The moisture in the insulation has a great impact on the life of the insulation and is not usually a consideration in loss-of-life calculations although it is always present in the insulation system

Benefits of smart breathers

Transformers are one of the key assets and the most expensive equipment in electrical utility companies. The life of the transformer generally depends on the longevity of solid insulation. Of the several factors that determine the life expectancy of solid insulation, those that have the greatest effect are temperature, moisture, and oxidation. The temperature of solid insulation is the primary factor in transformer ageing if moisture in the insulation is at a normal level (≤ 0.5 %). The moisture in the insulation also has a great impact on the life of the insulation and is not usually a consideration in loss-of-life calculations, and it is always present in the insulation system. The rate of thermal ageing of paper is proportional to its moisture content. Ageing calculations are based on ≤ 0.5 % moisture content with a corresponding ageing acceleration factor of one. If the water content of the paper is doubled, its life in terms of mechanical strength is halved. Moisture in solid insulation can also lead to bubble formation because it reduces the bubble evolution temperature and reduces the dielectric strength of the insulation system.

ABSTRACT

The life of the transformer generally depends on the longevity of solid insulation. Of the several factors that determine the life expectancy of solid insulation, those that have the greatest effect are temperature and moisture. Breathers are safety barriers for moisture for transformers. Traditional breathers are a low-cost solution, but they require maintenance and often use toxic materials. Smart breathers, on the other hand, require no maintenance, which means that there are no maintenance-associated costs. Additionally, smart breathers offer features like customisation of the silica gel regeneration levels, data logging and self-analysis.

KEYWORDS

cost analysis, regeneration, silica gel, smart breather, transformer breathing

The colour of the silica gel crystals indicates when the silica gel should be replaced, and it is done every 6 - 12 months for traditional breathers

At 0.5 % insulation moisture values, the bubble evolution temperature is above 200 °C, well above the 180 °C hot spot limit proposed [1]. However, at the insulation moisture value of 1.5 %, the bubble evolution temperature is about 157 °C, therefore the hot spot should be limited to the temperature of 150 °C to reduce the risk of a failure due to the generation of gas bubbles.

The major contributors to the level of moisture in the insulation system are residual moisture from manufacturing, commissioning and maintenance processes, moisture produced by the ageing of cellulose, and moisture from the atmosphere. This paper discusses reducing moisture ingress from the atmosphere.

Liquid preservation systems limit the exposure of the transformer insulation structure to the atmosphere while allowing thermal expansion and contraction of the liquid due to load and ambient temperature variations. These liquid preservation systems are:

- Sealed tank – A sealed tank system uses a gas space above the insulating liquid level of the main tank to absorb volume fluctuations. The gas space can be static or regulated. When it is static, the gas space is normally initially filled with nitrogen, but if the pressure drops below the maximum negative operating pressure, the atmospheric air is drawn through a pressure-vacuum bleeder valve and into the gas space. A regulated system uses a system in which a positive pressure of inner gas, usually nitrogen, is maintained from a separate source to keep the transformer sealed from the atmosphere. Both systems are normally used in North America.
- Conservator tank – A conservator tank is an auxiliary tank partially filled with the insulating liquid and connected to the completely filled main tank. It uses the gas space above the liquid for volume fluctuations. Conservator tanks can be free breathing or isolated from the atmosphere using a rubber air cell or diaphragm. This system is more used with a rubber air cell or diaphragm for bigger transformers generally. A conservator tank with the free-breathing system is normally used for smaller power transformers outside of North America.

The conservator tank provides space for the expansion and contraction of the insulating liquid. As the insulating liquid heats, it expands, the liquid level rises, and air leaves the conservator tank. When the oil cools, it contracts, the liquid level falls, and fresh air from the atmosphere enters the conservator tank. This air contains moisture that, for free-breathing transformers, can be transferred to the insulating liquid and then to the solid insulation. For isolated transformers, the moisture can condensate and become free water inside the rubber air cell. If the rubber air cell ruptures, this free water can fall inside the main tank and cause a catastrophic failure. Moisture may also accelerate the ageing of the rubber air cell.

For these reasons, both types of conservator tanks are generally fitted with a breather. A breather is an accessory of liquid-immersed power transformers attached to the conservator tank. They serve as the breathing point of the transformer. The breather contains silica gel crystals which have a tremendous capacity of absorbing moisture. As air passes through these crystals in the breather, the moisture in the air is absorbed by the silica gel crystals. Therefore, the air reaching the conservator is quite dry.

There are two types of breathers on the market today, traditional and smart breathers.

Smart transformer breathers use the silica gel-like traditional breathers and a heating unit that regenerates the silica gel when it becomes saturated

Traditional breathers

Traditional breathers contain silica gel crystals. The colour of the silica gel crystals is generally used as an indicator of when the silica should be replaced. It is dark blue, orange, or translucent when dry; when the gel absorbs moisture and becomes saturated, the colour changes to pink, green, or white, respectively (see Fig. 1). The dark blue silica gel contains cobalt (II) chloride, which is toxic and carcinogenic and has been reclassified in some places as a toxic material. Traditional breathers require continual maintenance taking note of the gel colour changes indicating the need for replacement. The silica gel can be regenerated or discarded once the colour changes. Typically, it is discarded because it is cheaper to replace than to regenerate. Traditional breathers are generally a cost-effective solution for initial installation but require frequent servicing depending on the moisture levels in the atmosphere, thereby incurring additional cost. When the silica gel is fully saturated, it no longer absorbs atmospheric moisture as it enters the transformer, and so the silica gel must be replaced. It is not uncommon for atmospheric moisture to enter the transformer through a fully saturated traditional breather that is past its maintenance requirement.

Smart transformer breathers (self-regenerating type)

Smart transformer breathers use the silica gel-like traditional breathers and a heating unit that regenerates the silica gel when it becomes saturated. They also use a moisture sensor to determine when the silica gel becomes saturated. The smart breather can be set to regenerate on relative humidity (R.H.), parts per million (PPM), or time thresholds to start the regeneration process to remove the water. The graphic user interface allows for easy customisation of regeneration settings and remote communication. Learning algorithms are used to identify when the transformer is inhaling or exhaling by tracking pressure changes in the conservator. If the algorithm senses a positive pressure, it identifies the transformer is exhaling, so that it learns the breathing pattern of the transformer and picks an exhaling time for future regeneration of the silica gel as necessary (see Fig. 2). In smart breathers with two canisters, the regeneration process takes place in one of them while the other is in operation. During regeneration, there is a solenoid that closes to prevent any moisture expelled from the desiccant rising into the conservator piping.

A data logging option allows for long-term trending of moisture readings and regeneration cycles, and all data can be accessed remotely.

No additional maintenance is required until the silica gel losses its ability to absorb moisture. The test of wetting for 6 hours at 35 °C and 95 R.H., and regeneration at 105 °C and 0 R.H. for 100 cycles performed to dark blue, orange, or translucent silica gel, showed that the silica gel continues to both adsorb and release moisture at the same rate. The tests were planned for 60 cycles, but after seeing no change in the silica gel ability to absorb moisture, it was decided to extend the tests to 100 cycles observing the same results, although, their ability to change back to their original colour condition diminished somewhat with each cycle. Other studies have shown a reduction of 20 % in the silica gel ability to absorb moisture after 100 cycles but did not change much after 500 cycles. The silica gel works in the temperature range from 0 – 100 °C, but it performs best at room temperatures and medium to high humidity (60 – 90 R.H.). There are other options for desiccant, one of them with better ability to absorb moisture but requiring higher temperatures to be regenerated. However, as a direct replacement for traditional and smart breathers, silica gel is the most cost-effective at this time.

Sensors with the smart control algorithm are used to determine when the best time is for the silica gel regeneration

Figure 1. Colour change due to saturation of the silica gel; the breather on the right is still able to absorb water; the breather on the left is saturated with water and requires maintenance

Breathers are sized according to the estimated air volume transformers inhale and exhale during operation, depending on the volume of the transformer oil. Smart breathers typically use a 10 to 15-year silica gel lifecycle with an estimate of 1 to 2 regenerations per month for most climates, with a typical regeneration time of 3 hours and 360 W power consumption during a regeneration cycle.

Both traditional breathers and smart breathers work well. Smart breathers

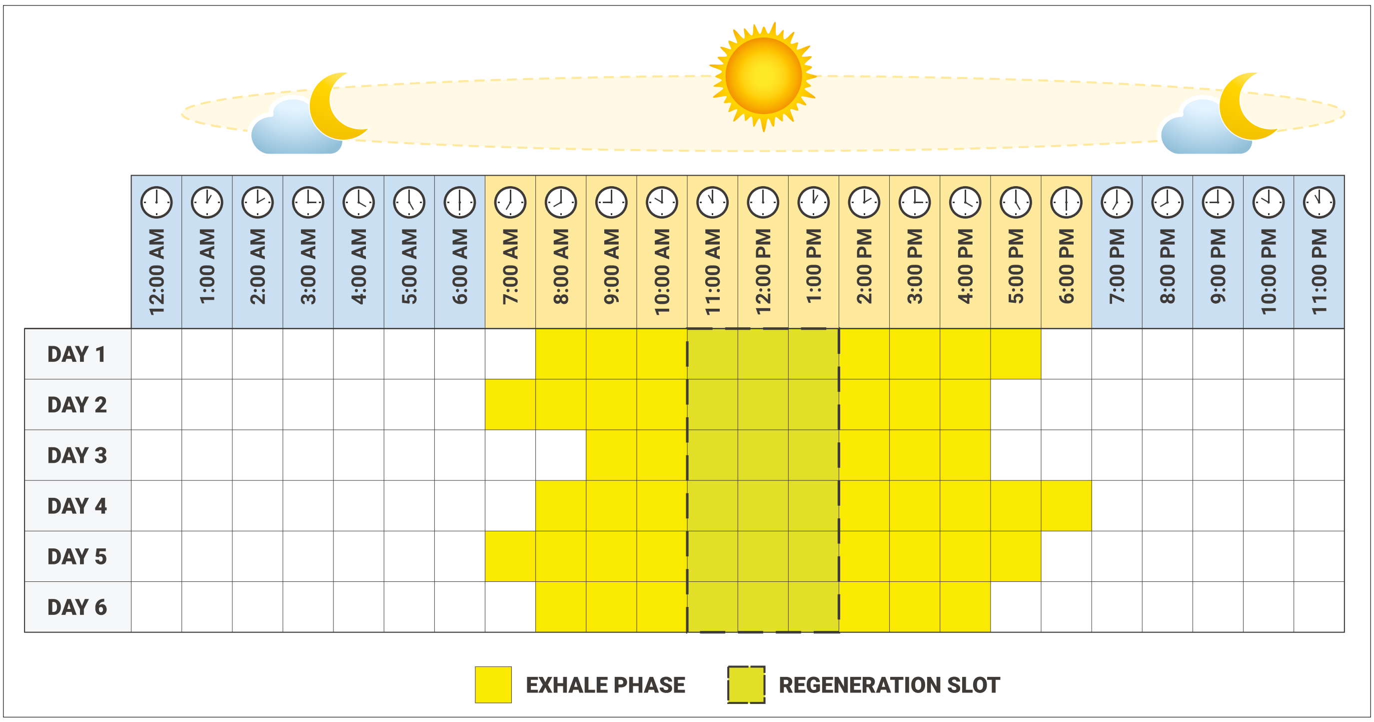


Figure 2. Breathing pattern for smarter regeneration

Table 1. Advantages of a smart breather over the traditional breather

The Smart Breather Advantage

Feature	TRADITIONAL BREATHERS	SMART BREATHERS
Initial selling price	~$500	~$2000
Additional maintenance costs	Crew + materials + time	None
Silica gel maintenance	6-12 months	None required
Remote accessibility	✗	✓
Graphical User Interface	✗	✓
Data recording	✗	✓
Preforms self analysis	✗	✓

Although the initial costs of smart breathers are higher, mantainance costs are significantly lower compared to traditional breathers

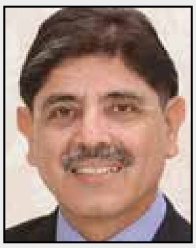
have a larger upfront investment than traditional breathers. However, traditional breathers require constant maintenance, and, if overlooked, will allow ingress of moisture in the oil preservation system. This may cause ageing acceleration of the insulation system and / or increase the risk of a possible failure.

Another benefit of using smart breathers has to do with the environment, while silica gel is biodegradable, smart breathers can be used as a solution to reduce a footprint on environmental issues caused by the disposal process of the silica gel.

Bibliography

[1] IEEE C57.91 2011 *IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators*, 2012

Author



Emilio Morales Cruz is a Technical Application Specialist in transformer applications at Qualitrol Company LLC. His main focus is to support Qualitrol's solutions in comprehensive monitoring for transformer applications. Emilio has a Bachelor of Science degree with a major in Electro Mechanical Engineering. He is a senior member of IEEE, a member of ANSI, CIGRÉ, USTAG, and a US nominated expert on IEC TC14. He actively participates in different task forces in the IEEE Transformer Committee and CIGRÉ. He has spent his entire career in the power transformer manufacturing industry. He has had over 30 years of experience in design, which includes transformers up to 500 MVA and 500 kV as well as furnace and rectifier transformers, and different type of reactors. Emilio previously worked with GE-Prolec, Ohio Transformer, Sunbelt Transformer and Efacec Power Transformers.

emorales@qualitrolcorp.com

+1 585 643 3732

Belton, TX