EXTEND THE SERVICE LIFE OF TRANSFORMERS

MAINTENANCE-FREE DEHYDRATING BREATHERS EXTEND OPERATING TIMES AND SAVE COSTS

Photo: Maschinenfabrik Reinhausen

Abstract

Power transformers are complex and critical components of power transmission and distribution systems. The continuous extension of operating times in conjunction with an ever-increasing current density impact power transformers and lead to increased demands on quality and reliability as well as a reduction in the life cycle costs of transformers and their accessories. Simple and practicable solutions are therefore required when converting and retrofitting transformers.

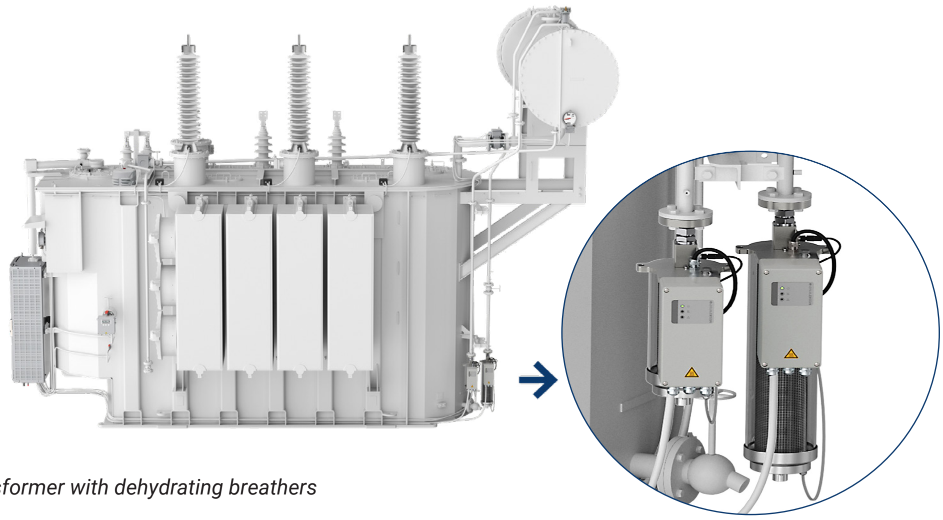
Comparison of a conventional (left) and a maintenance-free dehydrating breather (right).

The service life of transformers is closely linked to the service life of the oil-paper insulation system because if the mechanical stability of the oil-paper insulation is lost, there is a risk of electrical failure and therefore overall failure of the transformer. In addition to the influencing factor of temperature, humidity has increasingly proven to be an important catalyst for the aging process of transformers.

In order to ensure the longest possible service life, the primary aim is therefore to reduce this aging factor or to avoid its influence from the outset. These effects can be achieved through the use of dehydrating breathers for the oil expansion tanks which can therefore have a significant influence on the technical service life of transformers.

In typical applications conventional dehydrating breathers filled with silica gel are still used in many places today. The adsorption capacity of the desiccant is used up over a period of 3 – 12 months. The desiccant must then be replaced, as the silica gel will be completely saturated with water and therefore no longer able to absorb any additional moisture. Together with the disposal of the old and acquisition of new desiccant, the necessary periodic visual inspections and maintenance in regard to these breathers represent considerable cost factors.

In contrast, maintenance-free dehydrating breathers avoid frequent replacement of silica gel by measuring the humidity level of the air in the pipe system and forward the results to control unit. Thanks to a self-learning algorithm, the control system determines the exact time window in which the transformer "exhales" in order to regenerate the silica gel during this phase, then “bakes out” the absorbed water and thus makes the dehydrating breather ready for a new drying period. This system works autonomously, significantly reducing maintenance visits and the associated costs.

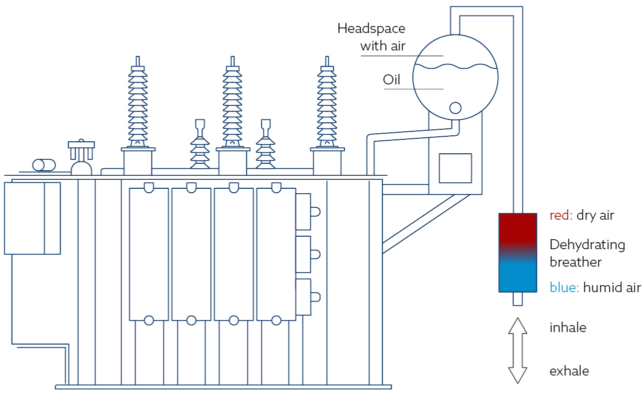


Transformer with dehydrating breathers

The Central Function of Dehydrating Breathers in Transformers

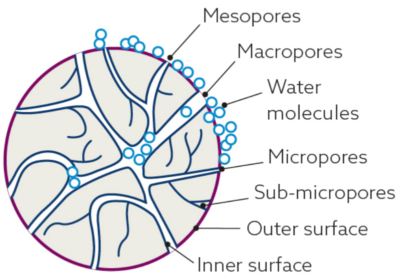
Moisture threatens the stability of oil-paper insulation and therefore the service life of power transformers. It is not only a component of the ambient air that meets the insulating oil in the transformer's expansion tank but is also itself an aging product of the insulation paper. The absorption of moisture follows the thermally induced cycles of expansion and contraction of the oil volume caused by operating temperature fluctuations in the transformer.

By design, each transformer has at least one expansion tank that is connected to the main tank to provide a compensation reservoir for the oil volume during temperature fluctuations. During these thermal cycles, efficient ventilation is crucial for controlling the changing levels in the expansion tank. Since the ambient air has a higher relative humidity than the insulating oil inside, dehydrating breathers are essential for dehumidifying the ambient air before it enters the expansion tank.



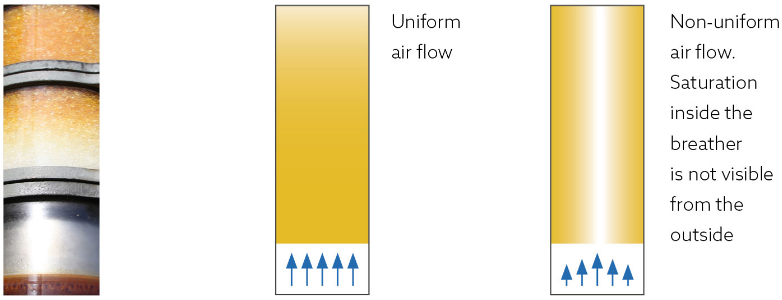
Typical setup for a free-breathing power transformer with dehydrating breather

Visual color change does not reliably indicate whether the gel is saturated, as the flow may be uneven. The condition of the silica gel inside the container is not visible from the outside. The sensor in the maintenance-free breather measures the current humidity in the transformer. The control system starts the regeneration of the silica gel at the right time, namely when the transformer exhales.



Typical structure of silica gel

Photo: Maschinenfabrik Reinhausen



Conventional dehydrating breathers with non-uniform air flow

Most transformers therefore make use of dehydrating breathers which contain silica gel to absorb moisture from the incoming air. The silica gel desiccant used in dehydrating breathers is characterized by its very porous structure which enables effective adsorption of water molecules. This high adsorption capacity with an internal surface area of several hundred square meters per gram makes it possible to effectively bind water molecules and remove them from the incoming air.

Silica gel in conventional breathers typically contains an additive that changes color from clear to orange to indicate when the silica gel is saturated and must be replaced.

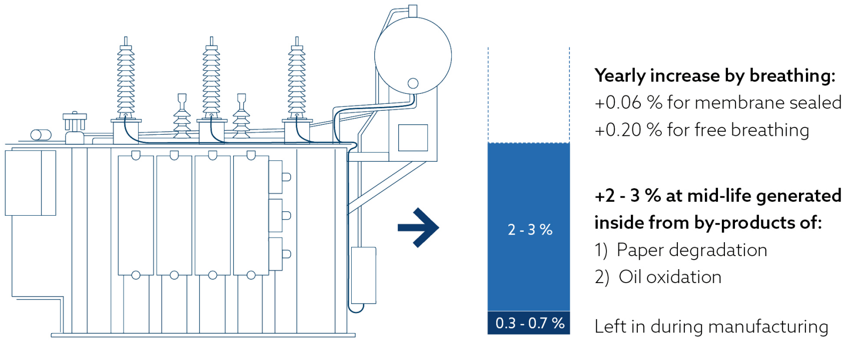
In a typical free-breathing transformer, humid air flows from the outside via the de-hydrating breather into the expansion tank of the insulating oil. In the inlet area of the dehydrating breather, the air reacts with the silica gel, which adsorbs the moisture. This interaction causes the desiccant in this area to become saturated more quickly. Over time, this saturation zone in the dehydrating breather expands further.

Conventional dehydrating breathers with color change from orange to colorless

The silica gel should be replaced at the latest when the color changes by 2/3 of the column in order to prevent unacceptable moisture from entering the transformer. Furthermore, an uneven color change in conventional dehydrating breathers generally indicates leaks between its individual chambers. Since the air flow through the dehydrating breather is often not uniform, the silica gel inside can become saturated and therefore no longer be able to absorb moisture even though this is not visible from the outside.

A color change starting from the top indicates that the insulating oil has already reached high relative humidity values due to the degradation of the paper and possibly late maintenance of the dehydrating breather and indicates that the transformer exhales moisture when heated.

Percentage of water by dry weight of paper accumulated over transformer lifetime



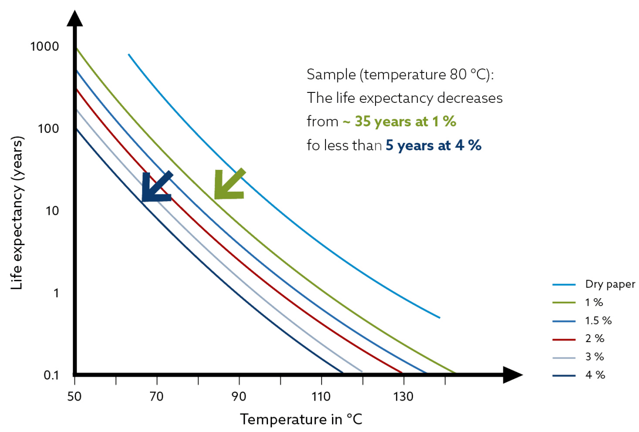
Overview of typical sources of moisture in a transformer [1]

Why Moisture in Paper Insulation Reduces the Life Expectancy of Transformers

Maintenance cost for dehydrating breathers can be high, and with negligent maintenance and the resulting increased ingress of moisture into the transformer, the use of such components can cause very costly and sometimes irreparable damage that cannot always be detected immediately. Excessive moisture in the paper insulation therefore considerably shortens the service life of transformers and optimum dehumidification is crucial for the trouble-free operation of transformers.

An important aspect in this regard is the irreversible aging process of the paper insulation for which, in addition to temperature, water plays a significant role since moisture considerably weakens the insulation system, and electrical and mechanical strength is reduced with increasing water content.

Expected service life of solid insulation and its dependence on humidity and temperature[2]



Expected service life of solid insulation and its dependence on humidity and temperature [2]

Studies have shown, for example, that at an operating temperature of 80°C and 1% moisture content in the paper insulation, a transformer's service life is around 35 years. At 4% moisture, however, the service life could be reduced to just 5 years.

The aging of transformers is primarily influenced by operation and the associated changes in the oil-paper insulation. A deterioration in the insulation properties, characterized by a reduction in electrical and mechanical strength, is a clear sign of advanced aging.

Photo: Maschinenfabrik Reinhausen

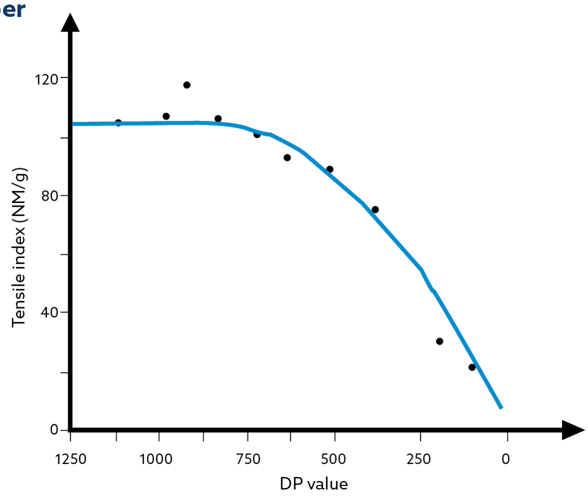
Insulation Systems in Transformers

The insulation system of a transformer essentially consists of insulating oil and insulating paper. Insulating oil fulfills a critical dual role: it dissipates the heat generated during operation and at the same time serves as part of the insulation system for the high-voltage-carrying parts of the transformer. The oil must meet stringent requirements, including high dielectric strength, chemical stability and good thermal conductivity – even at highly fluctuating temperatures.

Insulating paper is made of robust cellulose. In combination with the insulating oil, this material contributes to both the electrical insulation and the mechanical stability of the transformer active part. The number of rings in the chains of the cellulose molecules, the so-called degree of polymerization (DP), describes the aging condition of the solid insulation. A new paper typically has a DP value of 1200 to 1400.

The DP value and the tensile strength of the material also indicate the degree of aging: When a value of 200 is reached, the brittleness of the paper increases dramatically. As the tensile strength of the paper weakens, the risk of the transformer failing in the event of grid fluctuations also increases. For this reason, a poor condition of the cellulose is often regarded as an indicator of the end of the transformer's life, as it is not practical to restore or replace the paper insulation.

Tensile strength as a function of the DP value of the insulation paper



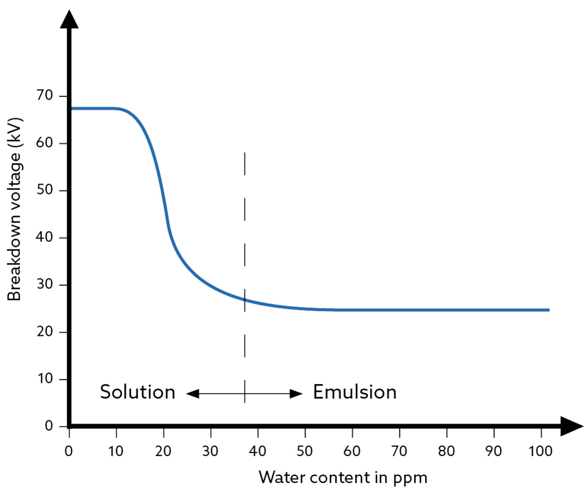
Tensile strength as a function of the DP value of the insulation paper

The aging of transformers depends in particular on the temperature and the presence of water in the oil. Water significantly influences the aging process of cellulose through hydrolysis. Cellulose is a highly hygroscopic material and can therefore absorb a large amount of moisture, which further accelerates the aging process. Drying is therefore essential before using cellulose as an insulation medium in order to minimize the moisture content. In the case of a new transformer, this is well below 1% after drying.

The insulating oil serves as a carrier medium for water during operation. Although the aging of the oil is hardly affected by water, the electrical properties of the oil suffer as a result. Due to the increasing water content, the breakdown voltage of the oil decreases from 65 kilovolts (kV) to 25 kV. This value does not deteriorate further as the oil ages.

Appropriate measures to reduce the absorption of moisture can help to slow down the aging process and maintain the availability of the transformer. This is where dehydrating breathers come into play, which reduce the moisture from the ambient air in the transformer.

Effect of water content in ppm on the breakdown voltage in kV of mineral oil



Effect of water content in ppm on the break-down voltage in kV of mineral oil

How Maintenance-Free Dehydrating Breathers Make Transformers Last Longer

The service life of expensive, important transformers that can only be produced with long order times can be significantly extended by using maintenance-free dehydrating breathers. They automatically regenerate the used silica gel and thus relieve the operator of all maintenance costs for the dehydrating breathers.

In addition, humidity and temperature sensors can be used to analyze transformer operating cycles to determine the optimum time for regeneration, and the bake-out process can be initiated automatically if a saturation limit is exceeded.

A self-learning algorithm can also be used which determines the correct time to start the bake-out process to ensure that the transformer is in an "exhale" phase so that no moisture can enter the expansion tank. Additional data recordings can also provide more detailed information about the operation of the transformer. More than 100,000 units of dehydrating breathers have already been installed worldwide and are proving their worth even under extreme climatic conditions.

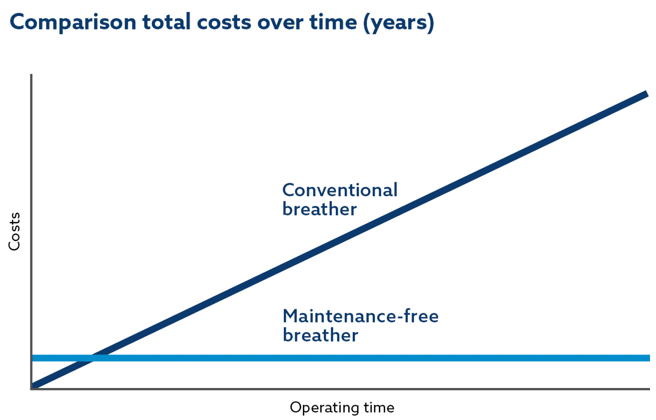
How Transformers Can Be Retrofitted in a Future-Proof and Cost-Efficient Way With Maintenance-Free Dehydrating Breathers

The devices can be easily installed on transformers with conventional dehydrating breathers in accordance with DIN 42562 / EN50216-5, as they do not require a large installation space and can be connected to any data platform with little effort.

They are primarily aimed at operators of electrical systems, energy suppliers and industrial companies. As a rule, their service or asset managers are looking for reliable dehydrating breathers to retrofit their existing transformer fleet.

The Advantages of Maintenance-Free Dehydrating Breathers at a Glance:

+ Actively protects the insulation medium from moisture
+ Reduces operating costs and increases operational reliability
+ Condition-dependent and self-learning algorithm
+ Compliance with the IEC 60076-22-7 standard at all times
+ Significantly higher efficiency than market competitors
+ Easy to integrate into ETOS® (Embedded Transformer Operating System)
+ Simple retrofitting to existing equipment
+ Operating status display (LED)
+ Test function (button for triggering the test for heating, sensors and displays)
+ With app for easy data readout



Comparison of investment and operating costs for conventional and maintenance-free dehydrating breathers

Maintenance-Free Dehydrating Breathers Pay for Themselves After Just a Few Years

Maintenance-free dehydrating breathers significantly reduce moisture absorption in the paper insulation - as the dehumidification performance is higher than that of conventional dehydrating breathers – and can extend the service life of transformers by up to 50%.

Taking into account acquisition, maintenance and servicing costs as well as the efforts involved, the cost advantage of maintenance-free compared to conventional dehydrating breathers can be up to 65% and, despite higher initial investment, the maintenance costs saved usually lead to a return on investment (ROI) after less than three years.

Investing in maintenance-free dehydrating breathers also helps to achieve ambitious sustainability targets since there is no need to dispose of the used silica gel and the elimination of regular maintenance trips can lead to a significant reduction of an operator's CO_2 footprint of up to 92%.

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Photo: Maschinenfabrik Reinhausen

Maschinenfabrik Reinhausen
Falkensteinstraße 8
93059 Regensburg
Germany

Your contact
Herbert Doll
h.doll@reinhausen.com

reinhausen.com

References

[1] CIGRÉ Technical Brochure 349 "Moisture equilibrium and moisture migration within transformer insulation systems", 2008

[2] Aging of Oil-Impregnated Paper in Power Transformers, Lars E. Lundgaard, Walter Hansen, Dag Linhjell, and Terence J. Painter, IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 19, NO. 1, JANUARY 2004