Intelligent maintenance decisions with ABB TrafoAssetManagement™ – proactive services

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ABSTRACT

Transformers are indispensable components of mines and big industrial plants. The consequences of a transformer failure can be catastrophic. This is why operators demand high availability and a rapid recovery time after an outage. With an aging fleet of transformers and tight maintenance budgets, transformers remain in service well past their optimal life spans. The assumption that all are fit for an extended working life can be a dangerous gamble. When it comes to transformer asset management, an operator’s main objectives are to reduce the risk of a failure and minimize the impact if a failure does occur. ABB’s TrafoAssetManagement™ approach provides just the support operators need to make intelligent maintenance decisions to face these challenges.

Operational managers require special tools to support their strategic and day-to-day decisions, which address the above challenges and result in the right maintenance actions at the right time. Here, a clear trend has emerged: Managers are moving from using time-based maintenance to implementing condition-based maintenance, where decisions are no longer driven by an average timeframe defined by past experience and observations, but instead take into account the actual condition of the equipment and the level of reliability required to fulfill its function. TrafoAssetManagement supports this trend by focusing on three elements: analysis, risk assessment, and planning of maintenance actions based on asset management scenarios.

ABB TrafoAssetManagement provides operators with the information, expertise and maintenance tools they need to face the challenge of managing their transformer fleets. The result is improved asset management and lower risk of unexpected failures. In addition, the comprehensive range of data collected, from design to condition assessment, helps reduce the impact of a failure by enabling the transformer to quickly return to normal operating conditions. By performing proactive maintenance based on the TrafoAssetManagement method, operators benefit from a lower risk of loss of production and revenue.
INTRODUCTION

Power transformers, which are often the most valuable asset in a plant, are indispensable components of high-voltage equipment for power generation plants, transmission systems and large industrial plants. Unexpected failures cause major disturbances to operating systems, resulting in unscheduled outages and power delivery problems. Such failures can be the result of poor maintenance, poor operation, poor protection, undetected faults or even lightning (figures 1 and 2).

Figure 1 A nearly catastrophic failure damaged a transformer

Figure 2 The transformer (figure 1) has been remanufactured to a fully functional status
Outages affect revenue and can cost a company its reputation and its customers. The operating costs of power transformers provide ample incentive for companies to ensure reliability and availability throughout the life cycle of these key assets. Power Transformers cost anywhere from $1 million to $4 million, and on the rare occasions they do fail, the financial impact can be even more significant – in extreme cases, they can leave a company facing financial ruin. Although transformers are regarded as highly dependable equipment, the world’s current transformer fleet is quite old. The average age for those in industrial plants is 30 years, and 40 years for those used by utilities. The failure rate of aging transformers as well as their replacement and repair costs are steadily – albeit slowly – increasing. Figure 3 shows the development of the failure rate of transformers.

Figure 3 Development of the transformer failure rate in three different applications

METHODOLOGY

Operational managers require special tools to support their strategic and day-to-day decisions, which address the above challenges and result in the right maintenance actions at the right time. Here, a clear trend has emerged: Managers are moving from using time-based maintenance to implementing condition-based maintenance, where decisions are no longer driven by an average timeframe defined by past experience and observations, but instead take into account the actual condition of the equipment and the level of reliability required to fulfill its function. TrafoAssetManagement supports this trend by focusing on three elements: analysis, risk assessment, and planning of maintenance actions based on asset management scenarios (Figure 4).
The design data, the information in the installed base system, the results of the condition assessment and the maintenance history provide ABB with a 360-degree view of a transformer fleet. This data plays a pivotal role for ABB in the assessment management process. Not only is it important for minimizing the risk of failure, but it also provides valuable information for initiating maintenance work should a problem occur – that means quick maintenance and short downtimes.

**Design analysis**

ABB has access to original designs for more than 30 legacy brands including ASEA, BBC, GE, Westinghouse and other predecessor technologies. All new ABB transformers are built using the same design concept, which incorporates standardized, service-proven components and modules, ensuring flexible, dependable and adaptable transformer designs.

**Historical review**

ABB’s installed data system monitors a wide range of the company’s products. A plethora of data on transformers is available and is continuously updated, e.g., current owner details, and history. The system provides an important basis for the proactive detection of problems. For example, an analysis revealed about 700 potential cooler problems in the installed base of transformers. The search focused on 10 to 600 MVA transformers that were over 20 years old and had oil- and water-type coolers. Many failed completely due to leakages in these cooling systems, and one such failure resulted in a three-month production shutdown and lost revenue for the operator. Using the
information in the installed base system, operators are contacted proactively and the systems are checked regularly.

**Transformer monitoring**

Transformer monitoring is becoming an essential component of transformer management. It serves as an early warning system for any fault developing in the main tank and in the accessories, allowing an operator to evaluate the severity of the situation. Multiple transformers are connected to the operator’s network and can be monitored from a local control room or from remote working stations. Sensors measuring dissolved gases, moisture in oil, oil temperature, load current for each unit, and ambient temperature send data to the system via analog signals. The interface provides exact status information by generating a model of the transformer and its working condition and then comparing the measured parameters with the simulated values (Figure 5). The six most important groups of factors monitored are: Transformer temperature, Transformer Loading, Overload capacity, Tap-Changer functionality, Gas and moisture content as well as the Cooling control. Discrepancies are detected and potential malfunctions and normal wear in the transformer and its ancillaries are indicated. The monitoring system also tracks transformer alarms, recording an actual event as well as the sequence leading up to the alarm to assist operators in determining the root cause. The benefits of monitoring are substantial. A CIGRE study has shown that transformer monitoring can reduce the risk of catastrophic failures by 50 percent (CIGRE 2004). Furthermore, it has been shown that early detection of problems can reduce repair costs by 75 percent and loss of revenue by 63 percent, and that annual cost savings equal to 2 percent of the price of a new transformer can be achieved (Boss et al. 2000).

![Figure 5 Transformer monitoring interface showing real time status of important parts of a transformer](http://tec2.vbetheat.as/)

*Figure 5* Transformer monitoring interface showing real time status of important parts of a transformer
The strength of ABB’s Transformer Electronic Control monitoring system is that it receives all the relevant information from just a few multipurpose sensors. Other necessary parameters are calculated, adding only minimal complexity to the transformer. The end user receives important information indicating the necessary actions for first-level maintenance, and the time spent sorting and interpreting data is reduced.

**Condition assessment**

ABB is a pioneer in highly customized condition assessment offerings. Its MTMP (Mature Transformer Management Program) is a state-of-the-art minimally invasive condition assessment process used to evaluate every power transformer in a customer’s fleet and to identify which units need to be replaced or refurbished and when. This process is implemented in several steps (Figure 6 and 7). It starts with a high-level fleet assessment based on easily accessible data, such as unit nameplate data, oil and dissolved-gas-in-oil data, load profile and history of the unit (transformer fleet screening; Figure 6). Next, a subset of the transformers identified in step one are examined (transformer design and condition assessment; Figure 7). Modern design standards and tools are used to evaluate the original design, and advanced diagnostic tests are performed to assess each of the principal properties of the transformer in a structured way. These include mechanical status, thermal status (aging of the insulation), electrical status of the active part and the condition of the accessories, such as tap changers, bushings, overpressure valves, air-dryer system, pumps and relays. The number of units identified for further analysis is typically limited to two or three out of a population of 100. At this stage global experts analyze the units using simulation tools. Detailed data is then sent to the end users’ operational managers, proving concrete information about whether a transformer can be overloaded, its nominal power or voltage rating increased or its lifetime extended (Boss et al. 2002).

**Risk assessment**

The risk assessment shown in Figure 6 is based on two variables. The first, risk of failure, is estimated using the input from the analysis phase, i.e., age or time in service, transformer’s nameplate data (kV, MVA, BIL, etc.), application and loading practices, operational problems or issues, latest field-test data (e.g., dissolved gas and oil analyses), availability of a spare transformer and spare parts. The second variable is the importance of a transformer in a network, indicating how much of the operator’s system will be out of service if a particular transformer fails. By comparing these two variables, different levels of urgency for maintenance actions can be defined. The asset manager can then ensure that maintenance of high-risk transformers is prioritized (Figure 7).
Figure 6 Transformer Fleet Screening (of the whole transformer fleet) provides a risk assessment

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<th>Plant 1 – Results of condition assessment and action plan</th>
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Figure 7 Transformer design and condition assessment (of a sub-set of high-risk transformers) suggest concrete actions for each transformer

Asset management scenarios

The risks for a transformer operator include not only the inherent technical risks but also the economic consequences of a possible fault, e.g., the cost of non-delivered energy. With this in mind, ABB and a large operator co-developed an economical model that evaluates the life-cycle costs of a transformer fleet over a given period. The model takes into account four categories of costs related to the cost of ownership over the lifetime: investment, maintenance, operational and consequential.
costs. Comparative investment scenarios and sensitivity studies can be run by varying the replacement year or maintenance of the unit. For each scenario, the process shows the associated net present value. An optimization routine can also be used to automatically minimize the life-cycle costs of the population. The process outputs a list presenting the optimum time to maintain or replace the individual transformers or transformer groups. The net present value of the whole population of transformers is determined by looking at the condition of each unit and the maintenance actions selected to improve their condition. The operational manager can then evaluate different maintenance scenarios and obtain a summary of the payback of planned maintenance actions. The novel aspect of the method is that not only are maintenance costs considered but economic benefits related to the impact of maintenance on reliability are considered as well (Lorin 2004).

Factory - & On Site – Repair: Case example

When needed ABB offers state of the art factory repair services –as shown by the following example for a Copper mine in Peru:

“ABB’s Transformer service repaired a damaged transformer in three weeks enabling the customer to continue to run at full speed. The emergency call from a customer confirmed he had two transformers burned on his production process line. During the revision of the transformers in the ABB plant, it was verified that the dielectric fluid of the transformer was MIDEL – a brand only available in Europe. After extensive searching and hard work by the logistics area and the supplier, getting the fluid shipped from Europe in a very short time was possible. An engineering and operations team was appointed to work on the emergency. The team designed the isolating system based on material available from current stock. This contributed to the reduced lead-time. In just 21 days, the transformer repair and transportation to site was achieved, in comparison to the alternative of a new transformer which has three months ex-works delivery time. The customer was relieved the transformer was back in working order in just three weeks.”

ABB on site repair is achieved by bringing the transformer factory setup to the work site. This is done by mobilizing special equipment and tools needed to perform any scope of work, from refurbishment to replacing all windings, which are manufactured in transformer factories under strict quality standards. An ABB onsite repair fulfills exactly the same quality standard as an ABB workshop repair. Such repairs have been done in many countries, on more than 400 transformers - on site repair has saved utilities and industrial users millions of dollars by reducing downtime by up to several weeks, in installations where production losses are worth hundreds of thousands or a million dollars per day. Due to significant progress in power electronics, new compact high-voltage test systems are now available. Therefore, most of the high-voltage laboratory tests can be performed on site, including applied and induced voltage tests with partial discharge measurements, heat run and impulse tests. These tests can also be performed as an extra quality check on new units after transportation and installation, as a preventive measure within a
condition assessment study, or to troubleshoot after a failure to identify and localize a defect, in order to reduce outage time during a repair.

Implementation & Training

The ABB TrafoAssetManagement method and its tool are implemented in close cooperation with the contact persons at the customer sites. In order to support site managers and operational managers in their strategic and day-to-day decisions, ABB offers extensive training programs in order to improve the knowledge on the specific characteristics, data and application of power transformers, protection and tests. Main contents are: Design Parameters, Construction Rules, Basic Design, Operation Rules, Overloading, Cooling, Economical Aspects for replacement, Tests, Optimization and Management of the Energy Flow, Regulation of Active and Reactive Power Flow, New Trends and Developments, Life Time Prolongation of Power Transformers, Test method for oil analysis, Advanced diagnostic methods, Interpretation of the results, On-Line Monitoring, Sensors, Data Acquisition, Transformer accessories, Oil cooler, Oil pump, Fans, Bushings, Maintenance and Repair, Periodicity of controls, On-site maintenance activity, Repair-Technology, Economical analysis of a transformer population & Economical justification of maintenance programs, Treatments on oil and windings, Filtration technique for oil, Winding drying with low-frequency heating.

DISCUSSION

Not knowing the risk structure of its fleet, a company tends to overspend on its low-risk transformers and underspend on high-risk transformers. Overspending on low-risk transformers is a high-risk procedure: Approximately 30 to 50 percent of maintenance activities are unnecessary (IEEE 2007). But needless maintenance work can be avoided by implementing regular fleet assessments. The use of preventive or predictive maintenance is improving the transformer economy, which has been challenged by the limited maintenance resources associated with utility deregulation. Focusing the personnel and capital resources to the prioritized needs – with the priority based on the condition assessment ranking – can provide improved reliability at a fraction of the cost of traditional time-based maintenance programs.

The benefit of a condition-based maintenance approach is the optimized use of time and resources, which results in increased fleet reliability. Much more of the maintenance budget is concentrated on the transformers that show a high risk of failure or are of high importance in the network. These transformers are maintained proactively in order to lower the risk of an unexpected failure. The economic advantage related to preventive maintenance work and corrective actions can also be expressed in terms of extended life of the transformer assets – this is achieved by eliminating failures that might have occurred due to the lack of timely critical maintenance. It is estimated that
life extension of five to 15 years can be achieved with properly focused preventive maintenance programs.

CONCLUSIONS

ABB TrafoAssetManagement provides operators with the information, expertise and maintenance tools they need to face the challenge of managing their transformer fleets. The result is improved asset management and lower risk of unexpected failures. In addition, the comprehensive range of data collected, from design to condition assessment, helps reduce the impact of a failure by enabling the transformer to quickly return to normal operating conditions. By performing proactive maintenance based on the TrafoAssetManagement method, operators benefit from a lower risk of unexpected failures as well as loss of revenue.

The importance of assessment management and proactive services based on condition assessments of transformers is paramount due to the increasing average age of the worldwide transformer fleet and the more demanding conditions regarding quality of uninterrupted energy delivery. ABB’s integrated modular asset-management approach provides a clear picture of the risk structure and the maintenance required to deliver needed asset reliability and availability. This allows operation managers to make the best use of maintenance and replacement budgets, allocating funds to high-risk units.

By reducing the risk of failure within given financial constraints and by minimizing the impact of a failure when it does occur, ABB’s TrafoAssetManagement is providing a powerful service.

ABBREVIATIONS

CIGRE Conseil International des Grands Réseaux électriques (www.cigre.org)
IEEE Institute of Electrical and Electronics Engineers (www.ieee.org)
kV kilo Volt
MVA Mega Volt Ampere
BIL Basic Impulse Level

REFERENCES