Sometimes asset health conditions change much more quickly than scheduled off-line testing can show

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A technical guide to condition monitoring: Where to begin?

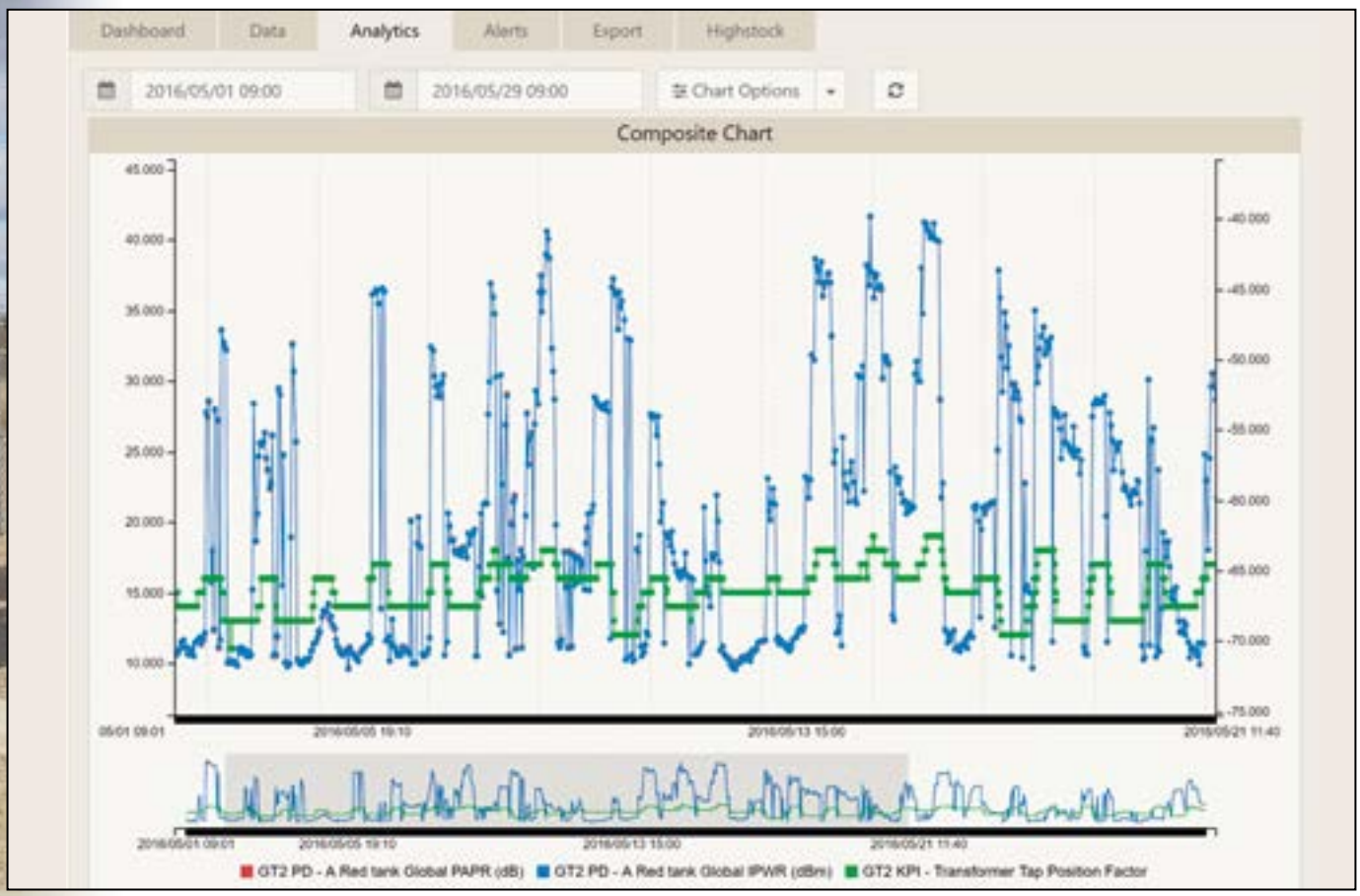
Introduction

When you own a transformer, it is often challenging to decide whether you have the data you need to confidently make critical asset health decisions. The very volume and variety of information at your fingertips – dissolved gases and load data, for example — can be overwhelming. You think you are looking at an important data trend that is going to help you understand the condition of a key asset in your fleet, but in reality, after thorough analysis and thought, you realize it does not really tell you anything useful. A spike in dissolved gas analysis (DGA) may reflect a bad transformer, but it could also indicate a load spike, a bad sensor or a communication glitch. You think you have found something "interesting," but how do you really know?

Condition monitoring provides near 'real time' information which supports both short-term condition decisions and long-term asset replacement plans. Condition monitoring can be a huge benefit – but you have to be prepared when that "interesting" data comes in: both how to deal with it and how to respond.

For successful condition monitoring, you need to be able to gather and analyze data from individual assets or stations. This means creating a scalable program that can grow with you as your needs and conditions change – the unit you are monitoring today may be different from the one you need to pay particular attention to a couple of years down the road, at which point you might need a comprehensive look at all transformers at that particular station.

By aggregating information across different transformers, you can data mine the larger set and seek out behavior that is not normal – the "interesting" stuff. It not only



Capturing and understanding the data: PD correlates with load

Condition monitoring practices should be based on answering one main question: What problem are we trying to solve?

simplifies the process, but also ensures real red flags are addressed quickly, even in between testing, maintenance and inspections, so you do not have to wait for a planned outage period to understand how your transformers are doing. A few questions condition monitoring can answer include:

- Has the condition of the unit changed significantly since the last maintenance period?
- Are there any signs of deterioration or a possible inability to perform a function that will require me to do something?
- Can I load this unit above nameplate for some period of time?
- Will this unit last another year or two, or do I need to consider replacing it?
- Is it even safe?

Starting out by asking the right questions will help you better understand what you need to do to overcome any transformer problem. Sudden increases in bushing leakage magnitude, for example, are key indicators for particular bushing types when they approach failure. This can be rapid – having a simple and actionable response plan ahead of time is required for a successful response.

A thorough condition assessment of all units before commencing a program is a great way to ensure that clear and present problems are addressed

Common transformer problems: What to do when you see these signs

Condition monitoring practices should be based on answering one main question: What problem are we trying to solve? Here are a few of the most common problems we see with transformers, and what teams should do when they see these failure signs:

1. **Sudden bushing failure.** This can often lead to transformer failure. Monitor, detect and plan for incipient failure.

2. **A through fault occurs**. Check monitoring with dissolved gas analysis and partial discharge (PD) and look for signs of other problems. It is also wise to plan for off-line testing, if necessary.

3. **Overloaded unit.** A winding hot spot could produce bubbles which may lead to failure. Monitor the temperatures and moisture levels, and use standards such as IEEE C57.91 for loading mineral-oil-immersed transformers to identify possible issues.

4. **Ineffective maintenance.** Given the number of insurance claims blamed on poor maintenance, conducting more off-line testing to assure condition would be wise before returning the transformer to service.

5. **Not understanding the data.** Many tests and monitoring data are available, and it can often be hard to ascertain what is most important and what each data point really means. If something looks strange, look for outside expertise to support you and make sure you are effectively analyzing the most relevant and critical information.

At a high level, if you are looking to monitor the overall health of a fleet, using gen-

Response and action plans should be agreed upon by asset management teams before a monitoring platform goes live

Planning ahead is much more effective than planning behind

eral monitoring mechanisms such as dissolved gas analysis and temperatures may be just what you need. On-line DGA is a great way to start, and very cost-effective, but it will not detect all problems — such as bushing or tap changer problems — and certain failure modes can occur without any warning. It is therefore a good idea to complement these strategies with other approaches that address known problems or failure modes. A thorough condition assessment of all units before commencing a program is a great way to ensure that clear and present problems are addressed.

For more comprehensive monitoring, consider bushing power factor/tan-delta, operational data including loads and temperatures (SCADA), partial discharge, on-line DGA and a means to correlate the data. This additional data will cover more failure modes and give teams more chances to detect incipient degradation and deterioration.

Transformers can fail from dielectric, thermal and mechanical issues – dielectrically not being able to withstand the voltage, thermally support the current or mechanically withstand the stresses of operational issues such as breaker operations and faults. If there are particular issues with a transformer, such as known suspect bushings or a tap-changer prone to rapid thermal deterioration – which is often due to poor maintenance — or a design susceptible to through faults, these should be identified with an initial condition assessment and managed through appropriate monitoring. Transformer failure rates can also be related to the specific design and depend on operation regimes. Every situation is unique, so make sure you understand the root cause of the problem before you go into fix-it mode.

What do I do with the data I'm collecting?

Hooking up various monitors for DGA, partial discharge and temperature will only get you so far. Teams also need to know what to do with the valuable data the equipment can provide. When the data comes in, being able to execute a detailed plan right away helps you:

- Ensure the information and alerts are going to the *right people*.
- Have peace of mind that the appropriate people know what the data and alerts mean.
- Understand what requires a response and how to respond.

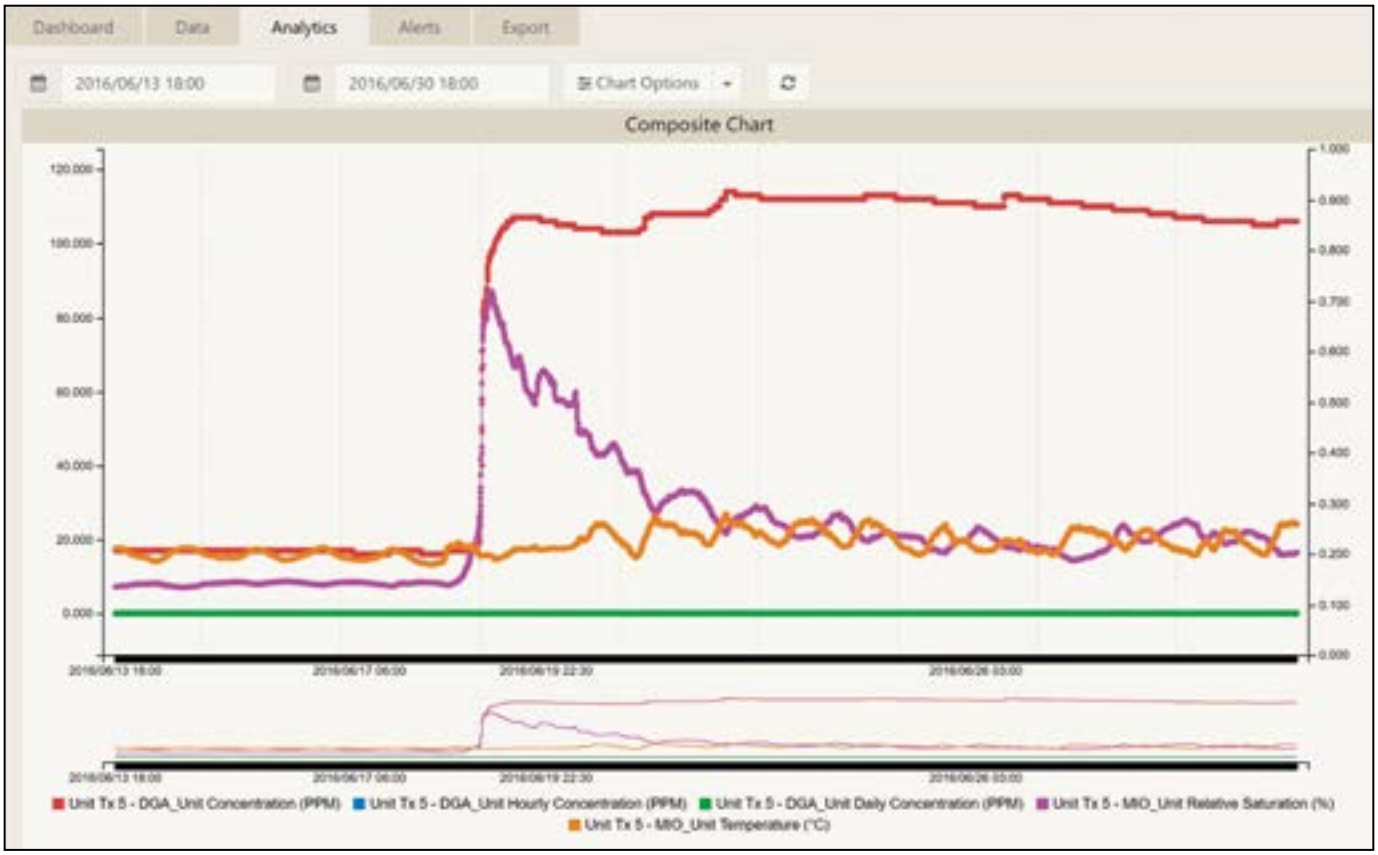
Response and action plans should be agreed upon before a monitoring platform goes live. Working out the details later makes things more confusing and difficult for everyone.

Condition monitoring best practices

To get the most out of a condition monitoring program and successfully prevent failures from occurring, there are a few best practices teams should keep in mind.

1. **Set clear goals.** Understanding what you are trying to accomplish through condition monitoring is a logical first step, and one that will set you up for lasting success. What is most important for your business: in-service failure preventing, life extension or maintenance deferral?

2. **Define parameters.** Identify what you want to measure to make sure you're on track with the goals you've outlined for your program. Does it make the most sense to do targeted condition monitoring for a known failure mode,



Composite data: DGA, relative humidity and oil temperature

or general assurance of asset condition? Make sure you choose a system that is proven to address these parameters.

3. **Communicate.** When the data comes in, the information and alerts need to go to the right people, and they need to know what the data and alerts mean so they can respond appropriately. Seems straightforward, but you would be surprised as to how many times this can impede teams from achieving success.

4. **Plan responses.** It pays to have a plan in place ahead of time. When the data indicates something is wrong, you do not want to be scrambling trying to figure out the best course of action. Understand what you need to know, who does it, and how soon it needs to happen before you get started with condition monitoring.

Sometimes asset health conditions change much more quickly than scheduled off-line testing can show. Having timely information on transformer condition at all times gives teams the power not only to target intervention activities and reduce costs associated with business interruption, but also to reduce operation and maintenance costs and avoid preventable failures.

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A failure rate of less than one percent a year is common, but when a failure does occur, the ramifications can be very costly and often last for quite a while. Effectively monitoring your fleet now can improve reliability and help prevent headaches and costly downtime down the road.

Author

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.