Transformer health in the real world

Maximizing transformer reliability on a budget

JOHN VINES, BERNARD BANH, CRAIG STIEGEMEIER, POORVI PATEL, LUIZ V. CHEIM – Many companies that utilize transformers are seeing significant reductions in maintenance budgets and expert resources, as well as new, tougher regulatory requirements and higher expectations from shareholders. This new reality requires a fresh approach to equipment management – instead of maintaining the status quo, different methodologies must be implemented. Many transformer maintenance methodologies are currently time-based. Because some units simply do not need as much maintenance as others this approach can result in unnecessary maintenance. The answer is the much more efficient approach of condition-based maintenance. With this method, the units that need maintenance are prioritized based on risk and importance, and money is spent where it is needed most. So what techniques are used to make sure the maintenance is properly prioritized? The answer lies in data analytics.

1 Outdoor equipment is especially prone to power system and environmental stresses.

Companies tend to rely on the same equipment experts year after year to keep assets running → 1. However, many of these experts are reaching retirement age and are not being replaced. This reduction in manpower is part of an overall cost reduction trend that is also seeing maintenance budgets decreased.

Many companies would like to rely on monitoring and data analysis to fill these knowledge gaps. However, the amount and complexity of the data quickly overwhelms even the best-intentioned organizations. This has initiated a search for a way to handle the large amounts of data involved and compensate for the loss of expertise.

Transformer health index reliability issues

One option available is the transformer health index calculation. There are several approaches to this concept, the majority of which utilize a list of technical parameters that experts may classify as essential for transformer operation and health. A weight is given to each item on the list to indicate its relative importance. It is then a matter of assessing the condition of each parameter and assigning a score (eg, between zero and 100), multiplying individual weights by the respective scores, and dividing the result by the sum of all weights times the maximum score per individual parameter.

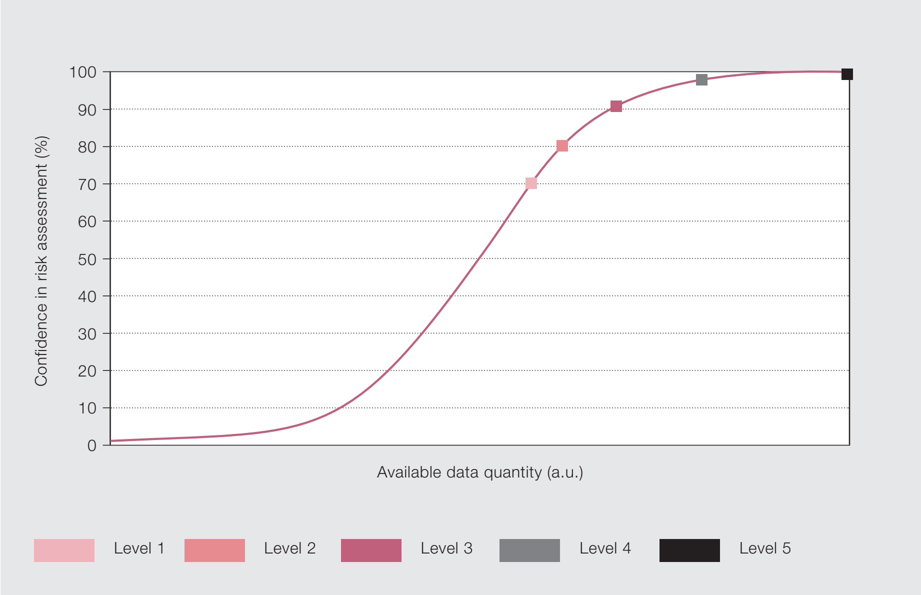
This approach has its disadvantages:
– The weights chosen by the experts are subjective and different experts may propose different weights.
– Poorly-chosen weights may easily overshadow the importance of other parameters or functions, consequently underestimating eventual problems with parameters whose weights are low.
– A robust sensitivity analysis is typically lacking – most approaches do not stress test the proposed solution to a point where real-life cases are tested and compared with the output of the procedure.
– Strangely enough, the method described will render the same output for any given selection of weights as long as all scores are at their maximum.

The ideal system includes a determination of the relative importance of the asset and the risk of failure.

Title picture
Approaching transformer maintenance in an intelligent way can reduce outlays and make better use of the dwindling numbers of experts. How can data analytics be exploited to achieve the best result?

It is important that the system provides recommendations and risk-mitigating advice to help keep the transformer healthy.

2 As available data increases, so does the confidence level of the assessment.



An ideal solution would be able to gather and analyze large amounts of data from many different sources. Flexibility is key here as data would come from many different types of sensors, monitors and systems. Whether it is hourly, daily, monthly or yearly, the data needs to be captured. Once organized, it should then be analyzed using expert algorithms that look at the system as a whole, not just at its individual parts.

Regular checkups

Comparing a person's year-to-year health checkups helps to spot any poor health developments and maintain well-being. The same approach has proven to be very effective for transformers. A transformer's condition needs to be assessed – information is collected, evaluated and compared with previous data in order to identify condition trends, then a diagnosis is made. The ideal system also determines the relative importance of the asset and the risk of failure. It is also important that the system provides recommendations and risk-mitigating advice to help keep the transformer in good condition.

Confidence level

The initial condition assessment must be very thorough and result in a risk-of-failure calculation for the unit → 2. Rather than simply creating a health index view of individual features and then adding them up, a better approach is to take advantage of transformer subject matter experts (SMEs) to assess functional aspects of the transformer, along with taking a view of the entire picture.

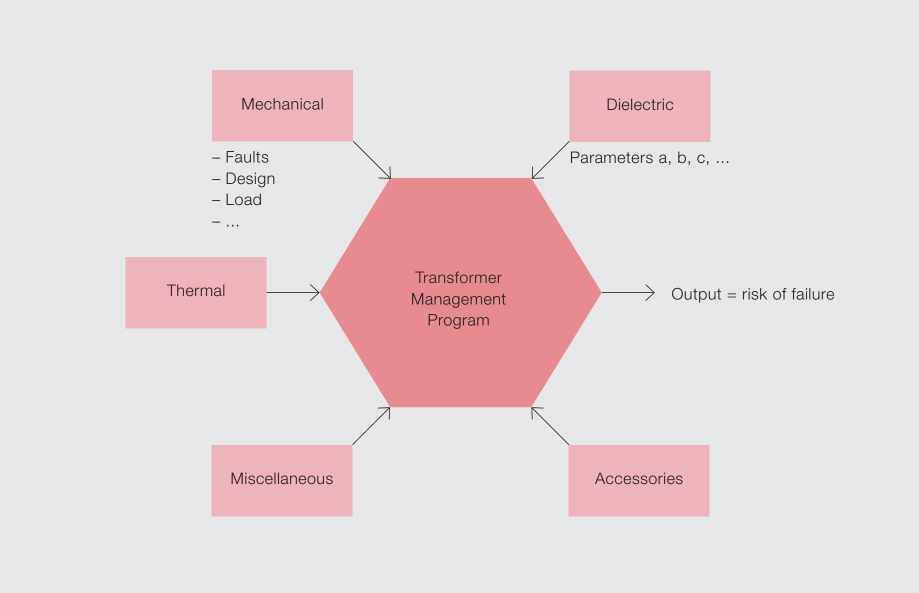
As a start, the following data should be collected:

- Nameplate information, dissolved gas analysis (DGA) and oil quality parameters
- Loading, transformer turns ratio (TTR) and insulation power factor
- Bushing – capacitance and power factor, porcelain condition, thermal scan, oil level, and type and vintage
- Load tap changer – type, maintenance data, DGA and condition

To handle the constantly changing data, ABB developed the Dynamic Transformer Management Program.

- Cooling system and oil preservation system condition, tank oil level, and age of accessories
- Tank integrity, leaks, rust, paint, main cabinet condition and controls
- Protection (Buchholz relay, arresters, pressure relief, etc.) and product history.
- Sister unit failure data, design and reclosing practice

3 Mature Transformer Management Program approach based on functionality



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- Special test results such as furan testing, degree of polymerization (DP), field-induced voltage test, sweep frequency response analysis (SFRA), dielectric frequency response (DFR), etc.
- Geomagnetically induced currents (GIC)

The data collected can be analyzed by ABB's Mature Transformer Management Program (MTMProgram™). The MTMProgram groups data into five functional groups – thermal, mechanical, dielectric, accessories and miscellaneous – to provide a complete condition assessment → 3–4. Reliability improvement recommendations are made for individual transformers. The main transformer functions covered include typical stresses, network solicitation, and short-circuit, thermal and dielectric capabilities.

The approach establishes a close connection between the most stressed conditions, the requirements for each individual transformer and the contribution of individual parameters to achieve that functionality. It then calculates the risk of failure for each of the specified transformers in the fleet. After more than a decade and close to 10,000 transformers assessed globally, this program has proven to have benefits for many end users of transformers in different applications.

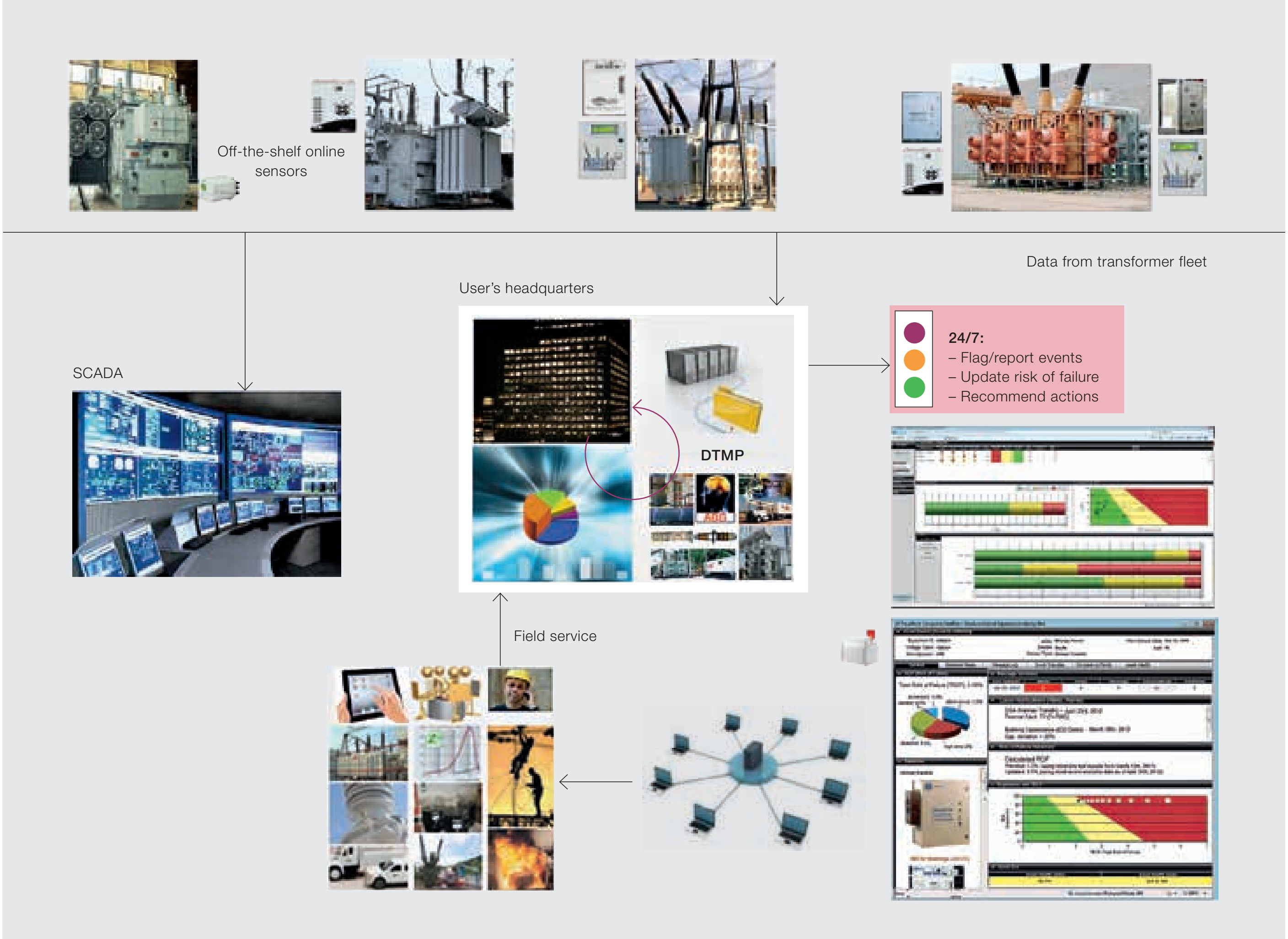
The program provides a one-time snapshot of the transformer's overall health. Therefore, as conditions change or new data is added, the risk of failure and maintenance or operation recommendations need to be updated daily. To handle the constantly changing data, ABB developed the Dynamic Transformer Management Program (DTMProgram™). The algorithms employed by the DTMProgram are able to analyze each of the functional aspects of a transformer then aggregate these into the five functional areas used by the MTMProgram. An expert system algorithm is then able to look at a transformer as a whole instead of at its individual components, as a health index would → 5. This expert system operates on a fleet-wide basis and is also capable of looking for cross-correlations among any issues found on the transformer.

ABB SMEs have also created algorithms for batteries and breakers using an approach similar to that described above. Many more algorithms are under development to support other critical assets throughout the industry. The key to the success of these algorithms is the utilization of SMEs during the design phase. The transformer algorithms are very flexible and can be integrated into multiple software platforms. No matter what the data sources and existing software systems are, there is a solution to support a condition-based maintenance approach.

Asset Health Center – further solutions

One of these further solutions is Asset Health Center (AHC), which incorporates ABB operational technology (OT) subject matter expertise and ABB information

4 Dynamic analysis of transformer data



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technology (IT) software knowledge to provide the latest online offering in fleet condition monitoring.

After a baseline assessment, the software uses online sensor data and/or manually entered traditional offline test data to perform automated condition assessments on a daily basis, and provide expert recommendations based on that analysis. Also included are condition monitoring, risk of failure, trend analysis, family comparisons, email and SMS alerts, reporting options and fleet scalability inputs.

Straightforward and easy-to-use dashboards allow users to see the transformer fleet health at a glance. Using traffic light indicators (green, yellow and red) users can quickly identify the units or areas that need more attention so maintenance budgets and resources can be allocated to where they are most needed. Most importantly, this helps avoid unplanned outages. The interface allows the user to drill further down into the information – down to a single transformer's sensor information – if needed. When conditions start to deteriorate past a predefined point, users

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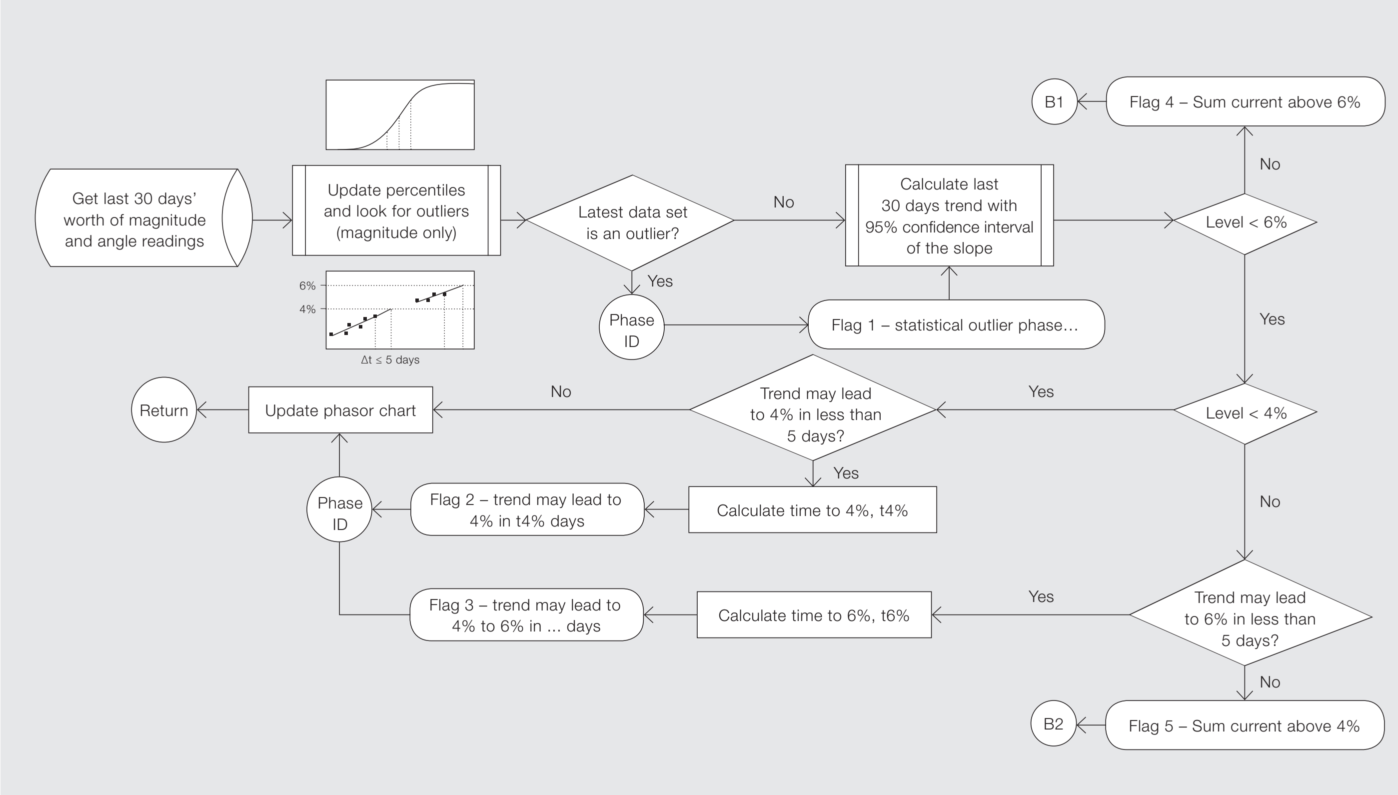
5 Example of an online performance model



can be automatically notified of the issues via email or SMS alerts.

Aging assets, rising energy demand and the critical need to avoid unplanned outages are challenging utilities and industries around the world. While financial constraints are reducing maintenance budgets and expert resources, demand for increased return on investment is undiminished. Maintenance managers facing these demands should utilize assessments, sensors, data analytics and software to adapt to condition-based maintenance planning. These methodologies can provide a much better understanding of asset risk and strengthen the confidence level of the actual condition as power equipment ages.

Avoid failures, increase asset reliability and predictability

The ABB DTMProgram expert system algorithm provides recommendations to optimize the maintenance and operation of transformers. By prioritizing maintenance, budgets can be concentrated where needed. Failure avoidance and risk mitigation with condition-based maintenance, structured and prioritized replacement plans, and the use of sensors for near real-time data delivery all allow the industry to maximize the return on transformer assets by ensuring high reliability, reduced life-cycle costs and optimized overall performance. The result of this data analysis helps create a prioritized list of maintenance actions for the entire fleet. Avoiding unnecessary service on assets in good condition and focusing attention on more risky assets with higher importance will satisfy shareholders and support adherence to new regulatory requirements.

The key to the success of these algorithms is the utilization of subject matter experts during the design phase.

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