Power transformers are valuable assets, and companies – utility as well as industrial – have every incentive to keep them running reliably for as long as possible. Many transformer fleets, however, are approaching the end of their design lifetime. TRES is a Transformer Retrofit and Engineering Support portfolio, developed by ABB, which lengthens unit lifetime and optimizes transformer performance through higher availability. Reliable life assessment surveys let customers prioritize service work in a way that ensures maximum economic benefit.

Dedicated solutions for managing an aging transformer population

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Looking for a higher return on fixed assets is part and parcel of electric utilities', and the rest of industry's, everyday business. Deregulation of the energy market and increasing pressure to reduce costs are forcing managers to continually look for ways to reduce the life cycle costs of their installed assets and improve return on investment.

The situation is especially acute in the case of power transformers. A large proportion of the worldwide population is nearing the end of its lifetime, and means are urgently required to optimize transformer fleet performance through higher availability. This has to be achieved at the lowest possible cost and with minimum environmental impact.

ABB developed the Transformer Retrofit & Engineering Support (TRES) portfolio 1 to provide customers with a complete range of service solutions that meet this need by ensuring optimized operation of power transformers over their lifetime. TRES benefits from an experience base leveraged from ABB's worldwide transformer fleet as well as a global presence that enables us to get transformers serviced and quickly back on stream.

The cost of failure

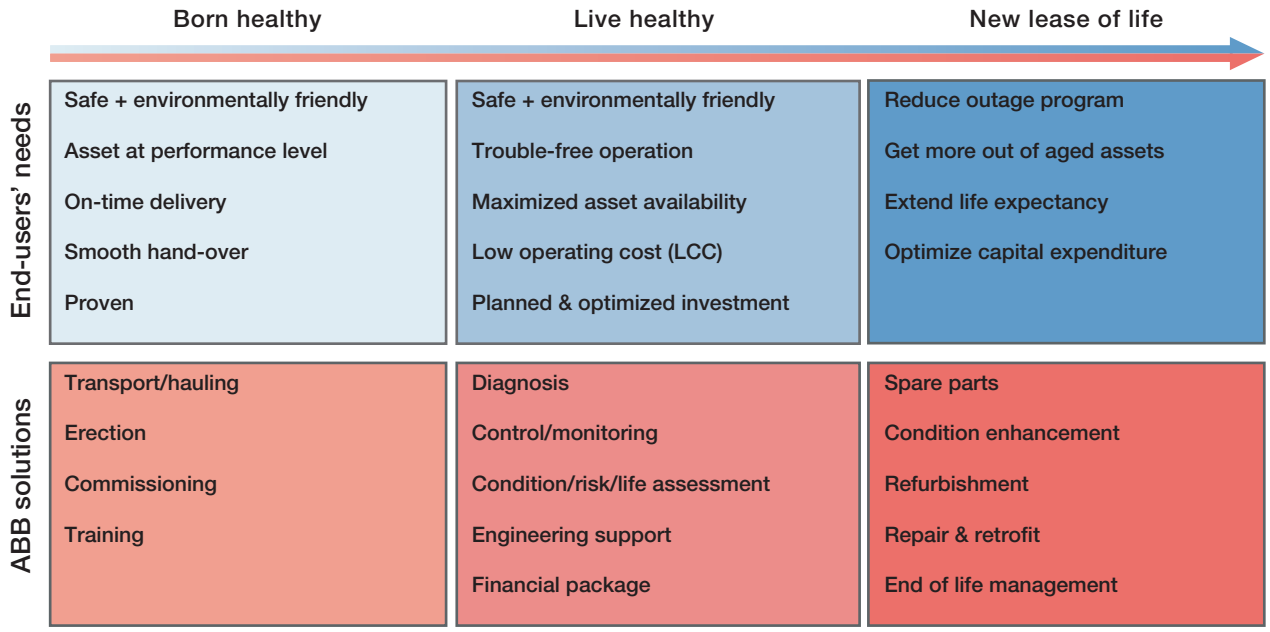
Power transformers are often situated at strategically critical locations in power supply systems, and as a result the financial consequences of their failure can easily exceed their actual asset value.

Most countries have strict laws in place that control and regulate power supply, with penalties for non-delivery that can be as much as a hundred times the price of the energy itself. The cost to industry of power interruptions caused by transformer failure can also be considerable; production lines that shut down unexpectedly can leave a company facing financial ruin. Companies therefore have every incentive to look after the reliability and availability of these key assets.

Since the mentioned issues span operation, maintenance and capital expenditure, asset managers clearly need special tools to support their strategic and day-to-day decisions. The real challenge lies in implementing the right action at the right time. Here, a definite trend has emerged: Asset managers are moving from Time-Based Maintenance (TBM) to Condition-Based Maintenance (CBM) or even Reliability-Centered Maintenance (RCM), where decisions are no longer driven by an average timeframe defined by observations and past experience, but instead take into account the actual condition of the equipment and the level of reliability required to fulfill its function.

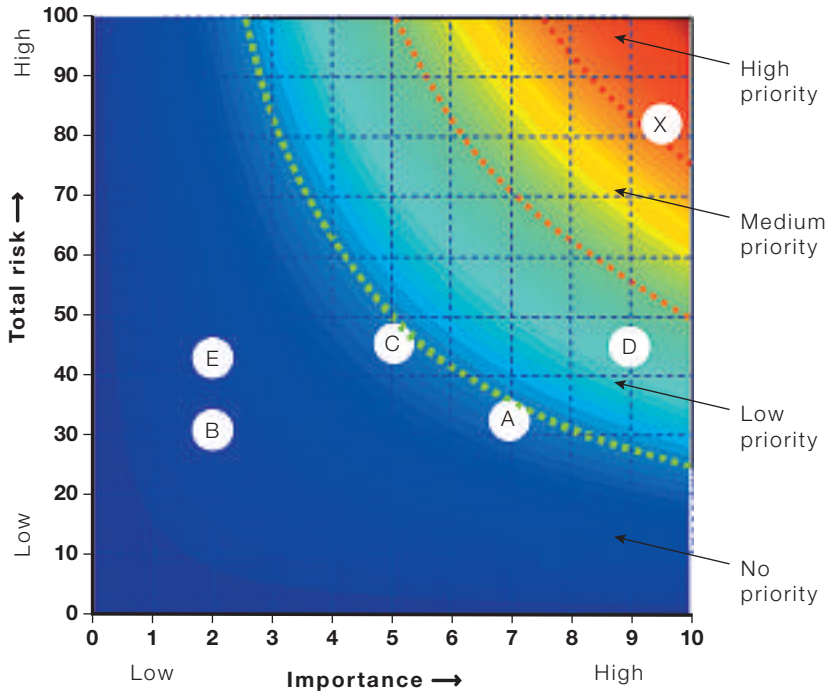
This approach is made even more important by the knowledge that transformer owners are running their aging assets under more difficult constraints than in the past. Given that the average age of power transformers and industrial transformers in most countries is around 25–30 and 15–20

1 Overview of the Transformer Retrofit & Engineering Support (TRES) portfolio



years, respectively, action clearly needs to be taken to ensure their continued reliability and functionality. This is backed up by the projections of a US insurance company, namely that the average utility transformer failure and replacement rate, currently around 1% per year, will increase five-fold in the next fifteen years [1]. Figures for industrial transformers tend to be even higher due to their unique applications and loading conditions.

ABB developed the TRES portfolio to help end-users improve their asset management strategies by providing proven condition assessment and predictive analyses as well as advanced maintenance and retrofit concepts. Apart from transformer lifetime extensions, solutions include the relocation or removal of units from service before failure, thereby avoiding power outages and the attendant production losses.



2 Transformer population map. Vertical axis: overall asset condition. Horizontal axis: importance in power system. Circles identify transformer units.

Informed decisions produce the best results

The portfolio helps end-users make maintenance and investment decisions by providing reliable support in the technical and economic areas.

ABB watches market developments closely, and some five years ago began to develop a methodology for evaluating, in the field, the status of single and also whole fleets of transformers, using non-invasive methods wherever possible [2]. The methodology integrates knowledge accumulated by ABB over the past fifty years and involves more than ten different brands.

TRES has a modular structure, allowing the level of investigation to be adapted to a customer's specific needs and the respective budget. Evaluations can be carried out progressively, beginning with a population screening (step 1), then moving onto the standard assessment (step 2) and, finally, to the highly selective advanced evaluation (step 3) [3].

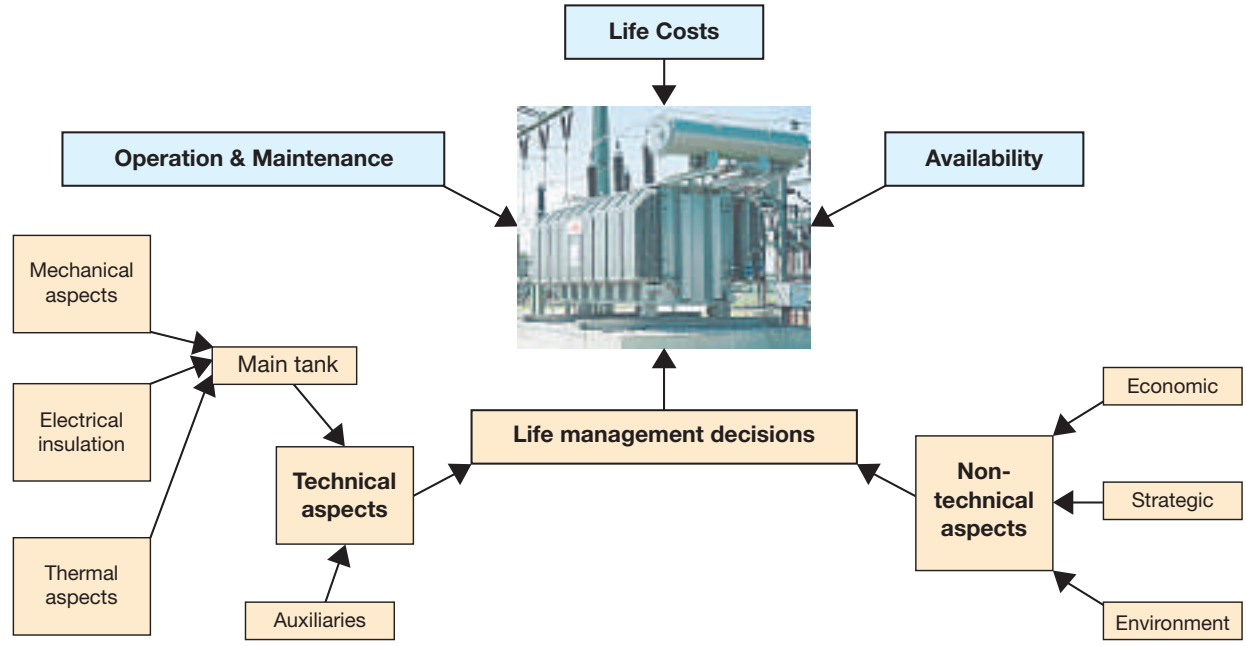
Step 1: Population screening

Large fleets (100 units or more) are evaluated using data that are readily available, such as types of application, time in operation, gas in oil, power factor, maintenance history and major events, or experience with sister units

The aim here is to obtain a general ranking for the population, based on technical and economic criteria, and to identify clusters of units requiring further investigation (step 2) or some basic maintenance. The results are mapped as shown in 2.

This screening also provides key information for the estimation of a rough budget for future maintenance or unit replacement, and identifies the units that should be given priority.

Budgeted investments in maintenance can be more effectively allocated and optimized as a result of this evaluation.



3 Criteria and process used to evaluate the status of transformers

Step 2: Standard evaluation

A smaller number of units are selected from the step 1 process for this evaluation. Step 2 re-uses basic information from step 1 and brings in further information (eg, design reviews, site inspection reports, diagnostics data, input from monitoring systems), if available. Step 2 is much more structured 3 to allow the key properties (general, mechanical, thermal, electrical and accessories') to be assessed separately.

Step 2 provides important information about the condition and suitability of the units with respect to each of these properties. The maintenance, repair or retrofit work necessary to ensure top reliability for the units in their respective operating modes can then be defined.

Costs are reduced as action is restricted to certain components and is only taken when it is really needed. If, for example, the actual condition of an aged transformer is suitable for overloading but not for short-circuit operation, action could be focused on just improving the rigidity and clamping of the winding blocks.

Step 3: Advanced evaluation

The number of units is reduced again for step 3. Based this time on information from steps 1 and 2, it incorporates further advanced calculation, plus simulation or root failure analysis. ABB specialists are brought in to carry out a detailed study of the operating conditions and history, and to analyze the original design using state-of-the-art software. Advanced diagnostics are also used to evaluate a whole range of properties [2], including:

- Oil, dissolved gas analysis and furan interpretation
- Frequency response analysis
- Dielectric response
- Partial discharge

Step 3 provides a solid understanding of each unit's condition, and yields reliable information which can be used for decision-making, eg whether to retrofit a unit or use it in another application. Step 3 is also useful for performing engineering surveys (overload capability, etc) or as an expertise after a unit has failed.

Advanced evaluations of this kind provide accurate, reliable information, even in complex cases, allowing decisions to be made quickly and efficiently. For example, it allows owners to decide already on site whether or not a unit is to be retrofitted, repaired

or scrapped. Time and costs are saved as a result.

From condition assessment to life and risk assessment

Condition assessments are used by insurance companies when drawing up new contracts or proposing ways to reduce operational risk. ABB's condition assessment concept can be instrumental in developing new 'win-win' relationships between the insurance companies and policy holders.

The three-step evaluation described has proved to be cost-efficient for determining the status of transformers based on different levels of information. With its status defined, the characteristics of each unit can be reviewed in terms of present-day or expected operating conditions to define the level of functionality and risk for every unit in a power system.

Once the status of a unit is known, recommendations for maintaining or improving its condition to meet the expected withstand level can be made. A priority list can then be drawn up, detailing what has to be done to specific transformers. This can range from minor maintenance (oil processing, etc) through overhauls, repairs, retrofitting or relocation, to scrapping and replacement.

ABB services based on life assessment surveys

ABB offers a range of services designed to ensure the serviceability of customers' installed transformers, based on their actual condition. Wherever possible, local teams of ABB specialists carry out the necessary work on site. In the following, a brief description is given of these services.

Basic maintenance

An important factor contributing to the safe and efficient operation of transformers is routine maintenance. The work can usually be carried out by local maintenance teams, as it requires only basic knowledge of transformers. Only the transformer externals are checked. For the most part, the work involves visual inspections, concentrating on silica gel status, oil leakage, bushing cleanliness, as well as checking of the pumps, cooling systems, motors and accessories.

Advanced maintenance program

Reliability, aging and lifetime depend largely on the condition of the transformer core and windings, and especially on the state of the insulation. Special services provided by ABB either on site or in specialized workshops include reclamping of the windings, cleaning of the active part, oil reclamation [4] and high-efficiency drying by means of low-frequency heating. The lead-time is reduced through process optimization. Quality control is diagnostics-based.

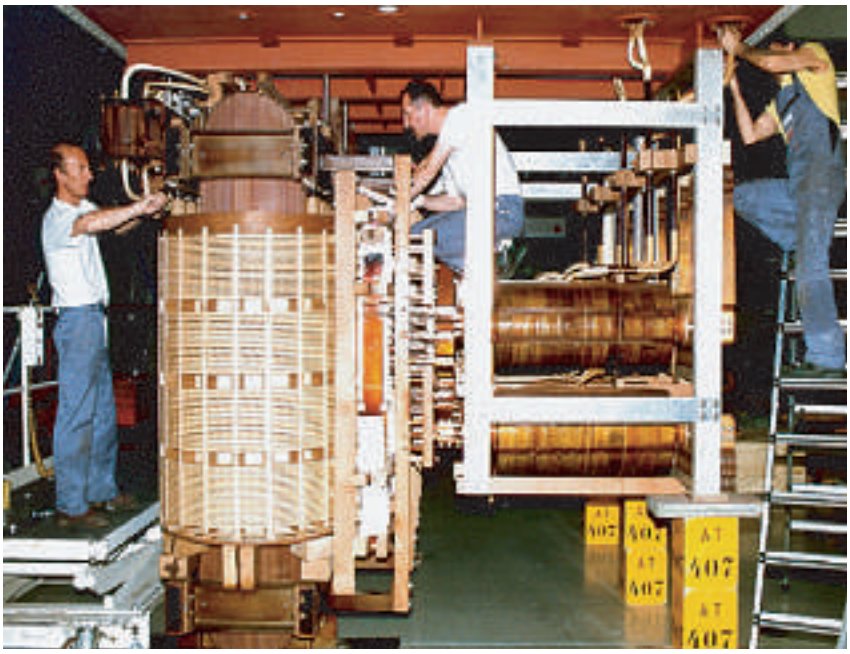
Monitoring

An on-line monitoring system can be installed for strategic or higher-risk transformers to increase their availability, plan maintenance or optimize performance [5]. Key parameters of the core-and-winding assembly as well as of important ancillaries, such as tap-changers or bushings, are monitored. Besides storing data, the system has embedded models for turning raw data into values the end-user can use to make operational or maintenance decisions.

Remote supervision contracts are possible for follow-up and advanced interpretation of data. Stored monitoring data can be used as input for the condition assessment survey.

Repair and retrofit

ABB is constantly developing new, innovative solutions designed to improve transformer functionality, raise quality and reduce throughput time. Transformers are repaired and retrofitted as close as possible to their original site to save time and transportation costs. ABB makes use of specialized workshops or on-site capability. A special process was developed to ensure quality on site [6]. Improvements were made to increase drying efficiency using low-frequency heating and enable high-voltage testing after modifications to the transformer. In addition, new high-performance insulation material and high-end design tools add value to existing units.



Understanding life-cycle costs in order to optimize investments

To enable end-users to make the best strategic investment decisions, ABB has developed a powerful model with which payback and net present value calculations can be run for specific maintenance work or replacement on large fleets or specific units [7]. The model takes account of the transformer condition and associated risk of failure, operation, maintenance, repairs and capital costs. It then simulates different scenarios, integrating the benefits of maintenance work and its impact on condition improvement.

This tool provides highly efficient support for decision-makers who need to consider and balance technical and financial issues.

Overview of TRES based on a typical case study

To show the full range of services TRES offers, it is useful to look at an actual project handled by ABB. The subject is an aluminum smelter that was planning to increase production by 10% over the next five years (first scenario) or, alternatively, the next ten years (second scenario) while maintaining availability at 98.5%. The owners wanted to know what needed to be done to ensure that the existing electrical installation, with eight industrial rectifier transformers between 18 and 40 years old, would be able to handle the new operating conditions.

In the course of the project ABB provided the following services from the TRES portfolio:

1. A condition assessment and engineering study to evaluate the feasibility of increasing the transformers' power rating.
2. Ranking of the population (four groups of two transformers) and risk evaluation.

3. Recommendations for necessary improvement and a proposal for the different retrofit scenarios:

a) Refurbish and upgrade the existing transformer fleet in the workshop and on site.

b) Refurbish and upgrade the existing fleet and monitor the complete installation.

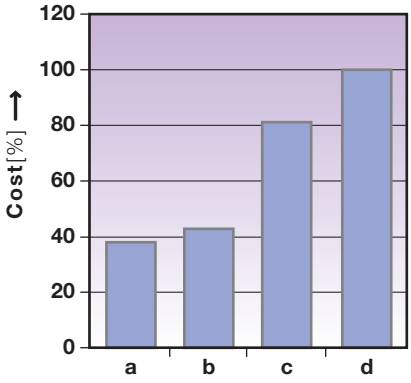
c) Refurbish and upgrade the existing fleet and install a spare unit.

d) Refurbish and upgrade the existing fleet, install a spare unit and monitor all units.

4. Cost comparison and payback calculation for scenarios 3a to 3d 4.

The payback calculation showed that scenario 3b offered the best return. It was estimated that the investment would pay for itself in one year.

Based on the condition assessment and engineering study, retrofit work was subsequently carried out in the workshop and on site. It included tank repairs and regasketing, upgrading of the connections, drying of the core-and-winding assembly and oil, tap-changer refurbishment, installation of the on-line monitoring system and remote supervision.



4 Cost comparison used in a typical case study carried out for an aluminum smelter with eight rectifier transformers between 18 and 40 years old. Scenarios a, b, c and d

Lifetime performance guaranteed

With its modular service portfolio, TRES, ABB offers transformer owners (also owners of non-ABB units) a one-stop shopping solution that looks after their interests over the entire transformer lifetime.

TRES ensures high reliability and availability for these key assets by, among other things, optimizing performance, extending lifetime, reducing operating and maintenance costs and lowering capital expenditure and insurance premiums.

TRES has been developed as part of a wider service portfolio offered by ABB for complete power systems in substations and industrial processes.

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