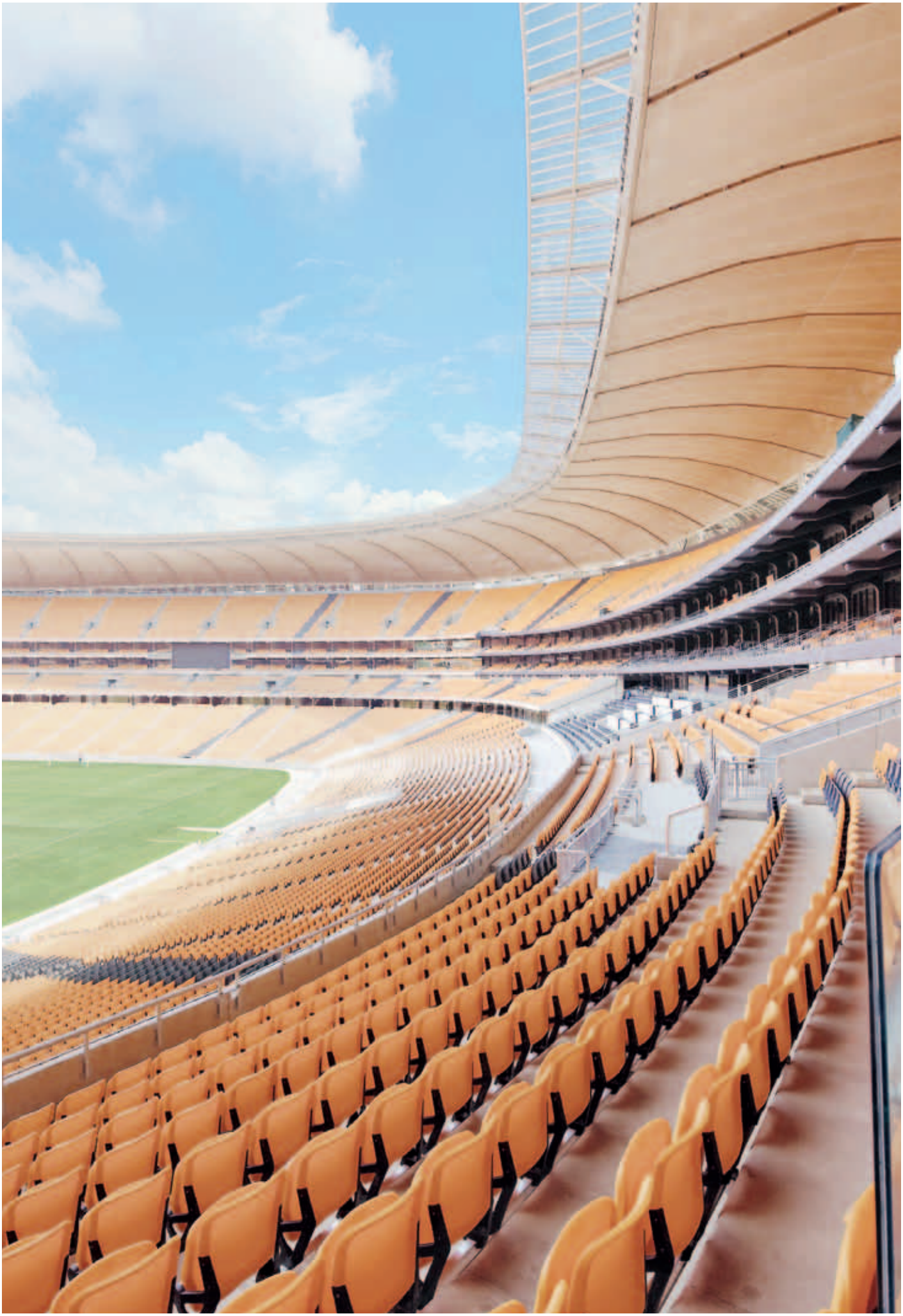


Smart transformer

Transformers will have to do a lot more than just convert voltages

BJORN WESTROM, INOCENCIO SOLTERIO, STEPHANE PAGE, NICOLA RAMPIN –

For many decades, the transformers that populate our power grids have led a fairly one-sided existence. Now, however, their world is being shaken up and a lot more is expected of them: They should cater for the plethora of renewable power sources appearing on the grid; they are required to help maintain grid power quality; they are expected to do their bit in reducing greenhouse gas emissions; and they have to fit in with smart grids. Of course, the traditional commercial pressures to decrease all-round costs, extend asset life, improve monitoring and optimize maintenance still remain. How are ABB's smart transformers rising to this challenge?

Transformers at critical nodes in electricity networks lead stressful lives. If they fail, the cost can be very high, so the reliability of these devices is paramount. However, load peaks – predictable as well as unexpected – generate high temperatures that shorten transformer lifetime. In the worst case, sudden failure may occur and cause havoc in the network, bringing financial, and other, penalties. Utilities are keen to control and monitor the status and condition of their transformer fleet so they can intervene before a failure or malfunction can occur. For many utilities, the motto is, "detect failure conditions early."

Ongoing changes in the energy sector are adding significant challenges. For example, renewable power sources operated by a large number of small, local energy producers change the flow of power in the distribution network at the consumer end of the grid. Another example is found in the growing popularity of electric vehicles: charging these in residential areas introduces dramatic changes in consumption patterns and heavy local charging activity can cause overloads of distribution transformers. Apart from these examples, there are many other indications that the number of nodes at the distribution transformer level that can be considered to be critical will multiply and this will lead to a demand for the type of monitoring and control that has, until now, been limited to large power transformers.

This development will lead not only to an increased number of transformers with inbuilt monitoring functions, but also to more sophisticated monitoring technology. Current high-end solutions include multiple intelligent electronic devices (IEDs) covering different aspects of the transformer. Using these, the asset owner can monitor the behavior of the transformer core, windings, oil, tap changer and bushings.

> Increasingly, for many utilities, the motto is "early detection of failure conditions."

Title picture
Transformers help power many aspects of our society – homes, factories, transportation and recreational facilities, like the Soccer City stadium in Johannesburg, South Africa, shown here. ABB's smart transformer products are key to meeting the increased expectations being put on transformer technology.

1 ABB's TEC online monitoring system

2 ABB's TEC Smart

There are many indications that the number of critical nodes will multiply, leading to a demand for monitoring and control of transformers.

Monitoring improves the reliability of the assets by constantly keeping a watchful eye on the most critical transformer components.

Compared to traditional transformer diagnostic methods, which are performed on-site with the transformer de-energized, monitoring gives the asset owner access to real-time condition information, even from remote locations. When changes in conditions are detected, the operator is notified immediately.

Through remote access, the asset owner can then evaluate the status of the equipment without dispatching an engineer to the site, saving both valuable time and resources. Since monitoring detects condition changes in real-time – versus periodically with traditional diagnostic methods – the asset owner has time to plan and act before faults occur.

Using IEDs, the asset owner can monitor the behavior of the core, windings, oil, tap changer and bushings of the transformer.

ABB monitoring solutions

ABB provides a very modular approach to transformer monitoring. The ABB transformer electronic control (TEC) product acts as the central IED unit of the transformer, ie, as the communication hub for all other IEDs → 1.

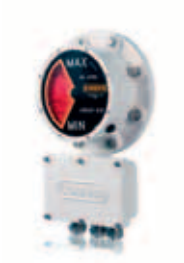
In this way, the end customer has a single, user-friendly Web interface for all monitoring equipment as well as a single point for setting up communication with SCADA systems. TEC has built-in monitoring of the ambient temperature as well as the transformer oil and winding temperatures. Currents are also monitored, as are several tap-changer parameters (oil temperature, operation statistics and contact wear). TEC features advanced thermal models for both the transformer and the tap-changer. These models not only calculate hot-spot temperatures according to IEC and IEEE standards, but also model the complete thermal behavior, allowing comparison of measured with expected thermal behavior. Based on customer requests and transformer applications, additional IEDs can be added.

The most common ones are different types of gas-in-oil IEDs. Bushing monitoring IEDs are also becoming more popular.

To cover the requirements for fleet-wide deployment, ABB also provides the entry-level model TEC Smart → 2. In essence, TEC Smart is a scaled-down version of TEC that has only a selection of the most critical TEC feature. This reduces installation time at the site and lowers costs to a

3 COMEM's new electronic transformer component portfolio

Electronic oil level indicator (eOLI)
- Constant monitoring of the oil level in the conservator
- Analog and digital signal proportional to the oil level inside the conservator (can be transmitted to a PLC, a PC, or an integrated monitoring system)



Self-dehydrating air breather (SDB)
- No silica gel salt maintenance required
- Continuous and safer control and monitoring of the silica gel salt hydration as well as regeneration

Electronic pressure relief device (ePRD)
- Continuous pressure monitoring
- Analog 4-20mA output
- Digital RS485 output
- Adjustable onsite pre-alarm change-over switch

Electronic Buchholz relay (eBR)
- Continuous gas formation monitoring
- Remote relay functioning check
- Reduction of maintenance steps
- No risk of incorrect alarm/trip
- Easy to identify alarm/trip causes
- Better risk prediction and prevention overall

level that is attractive for non-critical and/or smaller transformers.

Smart cooling – CoolTEC

Because it is based purely on relay technology, traditional cooling control of power transformers has many limitations. One such limitation is that the cooling is grouped into banks where the only possible operational states are no cooling, half cooling or full cooling. For large power transformers, one such bank may consist of many pumps and fans. ABB's TEC system removes this limitation by allowing independent control of six cooler banks, providing a more fine-grained regulation of cooling capacity.

In some cases, it is especially beneficial to optimize the cooling control even further – for instance when a transformer is located in a densely populated area where noise level is a concern, or when mechanical stress is being minimized by reducing temperature fluctuations in the transformer oil. ABB's CoolTEC provides frequency control of the coolers, allowing stepless regulation of cooling capacity. Running all coolers at a substantially lower frequency than 50 Hz results in considerably less noise than running a few coolers at 50 Hz, while providing the same cooling capacity.

It is also possible to temporarily overdrive the coolers by increasing the frequency to above 50 Hz, thereby providing an additional cooling margin for emergency overload situations.

The use of ABB's CoolTEC in a nuclear power plant in Hungary, in which the owners sought to extend the lifetime of a 30-year-old 400/120 kV substation transformer, provides a good example of the solution. The aim was to lower the transformer oil operating temperature and reduce temperature fluctuation. ABB's CoolTEC was able to continuously monitor the transformer and track the performance of the coolers. The advanced cooling logic driving the frequency controllers allows a lower working temperature and smoother temperature changes during operation. This reduces the aging of the oil-paper insulation system. The customer is now able to plan maintenance much more accurately, based on the new data delivered by the ABB product.

ABB's TEC acts as the main, central IED unit of the transformer, ie, as the communication hub for all other IEDs.

Smart-grid-enabled devices

The energy market is undergoing changes that are reshaping the entire transmission and distribution infrastructure.

These models not only calculate hot-spot temperatures according to IEC and IEEE standards, but also model the complete thermal behavior.

COMEM has developed a range of traditional transformer components with digital outputs.

4 ABB's PLC AC500

Various governments have put regulations in place that are intended to increase the proportion of energy derived from renewable sources, like solar photovoltaic and wind farms. Unlike the few, large, centralized generators that have dominated in the past, these sources are numerous, small and widely distributed. The current massive growth in such decentralized power generation is resulting in greater voltage fluctuations in the distribution network and sometimes even violations of the permitted voltage band. Grid communication will, therefore, become critical in the distribution network so that power generation and consumption can be balanced and voltage fluctuations eliminated. In this way, a continuous, reliable and efficient supply of power will be maintained and voltage band constraints will be complied with.

Obviously, transformers play a central role in power transmission and distribution networks and control and monitoring of their operation is, therefore, critical. COMEM S.p.A., an affiliate ABB company based in Italy, has developed a range of traditional transformer components with digital outputs, including an electronic oil level indicator, a pressure relief device, a Buchholz relay and a self-dehydrating air breather → 3. These are equipped with digital interfaces for easy connection to the smart grid and they can be integrated into a single system via a central control unit, such as ABB's PLC AC 500 → 4.

All the devices, whether in standalone mode or integrated into a single system, are compatible with the most common international communication protocol standards. Overall, COMEM's new electronic devices provide improved control and monitoring of the most critical transformer operational parameters by merging individual sensor data into actionable information on the transformer status. Such an integrated system is also perfectly suited to control and monitoring of retrofitted assets.

ABB asset health center

Asset management strives to minimize the total lifecycle cost of assets while fulfilling all commitments regarding service reliability to the consumers. This is a continuous optimization process that requires information from many sources (asset conditions, maintenance plan and costs, replacement plan and costs, etc.) to be combined. This process requires both extensive knowledge of the transformer itself and skills in planning and economics.

Deregulation of the energy markets has brought scrutiny to asset management and remaining life management, adding further to demand for power transformer monitoring. Traditionally, monitoring was performed by standalone units equipped with a few relay contacts to alert operators to changes in conditions. As such, they were very similar to traditional protection devices.

5 The ABB asset health center

The current trend is to route data from monitoring devices via substation SCADA systems to regional control centers. Using industrial protocol communications, such as IEC 61850, the monitoring devices can supply data a few times a day or up to several times per minute. Considering that the number of monitored data points on each transformer is increasing and that the number of monitored transformers is multiplying, this can result in a huge data stream, even for a small utility.

Traditionally, data collected from the monitoring devices has been treated manually. Given the increasing amount of data, this will no longer be feasible. Automated assistance is crucial to help transform the data stream into useful information.

Given the increasing amount of data, manual data collection will no longer be feasible. Automated assistance is crucial to transform the data stream into useful information.

ABB has long experience in engineering, equipment monitoring and systems in the area of power transmission and distribution. The ABB asset health center exploits this experience to provide a comprehensive, intelligent platform that enables utilities to establish enterprise-wide, end-to-end asset management business processes to manage operation and maintenance costs, minimize risk and improve reliability. In other words, it translates the data into actionable information so that the transformer end-user can make the most cost-effective decision possible → 5.

The ABB asset health center combines data from a variety of sources, such as sensors and monitoring devices, as well as information from enterprise resource planning (ERP) systems, data warehouses and the like. The data is assessed using algorithms that can recommend actions based on the current conditions. The algorithms will also rank all monitored assets based on likelihood of failure in order to help the asset owner make the right maintenance and asset replacement decisions.

The ABB asset health center combines data from real-time sensor and monitoring devices, as well as from ERP systems and data warehouses.

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