

Monitoring, Diagnostics and Condition Assessment What Is the Data Telling Us?

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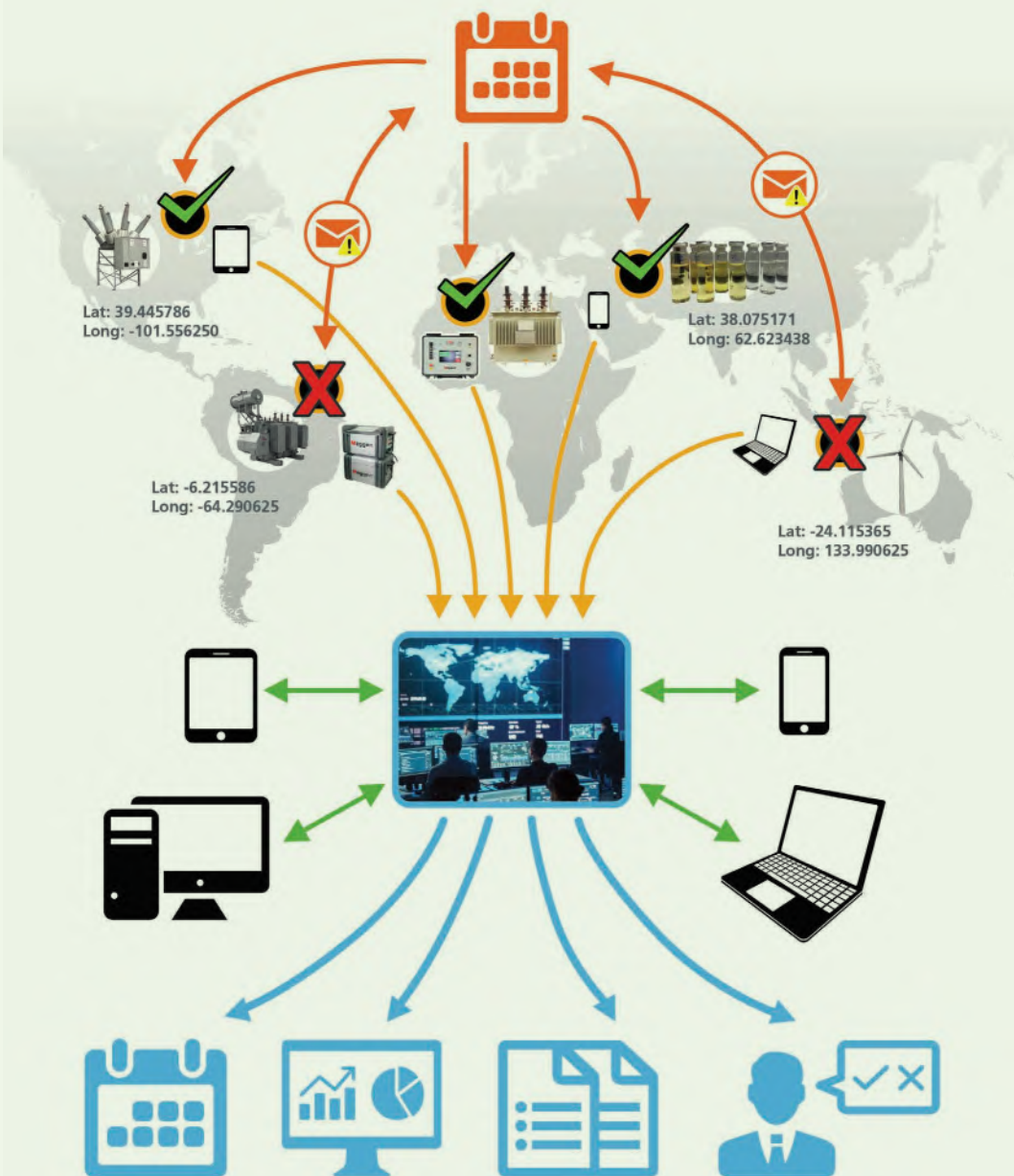
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Reliability of the system correlates with monitoring, diagnostics and maintenance of its assets. A chain is only as strong as its weakest link.

Monitoring, diagnostics and condition assessment of power and distribution transformers is a rather broad topic of discussion. Asset managers and field operations staff are challenged every day with the reality of a continuously aging infrastructure and growing loading profiles. Effective asset management solutions are rooted in the clear identification, acquisition, analysis,

storage, and management of test data obtained from offline, as well as online, monitoring and testing instruments.

Most field assets are not candidates for online monitoring. Therefore, a systematic approach to monitor and assess the condition of critical devices based on a secure data management system is paramount to the entire electrical industry.

In this article, the authors describe the methods for consistent, reliable, and efficient monitoring and diagnostics of critical electrical equipment including power, distribution, and instrument transformers, based on continuous data acquisition and expert engineering analysis. These methods culminate in notable technical and economic benefits for utility operators and service companies.

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Monitoring: A Good Starting Point

Asset management and operations & maintenance groups are intrinsically governed by an edict to maximize assets' ROI (returns on investment). Pressure to control OPEX money and extend the service life of assets has moved the gears from Time Based to the Condition Based Maintenance (CBM) process. Modern technology including power electronics, computer science, data processing, and high-speed data transfer, enable a much more efficient and cost-effective approach for monitoring, diagnostics, and maintenance programs than possible before. Today's modern technology allows monitoring, diagnostics, and CBM of almost every substation asset type, diverting unplanned shutdowns and emergency calls.

Every substation asset is critical and performs specific functions

in a continuous mode or under transient conditions. All these assets range from high voltage and high power to low voltage and low power, and they are part of the energy transfer, protection, control, or metrology schemes in a well-engineered network. Not all assets have the same high reliability or 40-year life expectancy as a power transformer. As reported by CIGRE TB 642 "Transformer Reliability Survey", the cause of failure of power transformers may not only reside inside the power transformer, but might be an effect derived from the failure of one of its accessories (bushings, tap changes, cooling system) or the failure of external assets such as instrument transformers, cables or grounding connections.

High-investment assets, such as transformers, are and must be monitored even before they start their service life. Manufacturing processes are monitored with rigorous Quality Assurance / Quality Control (QA/QC) procedures. The lives of critical network assets start from sound professional designs that consider the application, environment, and stressors that will be actively speeding up the asset's aging processes. Factory Acceptance

Test (FAT) records are the intersection of the Equator and the Prime Meridian (zero latitude and zero longitude). All offline testing is recorded and accepted by the buyer. At that point, monitoring has already started.

Asset management is a strategic science based on 'information'. Data management that renders the behavior and condition of network assets makes a better-informed operations team, now capable of making wiser decisions.



The 'Battlefield'

If you do not have the right tool and do not have a clear view of the 'battlefield', chances of winning this war are very slim. It is quite interesting to hear Alan Ross and his EPRA (Electric Power Reliability Alliance) friends discussing 'reliability'; an important topic often not well understood. Do asset managers look at the reliability of specific assets or do they scrutinize the reliability of the entire system? Of course, they prioritize the system. However, "a chain is only as strong as its weakest link."

If one decides to spend all available resources (time, technical, financial) on a single asset, good luck. Asset management is a strategic science based on 'information'. Data management that renders the behavior and condition of all network assets makes a better-informed operations team, now capable of making wiser decisions.

Remember: "no one else runs an operation like yours". Loading factors, environment, accessories, protection systems, etc. are uniquely yours. Consequently, knowing more about

the condition of the overall network and how each component presents risk to the reliable operation of the entire system is paramount. Reliability of the system correlates with monitoring, diagnostics, and maintenance of its assets.

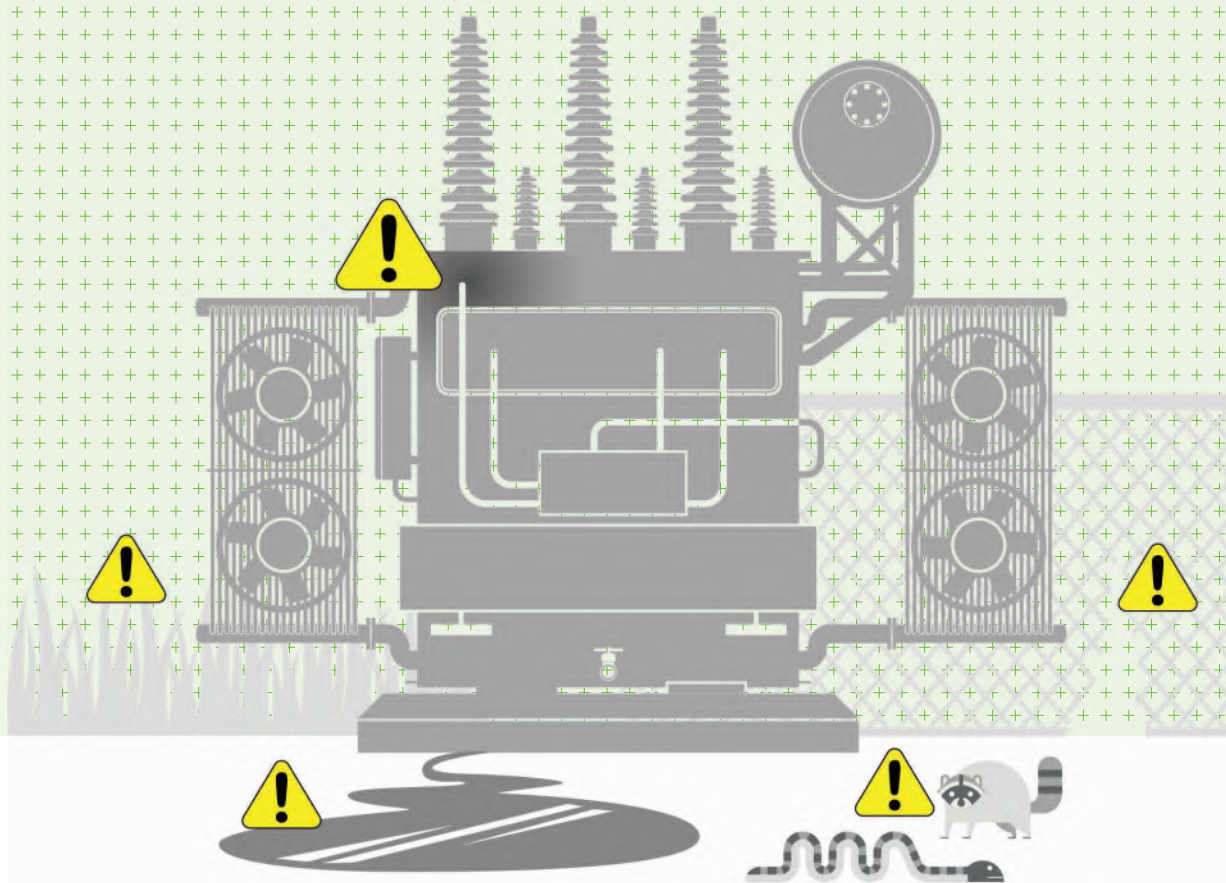
The lives of critical network assets start from sound professional designs that consider the application, environment, and stressors that will be actively speeding up the assets' aging processes.

Now the question is, how is monitoring carried out on all the network assets? A simple answer is through offline and online measures. High investment assets are very good candidates for online monitoring; others are not. Therefore, the best way to monitor the system altogether is by using a combination of both — offline and online — techniques so that all assets are considered in the reliability analysis.

Offline and Online Monitoring: The Ideal Combo

In the transformer industry, it is well-known that one single test may not be able to pinpoint fault conditions affecting the service life and reliability of the asset. A well-structured and properly supervised monitoring system involving a variety of offline and online (if available) test data is the ideal combo to better assess the condition of individual assets and the reliability of the entire system.

It is not a secret that many utilities operating in the electric industry will implement monitoring systems that will be later validated with offline testing procedures.



As mentioned previously, monitoring starts with a good set of FAT results. From the factory, the unit must be transported to its final destination, e.g., a substation. Therefore, the transformer has already been subjected to mechanical stress. Before start-up, must go through a commissioning and field acceptance process. This testing is fundamental to validate that FAT results have not changed during the transportation process, field assembly has not affected the integrity of the internal components, and contamination was avoided in this process. Testing also confirms that accessories have been assembled according to the manufacturer's and engineering specifications. Commissioning and field acceptance testing generate a baseline record, defining the 'state' of the transformer, before facing network load for the next forty years.

One of the most important, condition-indicating parameters to monitor throughout a transformer's service life is liquid insulation. Whether mineral oil or alternative insulating fluids are used inside a power or distribution transformer, liquid insulation serves many purposes including electrical insulation, cooling

of windings and solid insulation, and, not least, a trustworthy source of information. Conveniently, there is no need to de-energize the transformer. An oil sample is taken

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following the best ASTM or IEC recommendations, and is either tested on-site or sent to a lab for analysis. The most common testing practices carried out in the field are dielectric breakdown and dissipation factor testing. A complete analysis of the oil performed in the utility lab, or a lab of preference, will generate a trend covering physical and, chemical characteristics, as well as diagnostics metrics based on gasses dissolved in oil or other methods, including Furanic compounds quantification, and degree of polymerization estimation.

Data Management: We Know the Symptoms – Let's Run Some Diagnostics

There are two offline data acquisition approaches: rely on internal resources to perform testing or contract testing out.

In either situation, offline testing might be carried out with a variety of testing instruments of different brands and data capturing capabilities. One might imagine the inefficiencies of managing several reports in different formats, being manually added to a bigger database

wherein human transcription error becomes a factor. Thankfully, modern technology allows the transfer and conversion of offline test data into a single template that will allow the next important step in the process – Diagnostics.

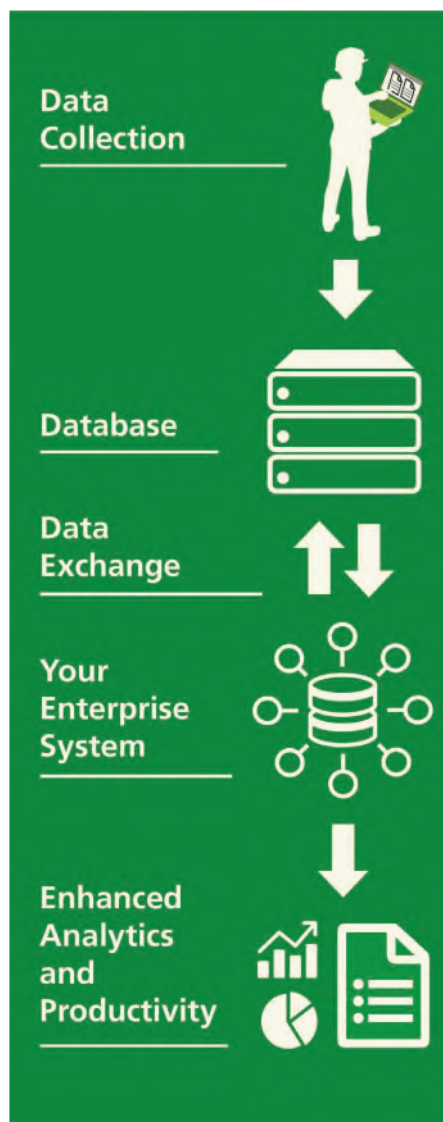
Now we step into the diagnostics section. Multiple tests carried out on a specific asset are far more revealing than a single test alone is. Each test examines a unique facet of an asset's health and, when thoughtfully grouped, provide a comprehensive view of the asset's present-day condition. In the next step, trending of critical information determines characteristic changes in the operation or the condition of a monitored asset.

Insulation data trending analysis, including line-frequency power factor, oil physico-chemical, dissolved gasses in oil, and insulation resistance testing, among the most relevant, has been a preamble for instantaneous condition assessment, additional investigation, and forecasting of maintenance activities. The testing program will be designed to ensure that, as far as possible, incipient faults are detected before they progress to failures and that assets are replaced when they have genuinely reached the end of their useful service lives, whether or not this coincides with the end of their nominal service lives. As well as the type of asset under consideration, the formulation of the testing program will acknowledge the criticality of the asset, the criticality of its function, and its operating conditions. Critical assets operating in severe conditions will, for example, be scheduled for the most frequent testing.

Once captured, test data is stored in a database, and the databases from multiple devices running should be synchronized into a single, central database for added security and to ensure wider accessibility. It is even possible to merge data imports from other sources – such as external databases – to aid analysis and trending.

The capabilities of advanced data management, however, go far beyond

Well-designed monitoring, diagnostics and maintenance programs must provide the tools to incorporate scheduling of activities and to correlate those with specific compliance state or federal regulations.



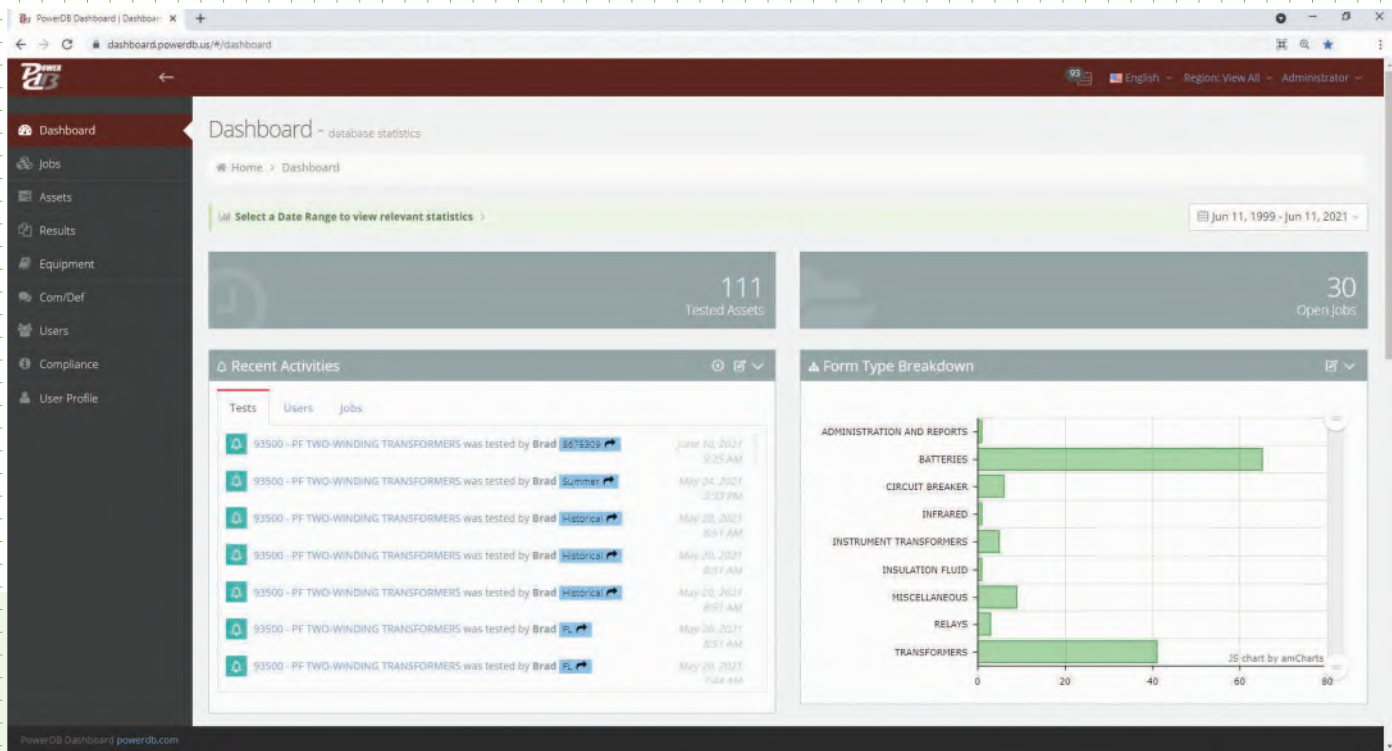
simply collecting, organizing, and storing data; although, these are the central elements of its functionality. Ultimately, the goal should be to create a system that allows for data analytics. The testing life cycle for these systems spans years. Therefore, to prepare data for analytical dashboard tools like PowerDB, Dashboard, or Tableau, several steps need to be taken to begin to create and maintain a quality data store.

Three key requirements for an effective program of regular testing are scheduling, consistency, and documentation.

To help ensure consistency in work practices and reports, and to provide an intuitive user interface, the database must provide dedicated forms for data entry, instantaneous and trending data display, and printed reports. As mentioned before, the battlefield is wide and many assets play an important role. It is not only important to have a good reference of a specific power transformer, but also fundamental to know the condition of its metering and protection devices, such as current or voltage transformers; other accessories mounted on the transformer, such as bushings and on-load tap changers (OLTC); and even better, if in the entire database there is information about circuit breakers, cables, battery banks, generators, motors, grounding system, capacitor banks and other substation components, which overall reliability of the substation is dependent.

Moreover, once these dedicated forms are chosen, a system must be in place to ensure they are used exclusively going forward. This is a common challenge when an asset owner uses a mix of internal technicians and one or more contractors to complete offline testing, but this can be accomplished by using a common testing database across all users. Little changes—like a variation in serial number entry or a change of units of a test result—do little to affect the outcome of a single test report. However, this can cause major headaches when mining the data for trending or other analytic purposes.

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An added benefit of a centralized testing database is that it can be configured to integrate with computerized maintenance management systems (CMMS). Enterprise-wide CMMS strengths are typically organizing all assets and scheduling maintenance activity. However, they fall short in facilitating the collection of granular test data. Integration between the two allows the CMMS system to focus on what it does best, without having to sacrifice the collection of the detailed test data. An ideal integration would have the work orders created in the CMMS system, flow into the Testing Database, and as the testing is completed, that CMMS would be updated with the key testing metadata. The Testing Data would then keep all detailed testing data for future trending and analysis.

The ultimate payoff of this system is the ability to use analytic tools for assessing asset health, trending like assets, auditing compliance and future scheduling.

Time for Action: Maintenance, Technical and Financial Decisions

As the symptoms are detected, a diagnosis is elaborated based on a variety of sources, and, of course, actions are expected from maintenance managers.

The decisions might be quite different: no immediate action required; maintain components as per CBM; prepare for major shutdown and a potential replace of components; or remove from service.

Maintenance activities are better when there is a process to plan them. Having enough time allows for a more convenient technical and financial solution, proper scheduling of specialists to perform the work, ordering of spare parts and tools, etc. Well-designed monitoring, diagnostics and maintenance programs must provide the tools to incorporate scheduling of activities and to correlate those with specific compliance state or federal

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regulations. In North America, an optional compliance view makes it easy to monitor compliance with NERC-mandated testing schedules or simply to track regular testing of assets or groups of assets. Users can create compliance categories and sub-categories and assign these to individual assets or groups. Powerful filtering capabilities then make it a simple task to determine the compliance or maintenance status of these assets or groups.

A wide range of analytical functions is available for processing test results. These include the generation of an asset 'health index' based on information acquired from multiple tests and failure studies that can provide revealing insights into the failure rates for a population of assets.

Carefully planned testing is undoubtedly the surest route to maximizing asset reliability, but it is only effective if the tests are carried out on schedule using prescribed procedures, and the results are properly organized, stored, analyzed, and reported. These requirements might seem onerous, but there are powerful software packages designed specifically to meet the needs of the electrical power sector, providing a complete and cost-effective solution. Simply put, a modest investment in software unlocks big gains in asset reliability. This, in turn, saves money and eliminates disruption!