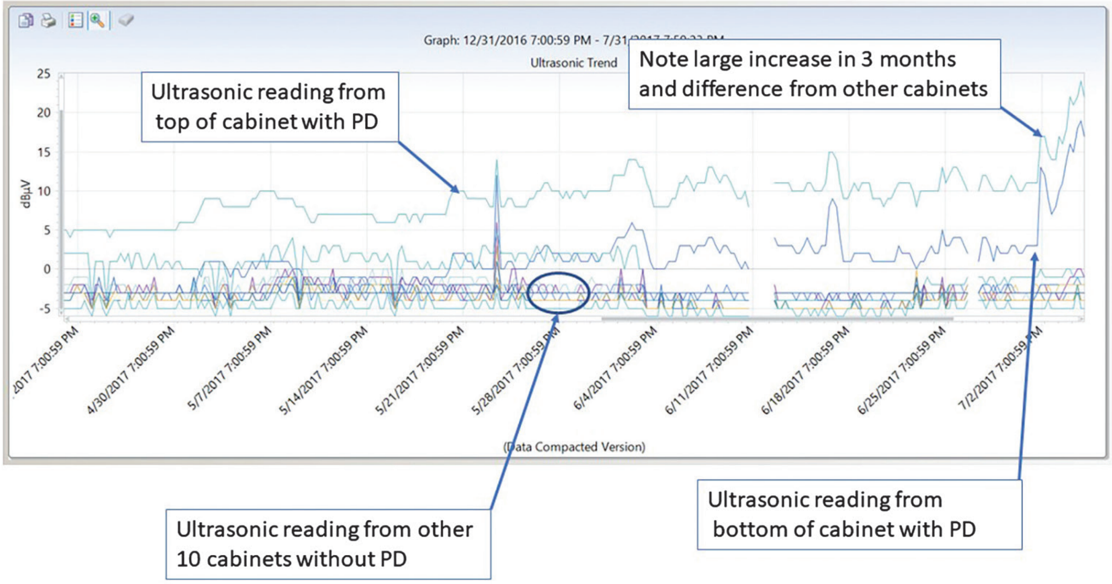

Figure 7: *Graph Showing Marked Increase in PD Signature*

DOES THIS MEAN PERIODIC SURVEYING IS DEAD?

Periodic testing is powerful and inexpensive, so it will take a lot to kill it. For assets below 2.5KV, periodic testing will always be more cost effective. Even for medium-voltage systems, it is the cheapest way to go.

When asset owners look seriously at the cost of outages and aging infrastructure, lowest testing cost shouldn't be the only consideration. Each asset failure has an impact, and the owner should do a risk and impact analysis before deciding what to do. For most applications, a mix of full-time monitoring on critical assets and periodic surveying on less critical systems will be the ideal route going forward.

WHAT'S INVOLVED IN FULL-TIME MONITORING?

Full-time monitoring systems roughly fall into one of two categories: invasive and non-invasive. Invasive systems require full shut-down and internal access to the cubicles. They are typically hardwired with sensors like coupling capacitors. These are capacitor dividers that are connected between the conductors and ground and have a test cable connection port. High-voltage (HV) wiring is required between the sensor and HV conductors. Low-voltage (LV) wiring is required between the sensor port and the electronics portion. A Hipot test is required after installation and before energization. Invasive systems are almost always permanently installed at the same time as the original system due to the work required to remove and relocate them.

Non-invasive monitor systems use the same technologies as handheld non-invasive test devices. These include ultrasonic detection and Transient Earth Voltage (TEV). The main advantage of these systems is that they can be installed on the outside of switchgear and do not require outages. Cable monitoring can be added to either system, but it does require access to the ground straps of the cables. Because of its ease of installation, non-invasive monitors can be removed and relocated periodically.

Either type of system can provide local or remote access. Local access is easier to install but does not provide instant response to emerging faults. Remote access with continual monitoring provides the additional advantage of allowing experts to analyze the data. The end customer (or the service company) does not need partial discharge expertise.

Going back to the wearable EKG monitor, would you rather try to interpret the charts yourself or have the data continuously streamed to the hospital where a doctor can analyze it?

WHERE DO TESTING COMPANIES FIT IN?

As MV asset owners make the inevitable move to more continuous testing, less periodic testing will be required. Additionally, if issues are caught before failure, fewer large repairs will be required. Testing companies that rely solely on testing and repairing failed equipment will suffer from reduced opportunities.

However, a testing company that evolves can still find plenty of opportunity. Designing, installing, and maintaining monitoring systems will need to be done. Responding to early indications of problems and making repairs in a timely fashion will increase as well. Testing companies would be well served to become familiar with monitoring systems and their installation and maintenance requirements.

A popular use for monitors is employing portable systems for several months and then removing or moving to another set of assets. This is a viable intermediate step to permanently putting monitors on all assets. Testing companies may want to purchase portable monitor systems and provide the install, remove, and relocate services as well as leasing the equipment to the asset owners.

One last gratuitous parallel reference to the 24/7 wearable EKG monitor: If they become inexpensive enough for everyone to have one implanted, and you are a medical technician who performs routine EKGs in a doctor's office, you might want to consider a new career. I hear jobs are opening in 24/7 PD monitoring.

William G. Higinbotham *has been president of EA Technology LLC since 2013. His responsibilities involve general management of the company, which include EA Technology activities in North and South America. William is also responsible for sales, service, support, and training on partial discharge instruments and condition-based asset management. He is the author or co-author of several industry papers. Previously, William was vice president of RFL Electronics Inc.'s Research and Development Engineering Group, where his responsibilities included new product development, manufacturing engineering, and technical support. He is a senior member of IEEE and is active in the IEEE Power Systems Relaying Committee. He has co-authored a number of IEEE standards in the field of power system protection and communications, and holds one patent in this area. William received his BS degree from Rutgers, the State University of New Jersey's School of Engineering, and worked in the biomedical engineering field for five years prior to joining RFL.*