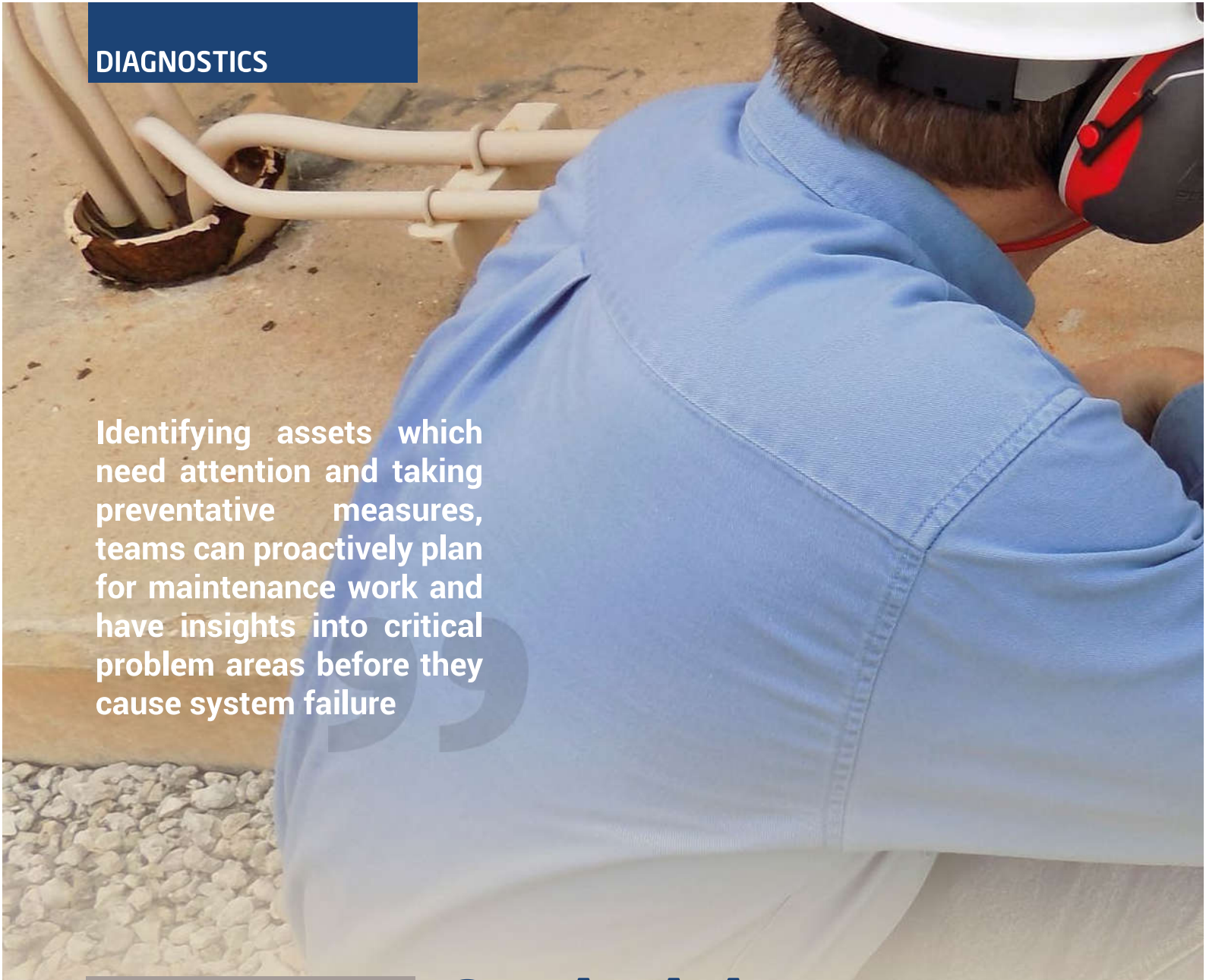

Identifying assets which need attention and taking preventative measures, teams can proactively plan for maintenance work and have insights into critical problem areas before they cause system failure

ABSTRACT

Outage planning is a critical consideration companies cannot spare to neglect. Identifying which assets need attention and by taking preventative measures to monitor the condition of your key assets, teams can proactively plan for maintenance work and have insights into critical problem areas before they cause system failure. This article will review partial discharge/electromagnetic interference in-service surveys, how to identify risks to your assets (like transformers) and share best practices to plan for your outages, ensuring both your asset's longevity and network health.

KEYWORDS

outage planning, in-service testing, condition monitoring, asset health and maintenance

Optimizing outage utilization for substations and transformers

In-service partial discharge/ electromagnetic interference surveying

1. Introduction

There is nothing more frustrating than an unplanned outage. Whether due to storms that cause downed power lines or unexpected asset failure, forced outages disrupt both the operations of power companies and the lives of customers who rely on electricity to keep the lights on and stay connected. Planned outages – those scheduled ahead of time for routine offline testing and maintenance – mitigate the negative impacts of these disruptions by carving out time for condition-based

maintenance and testing on important assets. Planning activities ahead of time ensures safe and reliable operations and identifies potential risks before they turn into problems.

PD/EMI (Partial Discharge/Electromagnetic Interference) surveying provides a set of tools to detect the symptoms of insulation breakdown – whether airborne radio frequency signals or conducted transient signals. PD and EMI are intimately related methods of detection, varying in frequency ranges and signal analysis approaches.

Both have value in particular applications and can use appropriate sensors to detect deterioration via:

- Antennae, as part of a general station

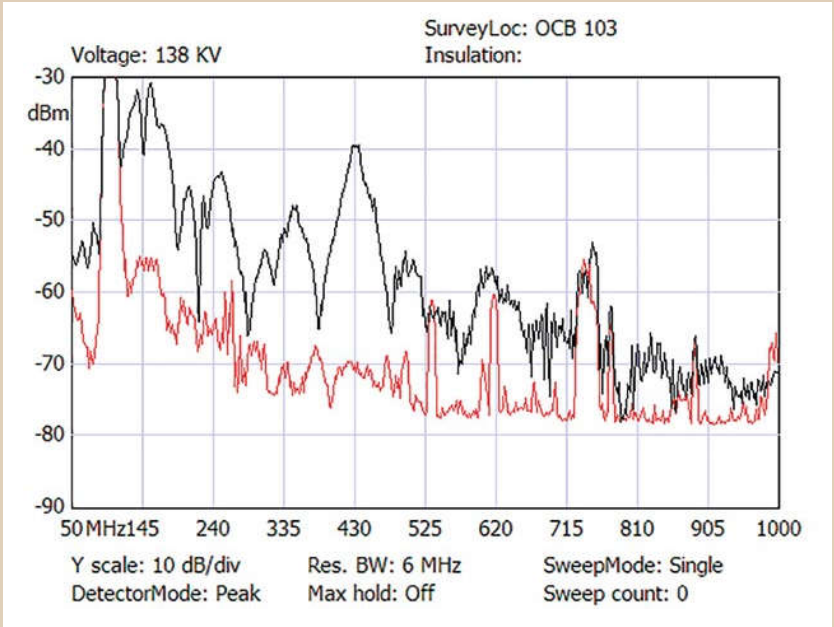

Figure 1. Variation in spectrum indicates change in state

PD/EMI surveying helps to detect the symptoms of insulation breakdown – whether airborne radio frequency signals or conducted transient signals

survey, with an optional directional antenna for more detail;
- High-Frequency Current Transformers (HFCTs) to detect PD/EMI in conductors which carry load or are grounded in service;
- Ground plane or Transient Earth Voltage (TEV) probes which pick up the effects of radiated emission ion grounded planes, such as metal clad switchgear cubicles.

This article dives into examples of issues found in practice and the organizational framework to enable a successful PD/EMI survey program.

2. In-service PD/EMI surveying

It is common to take PD/EMI recordings at several locations in a substation, in addition to a reference at a location where PD/EMI activity is likely to be low. In Figure 1, a baseline scan made at a substation as part of a regular routine survey is compared to a previous scan at the same location. The previous scan acts as a baseline, in red, and we see an uplift across a broad frequency range for the subsequent scan, from about 50 MHz up to 1,000 MHz. Such broadband activity is typical of a PD/EMI source and we can be confident that there is such a source in the vicinity. By comparing scans at other locations in the station, we can 'hone in' on where the source is likely to be and investigate in more detail.

Innovations in in-service testing tools and techniques give engineers access to critical health information so they can determine what needs to be addressed, effectively allocate resources and prioritize interventions to prevent future disruptions and failures. Through in-service PD/EMI, teams can:

- Make off-line inspections much more efficient, contributing to greater cost savings;
- Obtain detailed information about asset condition in advance of an outage, making the inspection and repair work more accurate, efficient and effective;
- Save time through condition-based surveying, allowing asset managers to immediately identify where the problem area is before taking a system off-line. In-depth testing of target areas gets to the root of an issue and solves it quickly.
- Reduce risk of in-service system failures through routine testing and identify developing problems. By knowing the status of assets while they are in-service, teams can proactively address potential problems before they lead to a forced outage.

It is common to make PD/EMI recordings at several locations in a substation, plus a reference at a location where PD/EMI activity is likely to be low

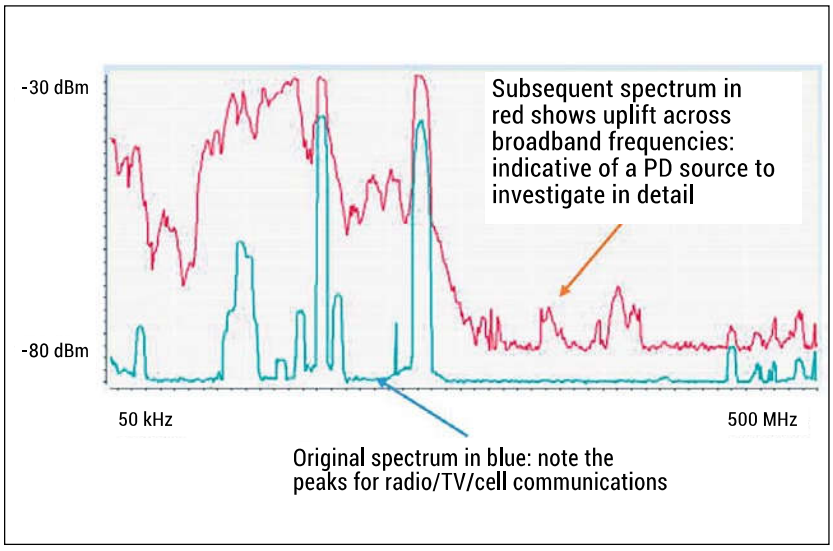

Figure 2. Spectrum in transformer neutral

3. Finding problem areas across an entire fleet: What in-service testing can do for you

In-service surveying means data is generated while systems are online with no interruption to asset operation. It gives teams the capability to examine asset health across an entire fleet and look at various stress points, including electrical and thermal performance under real in-service conditions.

With in-service surveying instruments, teams use the data they gather to proactively plan asset maintenance and prevent future failures identified with PD and EMI testing. These testing methods offer a more efficient way to conduct on-line testing to minimize outage times and return assets to service in a timely manner.

Examples of power transformer problems identified by substation PD surveys, confirmed through subsequent investigation and addressed to avoid failure, include:

- loose frame clamps and core bolts;
- selector problems or barrier board problems;
- internal connections and winding discharge;
- bushing and surge arrester issues.

PD surveys can detect possible problems early, allowing for actions to be taken before a failure occurs.

For example, a 300 MHz Radio Frequency Current Transformer (RFCT) can be used to pick up PD signals in a transformer neutral ground connection, as part of a substation survey making measurements at a range of locations and assets.

The variation in signal between the present spectrum and the previous spectrum, as shown in Figure 2, indicates that there is a PD source generating signals which can be picked up in the transformer neutral. The previous spectrum shows a number of peaks corresponding to local radio and TV stations, electronic components, and cell phones. The subsequent scan shows extensive 'uplift' in the measurement across a broad range of frequencies – indicating that there is a PD source in the vicinity, generating a signal which can be detected via the transformer neutral. By comparing with spectra from other nearby locations, the source of the PD can be investigated. A PD survey is the first line of defense in detecting, characterizing and diagnosing PD sources.

4. Four tiers for success: Inclusion in a condition-based maintenance program

Once problem areas are identified through PD/EMI survey, the next step is to develop a plan for resolving the issues. Teams often find categorizing maintenance plans into different tiers of responsibility escalates potential vulnerabilities to the right people. A tiered approach often includes four layers of examination:

- **Layer 1:** Technicians should inspect substations on a regular basis. Their toolbox typically consists of specialized infrared (IR) cameras and partial discharge tools to conduct visual inspections and take thermal images and radio frequency interface (RFI) spectra. If abnormalities are found, technicians will record findings, register the time and location and store it in a tablet. Should anything flag the technician's attention, the suspicions will be passed on to the next level.

- **Layer 2:** If an abnormal situation is reported, those responsible for the substation will do the first assessment of the findings. If the finding is caused by a temporary or minor issue, the case will be addressed and closed. If not, the findings will be escalated to level three.

- **Layer 3:** This team consists of maintenance engineers with condition monitoring and assessment experience. They are equipped with a broad range of tools both to locate the potential defect and do further assessments and measurements to uncover the criticality of the defect.

- **Layer 4:** If an abnormal situation reaches the last level, lead experts with extensive knowledge on transformers, circuit breakers and cables should step in to help those in Level 3 if they are not able to conclude on a finding. The approach is straightforward, but empowers teams to react rapidly and appropriately.

5. Planning to succeed

In one application scenario, an electric company needed more than 100 instrument transformers in continuous use inspected and assessed for suspected health issues. By using PD/EMI to survey the units, the team could detect many defects impacting asset health, even finding issues not commonly identified through traditional condition-based monitoring and testing methods, such as vulnerabilities in a cable joint.

In Figure 3, several scans taken at the base of several substation CTs are compared. Most of the traces overlay pretty closely, but one shows significant uplift across a broad frequency range. This is the CT, which is of most concern, and would benefit from a more detailed investigation.

> **If the scan shows extensive 'uplift' in the measurement across a broad range of frequencies, there is a PD source in the vicinity**

One other trace in Figure 3 is of interest. PD surveys are useful and have detected incipient problems on many stations – generation, transmission and distribution and industrial/commercial locations. Initial spectral analysis – comparing with spectra taken previously at the same location or at different locations on the same station – provides a very strong indication of PD sources and their severity. Deeper investigation may be taken through built-in tools, such as phase resolved PD analysis (PRPD) – which gives an indication of the pulse counts at different points on the reference power system waveform, and time resolved patterns to indicate repetition rates. Further analyses include offline testing to confirm the online diagnosis.

Conclusion

Systems fail and disruptions happen. Identifying which assets in your transformer need attention and by taking preventative measures and monitoring the condition of your key assets using PD surveys on electrical stations, you can proactively plan for maintenance work and have insights into critical problem areas before

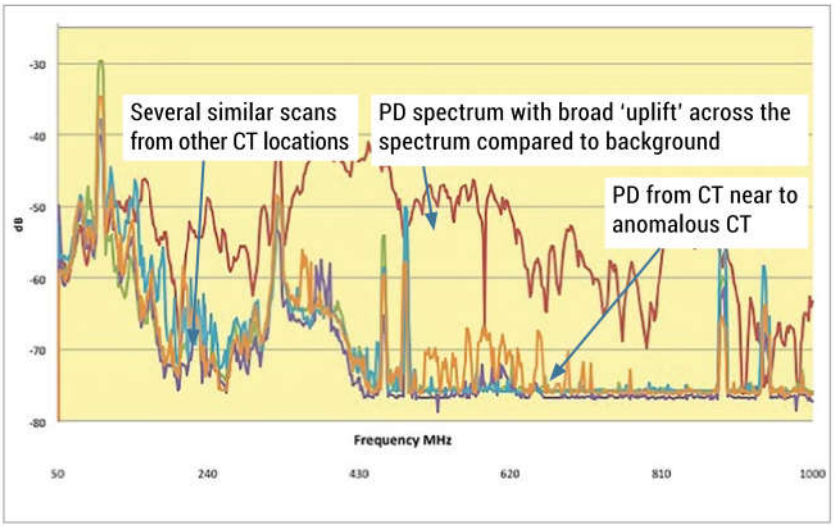

Figure 3. Survey data identifying anomalous CT

Figure 4. Survey being performed using a PD/EMI survey tool and HFCT

they cause system failure. Through these best practices with field proven PD survey tools, your forced outages can be reduced, resulting in shorter outage periods and improved network performance ensuring your transformer's longevity and network health.

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Using PD/EMI the team could detect many defects impacting asset health, even issues not commonly identified through traditional methods

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Tony McGrail is Doble Engineering Company's Solutions Director for Asset Management & Monitoring Technology, providing condition, criticality and risk analysis for utility companies. Previously Tony had spent over 10 years with National Grid in the UK and the US; he has been both a substation equipment specialist, with a focus on power transformers, circuit breakers and integrated condition monitoring, and has also taken on the role of substation asset manager and distribution asset manager, identifying risks and opportunities for investment in an ageing infrastructure. Tony is a Fellow of the IET, a member of the IEEE and the IAM, is currently chair of the Doble Client Committee on Asset and Maintenance Management and a contributor to SFRA and other standards at IEEE, IEC and CIGRE. His initial degree was in Physics, supplemented by an MS and a PhD in EE and an MBA. Tony is an Adjunct Professor at Worcester Polytechnic Institute, MA, leading courses in power systems analysis.