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Monitoring turns overloading into optimised use

Better control with continuous real-time monitoring

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ASSET MANAGEMENT
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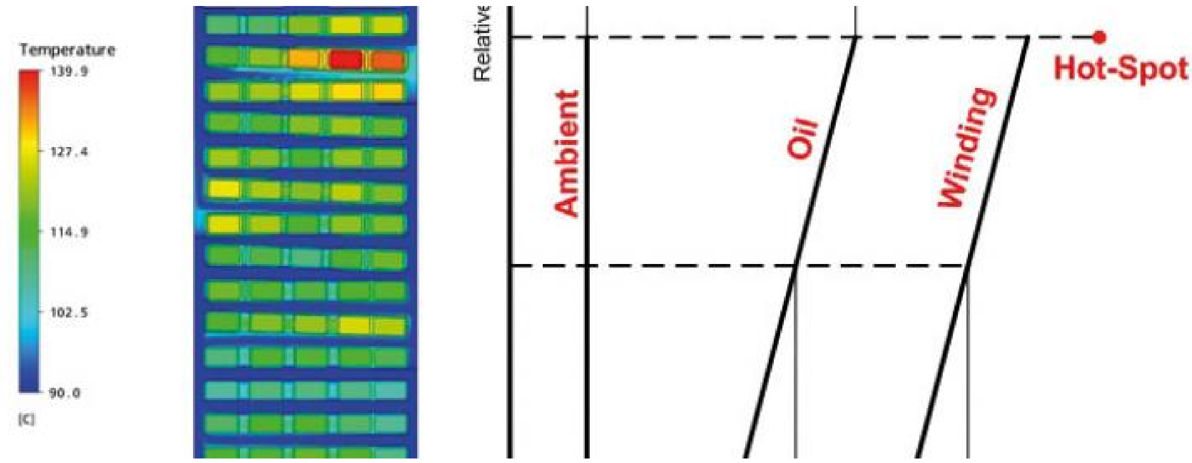
POWER TRANSFORMERS

In today's deregulated transmission market, many operators have little choice but to overload their transformers. Continuous real-time monitoring enables them to control overloads without overheating and ageing their transformer insulations.

1 comment

"Overloading" is by definition undesirable. Its excessive heat over time ages transformers' solid insulation. The paper in the insulation becomes brittle and unable to cope with any of the normal electrical and mechanical wear and tear that is part of the daily grind within a transformer. The ageing process of even thermally upgraded paper, designed to withstand a top-rated temperature of 110°C with normal ageing, doubles for every 7 K rise in temperature. Insulation cannot be repaired. The end of its life spells the end of the life for the transformer.

However, overloading is also necessary and the transformers designed in accordance with international standards can also be overloaded as indicated in loading guides such as the IEC 60076-7. Nevertheless, loads greater than the nameplate rating involve a degree of risk and accelerated ageing, as the IEC loading guide points out. The guide states that long-term overloads age the solid insulation, short-lived overloads impair its dielectric strength, and overloading generally can raise the temperatures of parts like bushing connections so high that it causes thermal runaway.



1__Smart grids require overloading

Such risks have grown steadily greater in the operating conditions particularly noticed in open, deregulated power generation and transmission markets.

« Loads greater than the nameplate rating involve a degree of risk. »

They are becoming ever more pronounced with the introduction of renewable energies, particularly wind power, as part of a demand-led smart grid. It can be practically impossible to plan for fast-fluctuating load cycles. Utilities, seeking to get the most out of their assets, turned to controlled overloading, which calls for careful real-time monitoring and condition diagnosis. “Alstom Grid’s MS 3000 online monitoring system is an interactive monitoring and expert system. It monitors, analyses and diagnoses in real time. And it correlates all the analysed data into a single integrated system – for one or more transformers,” says Bartlomiej Dolata, who manages Design & Engineering Monitoring Systems at Alstom Grid’s Competence Centre in Germany.

Sensors placed in a substation’s transformer or transformers transmit readings to a modular fieldbus system that converts the analogue readings to digital data for storage in a real-time database and a historical database. “The historical database is like a medical record,” says Dolata. “It helps understand how and even why the transformers behave the way they do.” The system’s visualisation software incorporates several modelling algorithms for condition diagnosis and prognosis. “It supports operators by advising what will happen if they don’t take remedial action,” says Dolata, “and recommends what parts or processes to check and what action to take.” The system uses IEC standard 61850 for communication with power systems, which enables reliable and flexible data exchange. “Users can also see what is going on in the meaningful, easy-to-read visualisation software,” says Dolata. “And they can use it to generate reports or get help and advice. Monitoring with MS 3000 is in fact an interactive experience.”

2__Hot spots a hot topic

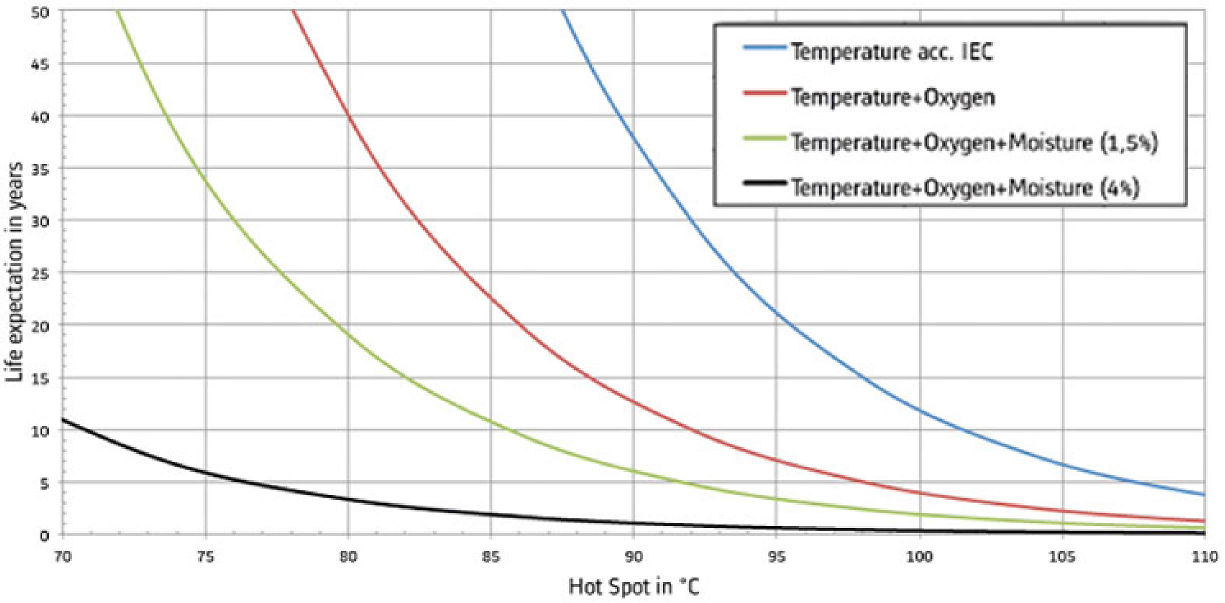
What actually limits a transformer’s overload capacity is the temperature of its winding. Although windings undergo tests to show that their temperature does not rise above industry standards, such tests give the average temperature across all the winding's parts. Its hottest area is known as the "hot spot" and is the real limiting factor. If no fibre optic sensor is installed in the winding, the hot spot cannot be accessed for measurement. And even then measurements yield only the current state of overload. "With modelling you can determine future developments," explains Dolata. New development of thermal model and pilot projects have been started to calculate the hot spot, which in turn enables it to continuously calculate a transformer's permissible overload.

The implemented thermal model based on principles of IEC standards is ample for calculating the temperatures of the hot spot and top oil in normal cyclic loading conditions where the load factor does not exceed the IEC´s standard 1.3 at a maximum hot spot of 120°C and 105°C for top oil temperature. Furthermore, under steady state condition, the modelling used calculates the time needed to overload the transformer in short-time emergency loading condition. However, in order to cope with sharp fluctuations in load or heavy emergency overloads, where IEC 60354 or 60076-7 requires transformers to withstand overloads of 1.5 times the rated current for up to 30 minutes at a maximum hot spot temperature up to 160°C, the thermal model has to be improved and advanced. The use of such continuous overload diagnostic models enables dynamic load management. The importance of continuous overload monitoring is thrown into sharp relief by the fact that the hot spot temperature of 120 °C, although permissible by international standards, nevertheless increases ageing by a factor of 12 compared to running at a temperature of, for example, 98 °C for no upgraded paper insulation.

« Its hottest area is known as the hot spot. »

For high-precision monitoring of continuous overload capacity, the insulation's moisture content should also be factored into the thermal model. As the transformer heats up, moisture migrates from the paper into the oil. When moisture in the oil exceeds 2 %, residual water may become trapped in the paper and then escape in the form of water vapour bubbles. These bubbles would go with the oil flow or get trapped in the winding, causing a possible breakdown of the insulation. Furthermore, water content in the oil of 4 % accelerates ageing by a factor of 20.

Key factors and figures
The lifetime of its paper insulation determines a transformer's life expectancy. Temperature is one of the main factors of cellulose chain ageing. The figure above shows the sensitivity to temperature of non-thermally upgraded paper in an oxygen-free environment. Its life expectancy is reduced at even faster rates if oxygen or moisture is present. Overload is the main factor causing high temperatures. To determine a transformer's overload capacity its hot spot has to be calculated. The MS 3000 monitoring and diagnostic system incorporates a thermal model to assess a power transformer's overload capabilities within the limits set by the IEC.



Life expectation for insulation paper versus hot spot temperature

IEC operation cycle loads

	Normal cyclic loading – High load cycles offset by low load cycles	Short-time emergency loading – Unusual heavy loads of durations shorter than transformer's thermal time constant (t ≤ 30 minutes)
Hot spot temperature	<120 °C ->ageing rate up to 12	<160 °C (oil bubble temp. 140°C)
Top oil temperature	<105 °C	<115 °C
Maximum load factor	1.3 (130%)	1.5 (150%)

IEC operation cycle loads

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EXPERTS

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