Lifetime decisions

Optimizing lifetime costs for transformers through informed decisions

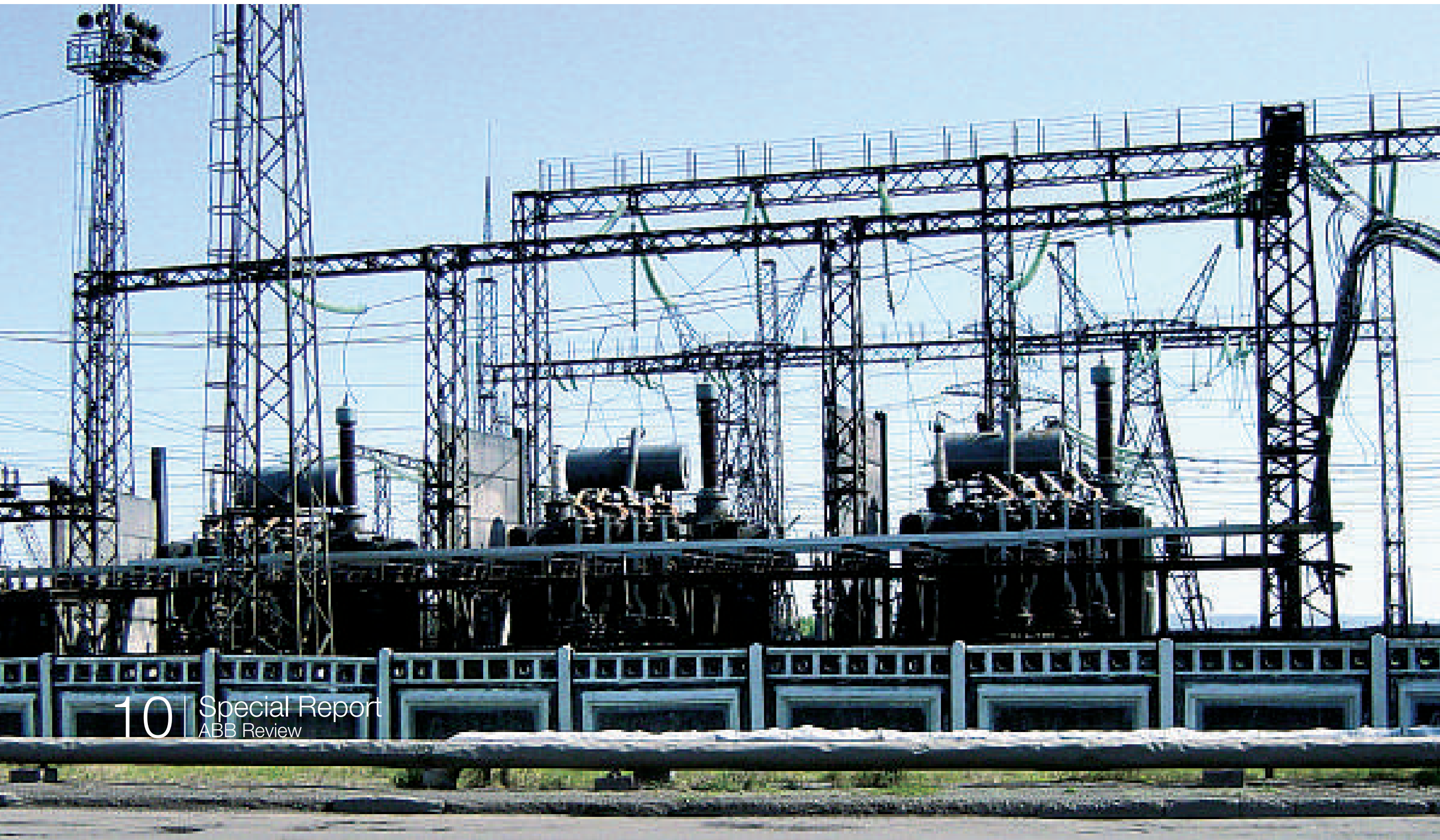
Pierre Lorin

Ageing assets, rising energy demand, and the need to deliver without outage are issues facing utilities and industries around the world. At the same time, financial constraints demand an increased return on investment over reduced maintenance budgets and spending.

These apparently contradictory demands can be met through optimized asset management. This, in turn, requires accurate and reliable models considering both technical and economical criteria. ABB provides a service portfolio furnishing this precise life-cycle analysis and the associated technological support.

A computer-based evaluation of different scenarios modeling different fleet management, maintenance and replacement strategies over longer periods of time can tell decision makers such facts as, when maintenance is more economical than replacement and how much has to be invested and when.

Investments can be planned, lifetime costs of equipment made transparent and decisions based on informed fact.



Over the past decades, asset related decisions were primarily based on accumulated experience. Capital expenditure was mostly trigged by a fast growth in energy demand and power assets were replaced by new and more powerful installations long before their reaching the end of their useful lifecycle. In today's rapidly changing environment, however, with its severe technical and financial constraints, assets managers must base their strategic decisions on reliable and precise facts to convince decisions makers.

One of the most frequent issues reported by transformer owners is the lack of reliable information on asset condition and the difficulty in defining improvements that are justified from both a financial and technical point of view.

The service portfolio 1 presented in this article is a combination of several products that provide both utilities and industries with the following advantages:

- It offers a clear understanding of the condition of the transformer fleet and accurate information on possible risks associated with every unit.
- It has the ability to draw alternative asset management scenarios based on the company's strategy and the condition of the fleet.
- It can define actions to be taken for each specific asset and evaluate payback or net present value for each scenario, considering technical and economical aspects.
- It can implement defined actions by using efficient maintenance and repair technologies.

Understanding the status of the assets: condition assessment

Condition assessment is a key ingredient for every asset management survey. It provides the base for any sound decision 3.

A statistical approach based on international data on transformer reliability can be useful as a first step in estimating maintenance and investment budgets. However, ABB's experience shows that each unit must be considered individually so that user can decide whether it should be maintained, relocated, retrofitted or replaced. ABB provides such assessments for a fleet of transformers or for individual units.

ABB has developed a modular approach to meet different expectation levels defined by the end-user in terms of population size, level of information requested and available budget.

The assessment methodology is based on three steps:

- *Step 1: Fleet screening:*

Quick scanning of a large population (20–200 units) using easily accessible data such as unit name plate data, oil and dissolved gas in oil data, load profile and history of the unit.

This first step provides higher-level management and asset managers with an overview of their assets. It gives relevant inputs for maintenance or investment budget strategy.

It is also used to select units that must be further investigated either because they are of strategic importance or because their status is critical.

- *Step 2: Condition assessment*

Here, experts focus on a smaller number of units (10 to 20) identified during step 1. Experts use modern design rules and

1 Overview of ABB service portfolio for transformers.

	Born healthy	Live healthy	New lease of life
End-users' needs	Safe + environmentally friendly Asset at performance level On-time delivery Smooth hand-over Proven	Safe + environmentally friendly Trouble-free operation Maximized asset availability Low operating cost (LCC) Planned & optimized investment	Reduce outage program Get more out of aged assets Extend life expectancy Optimize capital expenditure
ABB solutions	Transport/hauling Erection Commissioning Training	Diagnosis Control/monitoring Conditions/risk/life assessment Engineering support Financial package	Spare parts Condition enhancement Refurbishment Repair & retrofit End of life management

2	Result of a condition assessment survey (step 2: Normal evaluation) on eight transformers.

Unit #	Mechanical	Electrical	Thermal	Accessories	Overall	Actions
TFO 2	Winding	Arcing	Heating		95	Visual inspection and repair in factory/rewinding
TFO 5	Tank			OLTC heating	80	Repair on site and OLTC overhaul
TFO 1			Aged oil	Bushing	70	Oil regeneration/filtration and advanced diagnosis/change HV bushing
TFO 6		Arcing		Thermometer	50	Exchange TopOil – thermometer/on line monitoring of DGA
TFO 3				Silicagel	40	Exchange silicagel
TFO 7					25	Standard maintenance actions and controls
TFO 8					15	Standard maintenance actions and controls/10 % overload capabilities
TFO 4					10	Standard maintenance actions and controls/15 % overload capabilities

tools to evaluate the original design. Advanced diagnosis tests [1] are performed to assess each of the principal properties of the transformer in a structured way: Mechanical status, thermal status (ageing of the insulation), electrical status of the active part and the condition of the accessories such as tap changer(s), bushings, over-pressure valves, air-dryer system, pumps and relays.

Taking into account the results of this assessment, ABB defines the action for improving the reliability of every unit.

This part of the survey benefits asset, maintenance and operation management. Valuable inputs 2 strengthen daily decision making with factual support and explanations: Such inputs can be a list of spare parts to be kept in stock, a prioritized list of on-site maintenance measures, proposals to relocate units, decrease their load, repair or replace them.

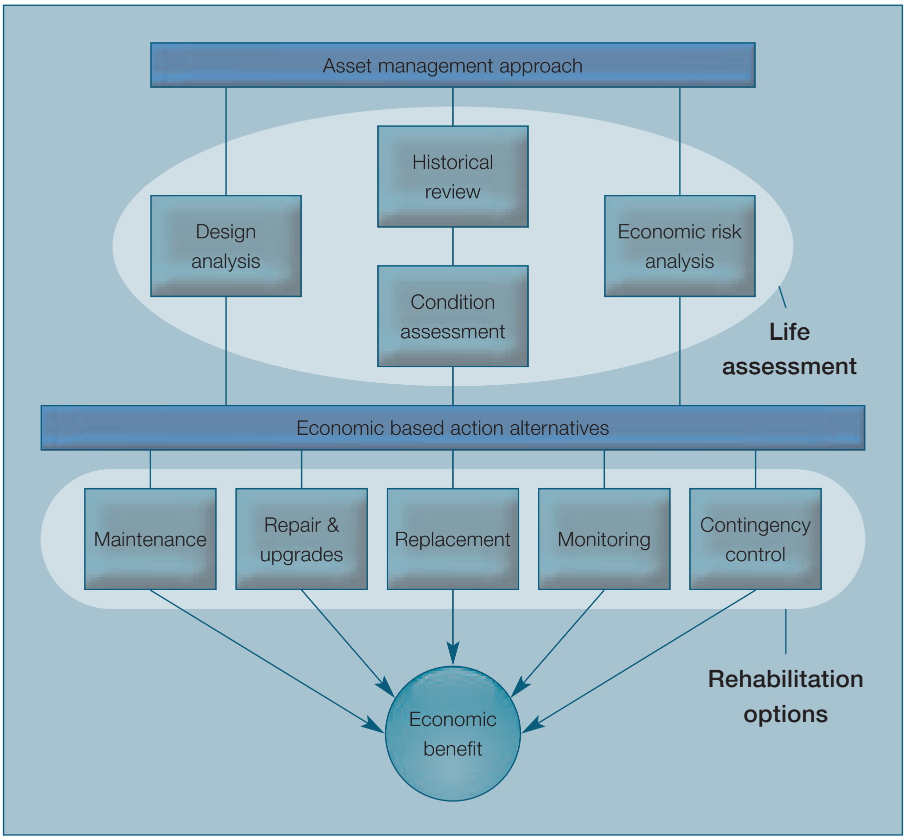
■ *Step 3: Expertise*
The number of units to be further analyzed is typically limited to two or three out of a population of 100 units. International experts using state of the art simulation tools are involved.

This third module within the assessment process provides accurate information to the end-user's engineering manager, for example when a transformer needs to be overloaded, nominal power or voltage rating increased or lifetime extended.

Maximizing the benefits at each management level

The modular assessment [2] provides valuable inputs to end-users at different management levels to ensure a high reliability and availability of installed assets. It reduces risks of unplanned outage, defines the right maintenance strategy and associated budget, improves the efficiency of maintenance investments by focusing on the right assets and optimizes capital expenditure by postponing investments. These data can also be used for discussions with insurance companies, aiming to setup the most appropriate insurance contract for the fleet.

3	Flowchart of ABB's approach to asset management.



4 Lifecycle costs calculation.

$$LCC = C_A + C_E + C_1 + \sum_{0}^{n} + (CP_M + CC_M + CO_P + CO_0 + CR) + C_D$$

where
C_A = cost of apparatus
C_E = cost of erection
C_1 = cost of infrastructure
CP_M = cost of planned maintenance
CC_M = cost of corrective maintenance
CO_P = cost of operation (load and no-load losses)
CO_O = cost of outages
CR = cost of refurbishment or replacement
C_D = cost of disposal

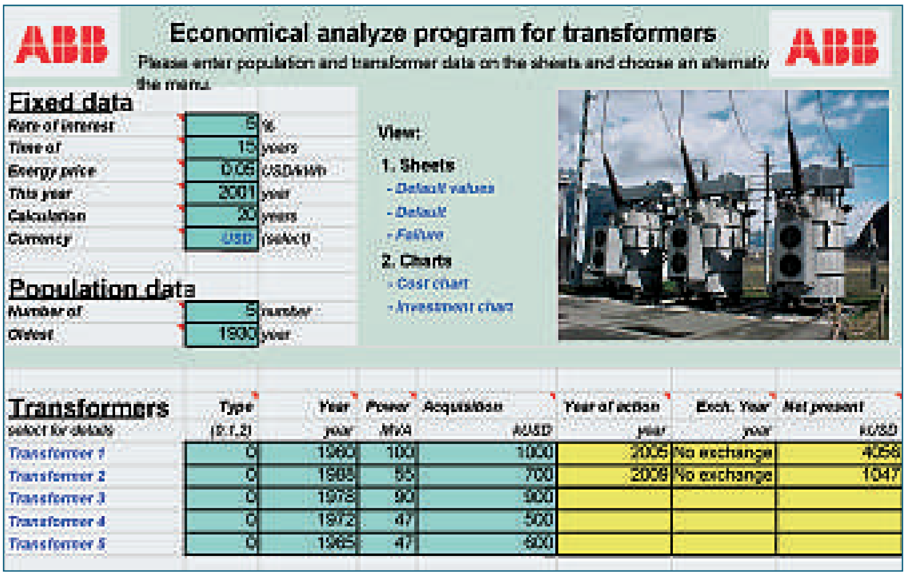
Economical analysis for pay-back of maintenance actions

The result of a condition assessment survey is a ranking of the transformer population according to the evaluated reliability of the unit. Priorities are then defined to take corrective or preventive actions on the most critical units to improve the overall reliability of the fleet and reduce costs associated with the risk of unplanned outage.

Priorities are driven by technical considerations related to the condition of the units but also by the overall strategy of the company that owns the assets. Several asset management scenarios are therefore possible. An important criteria directly linked to the strategy of the asset owner is to minimize the life cycle cost of the assets or the total cost of ownership.

For the condition assessment to provide more value to the end-user, and to support decision makers in defining which scenario is financially more attractive for the asset owner, ABB developed an economical model in cooperation with large utilities. This evaluates lifecycle costs of a transformer fleet over a given period [3]. The model can also be applied to an individual transformer.

5 Software to evaluate costs and benefits of maintenance actions or renewal of transformers.



The model takes into account four categories of costs related to the cost of ownership over the lifetime:

- Investment costs
- Maintenance costs
- Operational costs
- Costs of failure risk

The lifecycle costs caculation uses the formula 4. The criteria used in such an economic analysis also indirectly consider the following:

- Safety
- Condition of the assets
- Age
- Operation condition
- Availability
- Maintainability
- Environmental
- Environmental legistation
- Risk (consequential costs at fault)

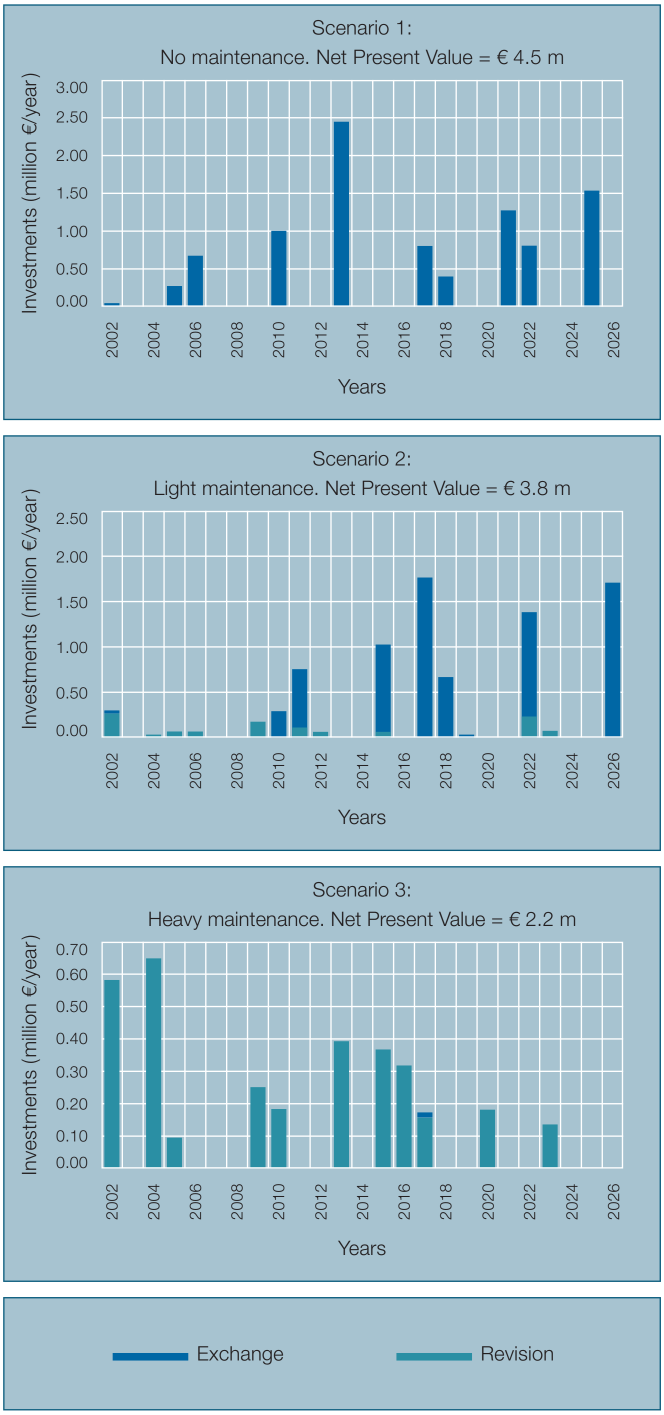
Comparative investment scenarios and sensitivity studies can be run by varying the replacement year or maintenance of the unit. For each scenario, the software computes the associated net present value.

An optimization routine can also be used to automatically minimize the life cycle costs of the population. The software outputs a list presenting the optimum time to provide maintaince or replace the individual transformers or transformers groups.

The method permits two levels of investigation. A first approach that principally benefits asset managers provides a general view of fleet maintenance costs and forecasts the capital expenditure for the requested time frame (for example, 2004 to 2034). The condition of each unit is integrated in a generic way based on statistical evaluations. The software uses curves published by CIGRE, presenting the reliability of transformers versus their age.

The second approach principally benefits maintenance managers. The software 5 calculates the net present value of the whole population of transformers depending on the specific condition of each unit and the specific maintenance actions selected to improve their condi-

6 Comparison of maintenance scenarios.



tion [4]. The method is also applicable for a single transformer. This more detailed approach assumes that the user knows the mechanical, thermal and electrical condition of the transformer (which can be taken from an earlier condition assessment).

The maintenance manager can then evaluate different maintenance scenarios and obtain an evaluation of the payback of planned maintenance actions. The novel aspect of the method is that not only maintenance costs are considered but also economical benefits linked to the impacts of maintenance on the reliability.

To illustrate the benefit of such a survey, the results of a study made by ABB for a Swiss utility are presented. A condition assessment study and economical survey were made. The population studied is composed of 50 medium size (5 to 250 MVA, 50 to 240 kV) network and generator step-up transformers. The average age of the population is 29 years.

Three maintenance scenarios were considered:

1- No maintenance, except the very basic and mandatory actions such as fixing oil leakage or changing the air-drying compound.
2- Light maintenance: basic maintenance plus oil and gas analysis, oil filtering and drying, periodic on-load tap changer overhaul.
3- Heavy maintenance: mid life refurbishment – after 15 to 30 years in service (depending on the condition of the unit defined through the condition assessment survey). The transformer is untanked to permit work on the active part, complete check, electrical connections and winding block clamps tightened. If necessary, the oil is regenerated and the active part dried. Besides work on the transformer itself, bushings, tap changer and other accessories are checked and corrective actions taken.

For each of these three scenarios, the optimization process was run to compare the costs of the individual strategies. The graphs 6 show the capital required per year for maintenance and replacement during 25 years of operation.

The present net value of the costs of operating, maintaining and renewing the fleet over a 25 years period varies from € 1.5 m to € 3 m depending on the scenario selected. In this specific case, refurbishing the transformers after 15 to 30 years (depending on their condition) is the soundest scenario economically.

Implementation of the maintenance action plan: Maintenance and repair technology

Depending on the condition assessment, the following corrective actions can be considered, evaluated and implemented:

- Refitting of gaskets, oil processing, oil regeneration, drying of active part to improve the general condition of the transformer and reduce the ageing process.
- Retightening connections of the active part, adding new shielding, cleaning the contacts of the off-load tap-changer to improve electrical performance.
- Reclamping the windings and the core, checking the cleats and lead structure to improve the mechanical condition of the unit.
- Overhauling the on-load tap-changer, maintaining the bushings, the cooling system, the fans, the pumps, the relays to increase the reliability of the accessories and thus of the transformer.

Besides the traditional maintenance and repair techniques in use, some new technologies adopted by ABB should be pointed out:

On-line oil regeneration [5] demonstrably has technical and economical advantages when applied to old transformers with aged acidic oil. The process is more environmentally friendly than oil replacement and shows a much better efficiency over a long time period.

On-site repair [6] using high voltage on-site testing capabilities [7] and a very efficient on-site drying method is an attractive approach to transformer repair in remote locations where transportation is difficult and costly. This approach has been used by ABB in several countries (especially in South America[1)]) on more than 100 transformers and shunt reactors. It is praised by end-users as a high quality solution and has already saved utilities and industrial users millions of dollars; reducing for example the lead-time to repair a transformer by two weeks, so saving 0,5 to 1 million US$ in lost production per day.

A low frequency heating system [8] is now also a proven solution for drying transformer active parts much faster without compromising quality. The remaining moisture content of the solid insulation is typically below one percent. The drying time can be less than half of that for a traditional hot oil and vacuum process. Lead time reduction when drying a wet transformer or repairing a failed unit on site presents significant owner benefits.

1) See also pp 59–62 of this issue of ABB Review Special Report

Last but not least, facing an increasing demand from end-users wishing to increase the power of their existing units, ABB proposes a concept for boosting existing transformers by rewinding the coils with Nomex® high temperature insulation material [9]. As a result, lifetime and reliability are significantly increased. Besides the cost advantage gains on the unit itself, side benefits worth consideration include: lower environmental impact than scrapping, no construction needed to prepare the site (the footprint remains identical) and the lower weight compared to a conventional unit.

Conclusion

The integrated and modular approach presented here supports the decision process of transformer owners in choosing between maintenance and replacement.

On a long term and strategic level, a significant benefit of such a study gives top management a clear picture of the maintenance and renewal investments required over the next twenty to thirty years to provide the required asset reliability and availability. It provides solid information to compare different asset management strategies and choose the approach that best supports the overall technical and financial strategy of the company. A program to extend the lifetime of aged units will, for example, postpone investments in new units and so improve the cash flow of the company.

In a medium term time perspective, assets managers obtain input on making best used of maintenance or replacement budgets. Funds can be allocated to units that show the best return on investment while reducing technical and environmental operation risks.

In the short term, the method allows the maintenance manager to quantify the benefits of each maintenance action and thereby optimize decisions considering technical and economical aspects.

The benefits of the integrated service portfolio developed by ABB for transformers aims to support transformer owners in optimizing their lifetime asset management strategy to minimize cost of ownership. New technologies developed to improve service quality and reduce asset downtime are made available through an impressive network of locally based service experts. State of the art tools, highly qualified experts and an efficient organization allow ABB to deliver services in more than 100 countries with an impressive responsiveness.

The portfolio can easily be combined with other service solutions from ABB to serve all kinds of power equipment.

Pierre Lorin
ABB Transformers
Geneva, Switzerland
pierre.lorin@ch.abb.com

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