Transforming Transforming

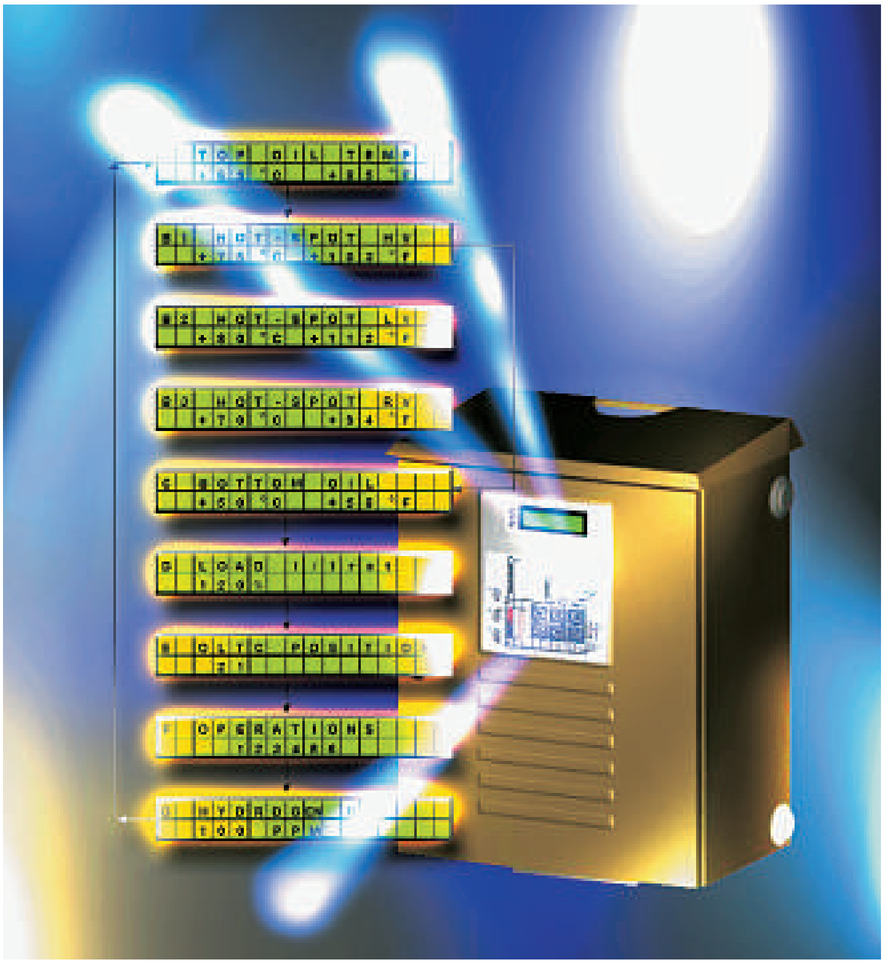
Advanced transformer control and monitoring with TEC

Lars Jonsson

Getting the most out of electrical equipment is vital to energy enterprises in today's increasingly deregulated world. With power transformers making up a substantial part of that equipment, it is little wonder that utilities put a premium on enhancing the lifetime and performance of these industry workhorses.

Conventional control and monitoring schemes rely on past results – good enough, perhaps, for routine maintenance and non-critical units, but not to keep transformers performing constantly, and unfailingly, at the highest level. Not so ABB's Transformer Electronic Control (TEC) system. This models the actual state of the transformer, creating a 'virtual copy' that provides the parameters required to optimize cooling as well as the data utilities need for condition-based maintenance.

Power transformers at critical nodes in electricity networks lead stressful lives. Reliability is everything. Load peaks – predictable as well as unexpected – generate high temperatures, which shorten component lifetime. In the worst case, sudden failure can occur, causing havoc in the network. It is because of this risk, and the penalties that can attach to it, that utilities give such a high priority to controlling and monitoring the status and con-



1 TEC receives the information it needs for transformer control from just a few multi-purpose sensors.

dition of their transformers. This lets them intervene *before* failure or malfunctioning can occur. Increasingly, for many utilities, the watchword is 'early detection of failure conditions'.

Enter the 'intelligent transformer'

Deregulation of the energy markets has brought about a paradigm shift and focused attention on, among other things, 'asset management' and 'remaining life management'. As a result, an increasing number of power transformers around the world are being equipped with monitoring devices. As this trend intensifies and more and more functionality is added, transformers are likely to play a new role – as 'intelligent units' – in future transmission networks.

The trouble with many transformer monitoring systems is that they are not able to control or make decisions and recommendations based on the available data, forcing engineers to spend a lot of time sorting and interpreting the information they receive. This is the strength of Transformer Electronic Control (TEC) **1**. TEC receives all the information it needs for transformer control from just a few multi-purpose sensors; other necessary parameters are calculated. Thus, TEC adds only minimal complexity to the transformer.

To achieve the goal of making power transformers 'intelligent' and maintenance-free, ABB created and integrated a common electronic interface that exchanges information with the following apparatus:

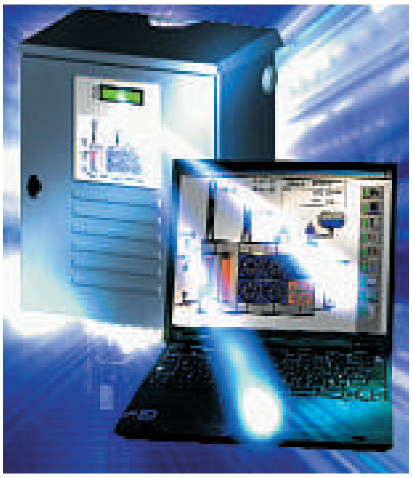
- Monitoring and diagnostics devices of the transformer and components
- Transformer control cabinet
- Tap-changer motor-drive
- Voltage regulation system
- Overall protection system

Through this interface, TEC provides exact status information to enable utilities to extend transformer lifetime and save costs by reducing maintenance and increasing availability.

It does this by generating a model of the transformer and its working condition and then comparing the measured parameters with the simulated values. Discrepancies are detected and potential malfunctions and/or normal wear in the transformer and its ancillaries are indicated.

As ABB's fully integrated control and monitoring solution making use of one original set of multi-purpose sensors and employing specific transformer design data, TEC is the latest addition to a product portfolio that already includes the ABB T-Monitor. The T-Monitor is a proven retrofit solution that provides adequate predictive power by means of easily fitted add-on sensors and models that require less detailed information about the transformer and its component design.

2 The main parameters can be viewed on-line on the TEC front panel or on a PC terminal.



TEC architecture

The system hardware and software features proven ABB technology and has been designed to allow extra functionality to be added in the future. Being microprocessor-based, the system has more flexibility than a PLC and provides a more stable platform than a PC solution.

TEC gets its capability to control and monitor not only from its superior software, but also from the fact that it has unlimited access to all the information it requires. It knows everything about your transformer. This 'knowledge' begins with the transformer design data. Next, temperatures and loss-related parameters obtained from the transformer heat-run test are fed in. So much data is transferred to the TEC system that it becomes a 'virtual transformer copy'. Each transformer has its own 'fingerprint', with all the parameters needed for optimized control. The model created by TEC works in simulated conditions but reacts in the same way that a real transformer would.

The main parameters are processed in the TEC cabinet and transferred to the station PC via a single optic fiber. They are made available to the operator via easy-to-use software and a display.

TEC and IndustrialIT

IndustrialIT [1] has been introduced by ABB as an architecture for seamlessly interconnecting all our Group's products, solutions and processes. More than that, it allows our customers, service partners and third parties to connect with them too. Industrial IT enables the *total* integration of business processes with real-time and lifetime data management. As a consequence, utilities will be able to substantially improve the efficiency of their business.

Utility assets, such as power transformers, are prime candidates for such real-time integration. And TEC is an ideal means of integrating them. It is certified to Level 2 (Integration), which means that it is not only information enabled and can be connected to and will work well in an Industrial IT system, but also is able to exchange extended data, like status and maintenance data, via defined protocols. Systems with Industrial IT Enabled components offer a variety of advantages, including 'plug and produce' capability. Disturbances are reduced at the same time that flexibility is increased.

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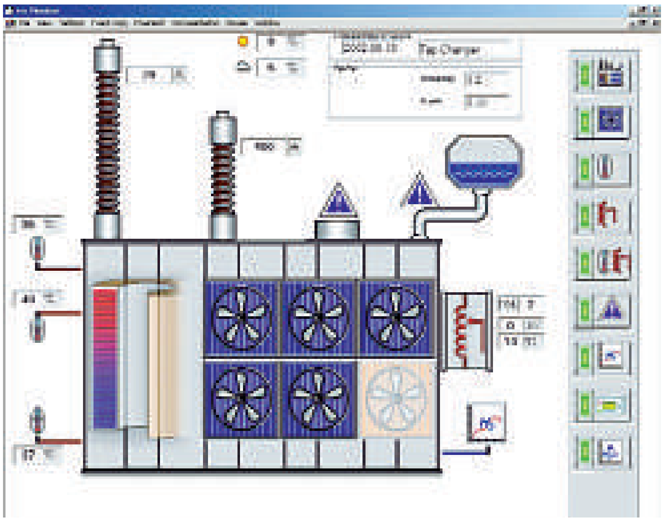
Feature overview

TEC offers a whole range of functions designed to let utilities use their transformers to the maximum. Until now, service criteria have been based on load assumptions and the results of the last service. TEC changes all this. Real-time information opens up new possibilities for optimizing operation and maintenance.

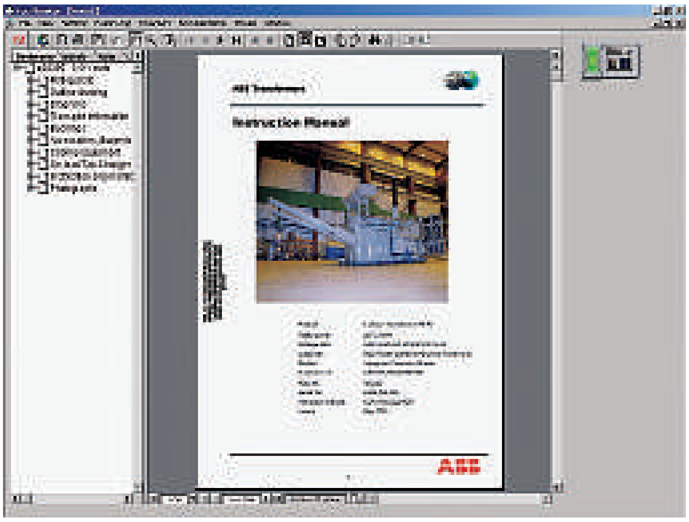
Cooling/overload forecast

Traditionally, transformer cooling is a two-step system, with the option of 50% or 100% capacity. With TEC, six steps are possible, according to load, ambient conditions and cooler status. The coolers are controlled individually and can be started prior to an anticipated load increase. This reduces thermal stress and adds hours of operation at maximum capacity.

3 Start panel showing a transformer model with basic data

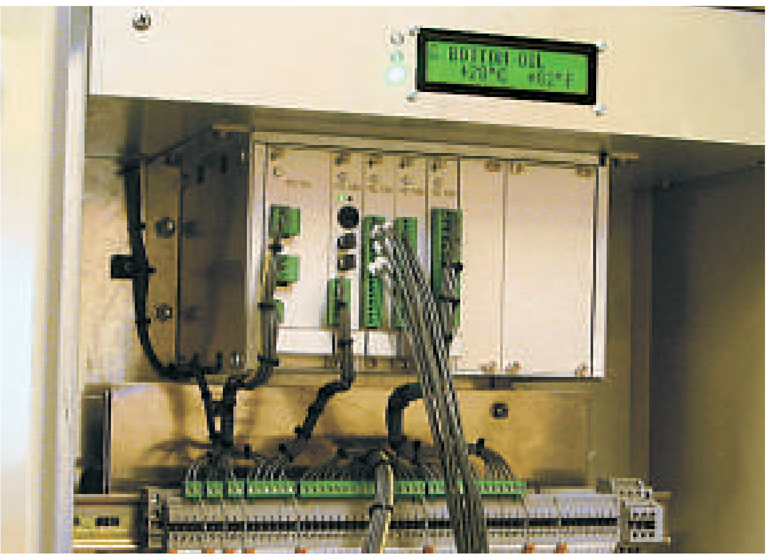


4 TEC users can easily access more detailed information as well as transformer or tap-changer documentation.



TEC advanced cooling control is based on algorithms that calculate the heat losses and the number of coolers required to dissipate them. It also keeps track of the number of hours each fan is in operation and runs all motors accordingly. As input, TEC receives data on the actual and/or predicted load and ambient conditions. Armed with this information, the system is able to respond immediately to load peaks, and the cooling capacity can be better adapted to actual demand. Further, it can simulate the results for a specific load condition or forecast the maximum overload duration based on the hot-spot results.

5 TEC electronics – tried and tested



Real-time status/availability

The parameters measured during service are compared with the simulated values. The transformer model detects discrepancies and indicates potential malfunctions and/or normal wear in the transformer itself, the cooling equipment and the tap-changer.

Real-time information from temperature sensors and from optional moisture sensors is stored by the TEC system. If required, a hydrogen detector can be mounted on the tank to obtain an early indication of potential problems in a transformer winding.

A rolling LCD on the front panel shows the main parameters together with a three-lamp status 'traffic light'

By giving utilities the means to monitor, and thereby optimize, the way they operate their power transformers, TEC can be said to be truly transforming transforming.

(green/yellow/red). The same information can be viewed on a PC terminal, either in the substation control room or at a remote location 2.

Lifetime

Temperature control, based on overload forecasting and winding hot-spot calculations, allows the consumed lifetime to be computed in accordance with the latest IEC and IEEE standards.

Event recording

TEC also keeps track of transformer trips and alarms, recording the actual events as well as the sequence to assist operators in determining their root cause.

Condition-based maintenance

The status traffic light identifies the most heavily worn contact in the tap-changer, based on the actual load during each operation. The user sees when the next service is due.

Oil treatment is condition-based, being dependent on the development of moisture as indicated by the temperature and (optional) moisture sensor in the tap-changer compartment.

Early warning is given of any increase in tap-changer temperature beyond the normal value.

Operation and updates

The user interface runs in the Windows environment. The PC start panel 3 shows a transformer model with basic data such as the top-oil and bottom-oil temperatures, up to three hot-spot temperatures, the apparent power and the tap-changer position and operations. More detailed information can be obtained by clicking on the object on the transformer model or by pressing one of the status information buttons.

All of the transformer and tap-changer documentation, including instruction films, can be viewed on the PC in the control room or any other place of convenience 4.

Tried and proven

Environmental tests, hardware/software functional tests and on-site tests in various parts of the world have shown that the system is well suited for substation environments.

ABB's extensive experience with electronic equipment in harsh industrial environments has also been incorporated in the design of the TEC 5. For example, it is EMC compliant and vibration proof.

A modular system

TEC is the first of a generation, and ABB continues to investigate new approaches and ways to improve the system as a whole and in part. Further parameters for the transformer, tap-changer and bushings will be included in the future. TEC's modular design makes this easy, and provides the flexibility that will ensure its success as an innovative and cost-saving product. By giving utilities the means to monitor, and thereby optimize, the way they operate their power transformers, TEC can be said to be truly transforming transforming.

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Reference

[1] **C. Rytoft, B. Normark:** Industrial[IT] and the utility industry. ABB Review 3/2002, 23–28.