MOISTURE MANAGEMENT IN POWER TRANSFORMER: WHY IT MATTERS?

Moisture is the enemy for transformers as it will reduce the dielectric strength, cause contamination and lead to deterioration of insulation system. In the long run, excessive moisture accelerates the ageing of paper insulation and weakening the hydrogen bonds of molecular chain of the paper fibre. For this reason, it is important to maintain transformers in a reasonably dry state. This article will look at holistic view of moisture management for power transformer and the effective solution to reduce the moisture content and thus extend the reliability of transformer operation.

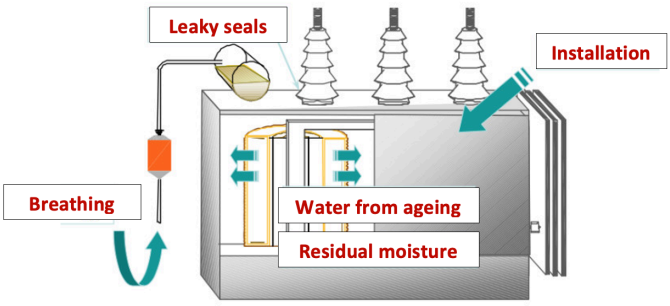
INTRODUCTION

Moisture management in power transformer is a great concern to the asset manager. The presence of moisture at high temperature can trigger the release of free gas bubbles and creating an immediate threat to the dielectric integrity of the insulation structure that can seriously affected the transformer.

High loading event can cause excessive moisture from the paper insulation to move into the oil. This then results in the relative saturation of water being very high causing the formation of free moisture, which will affects the dielectric properties especially around the active parts resulting in discharges that can cause long-term damage. Free moisture also causes rusting of the metal parts like the tank, pipes and radiators. Therefore, effective management of moisture is important for the safe operation of in-service transformer.

SOURCE OF MOISTURE IN TRANSFORMER

The moisture can entered in power transformer in different ways; internally and externally. Water can come from outside during transformer manufacturing process and transportation. In free breathing transformer, small amount of water enters into the transformer during breathing. During in service, water is created as transformer ages as a by-product.



Possible sources of moisture in transformer

Residual Humidity Remaining From Factory Drying Process

In factory, the drying process will attempt to remove a much of the water as possible but there will always be a certain amount of water remaining in the transformer. That is why the quality control process during winding installation, oil filling and dry out process is very important in maintaining low water levels.

Drying process in factory

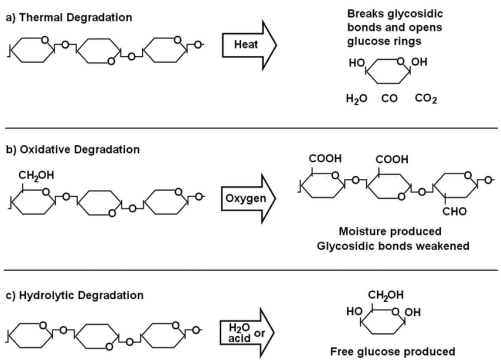
Air From Atmosphere During Normal Breathing

From the time the transformer leaves the factory, it will start absorbing water from the atmosphere especially for transformers which are transported without oil and are filled under pressure with nitrogen or dry air. It is important that steps are taken to reduce the exposure of the internals of the transformer to water and this must be maintained until it is ready on-site for the oil filling process.

Desiccant drying is used for free-breathing transformers but eventually small amount of water may also absorbed during breathing process. Most transformers are now installed with a conservator air cell which forms a barrier to the external environment and prevents air from entering the transformer. Leaks on transformers are another place where water can enter the transformer. Leaks must be identified as soon as possible and rectified at the next available opportunity.

Leaks in transformer should be rectified at early stage

Byproduct of Oil-Paper Decomposition

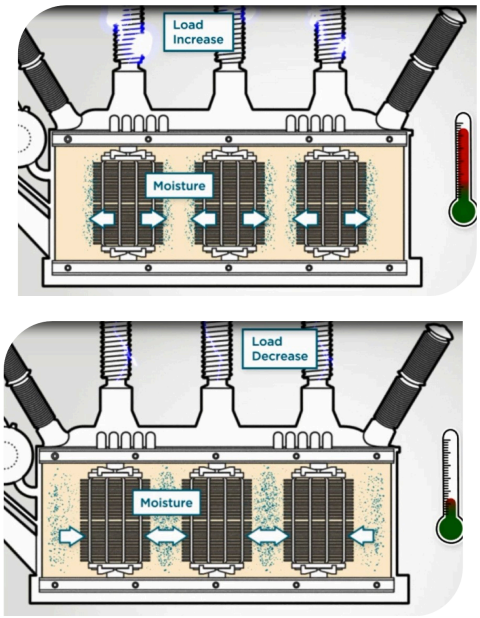


Decomposition of cellulose chain produce water molecules

Transformer insulation consists of paper and pressboard elements which provide the mechanical stability of the insulation. The main component of paper and pressboard is cellulose, consists of glucose molecules which are linked and form a chain. Under electrical and thermal stresses, these long chains are decomposed and produce water molecules.

DISTRIBUTION OF MOISTURE IN TRANSFORMER

Distribution of moisture in transformer is not uniform and follows the thermal gradients. In normal operation, there still are temperature differences and therefore different moisture contents in the various parts of the insulation structure. Since cellulose paper has a much greater affinity for water than does the oil, majority of the moisture in the transformer insulation system resides in the solid insulation (paper and pressboard) than the oil.



Distribution of moisture in power transformer

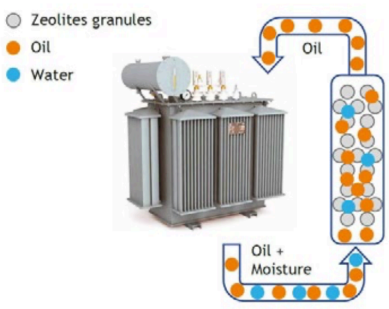
The water does not remain at the same concentration in the insulation but rather it is continuously migrating between the solid and liquid insulation depending on operating temperature. When the transformer is energized, the water is forced from the paper into the oil and begins to migrate to the coolest part of the transformer and the site of the greatest electrical stress. As load decrease the temperature decrease as well, and the moisture is absorbed again by the paper insulation.

MOISTURE DRYING PROCESS

The dryness and ageing condition of the oil-paper insulation are key factors in both the short- and long-term reliability of a power transformer. Thus, drying of the wet insulation is an important measure to extend the life of a transformer. There are several methods for drying the insulation system of transformers which substantially differ in the applied set of equipment, the extraction method and the applied media and process temperatures. Depending on the applied method the required process periods are different to achieve equal results.

Drying of transformers can be achieved either through on-line or off-line techniques. On-line techniques have the advantage that the transformer remains in service all along the drying process. Meanwhile, off-line techniques have the advantage of providing a better drying quality of the solid insulation within a relatively short time.

Molecular Sieve

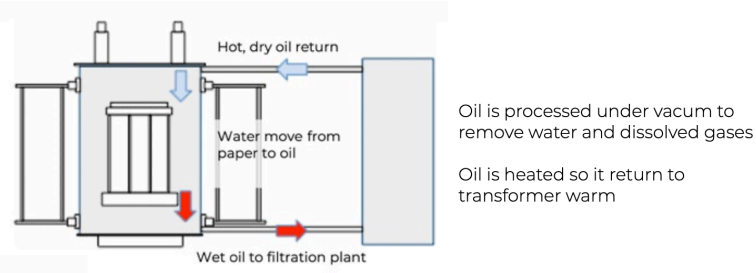


Drying process using molecular sieves

Molecular sieves are well established method for online drying process. It is a material that have characteristic of binding dissolved water from the transformer oil and gradually drying the oil. A molecular sieve can adsorb up to 20% of its own weight in water. Due to the limited drying affect on the solid insulation, it is usually advised to use molecular sieves to keep transformer dry (new transformers or old transformers after an off-line drying) rather than drying out a wet transformer.

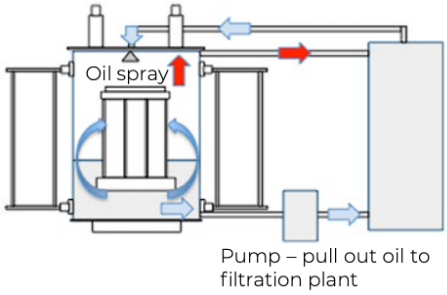
Hot Oil Circulation

Hot oil circulation process commonly includes filtering and removal of dissolved gasses and moisture from the insulating oil. In this method, the oil is constantly drawn off through the lower tank valve, passes through an oil processing plant, then returns into the upper part of the transformer through an upper valve.



Hot oil drying process

Vacuum Drying

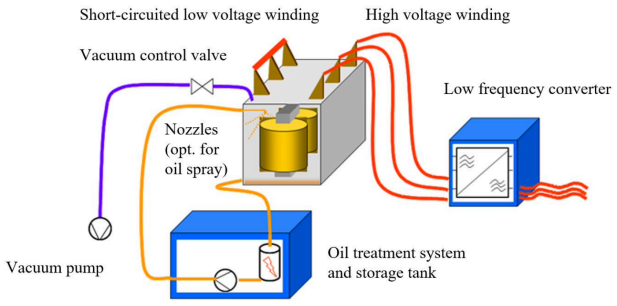


Hot oil and vacuum drying process

In vacuum drying technique, the hot oil circulation is used in conjunction with vacuum applied to the transformer. The techniques used include of hot oil plus vacuum; hot oil plus vacuum plus hot oil spray; hot oil plus vacuum plus a cold trap. The pump helps pull oil out of the vacuum and push it to the purifier whereas the oil spray pour the oil over the coil to transfer the heat

Low Frequency Heating

The low frequency heating technique requires the transformer's low voltage winding to be short- circuited and the high voltage winding to be connected to the LFH unit. The combination of the hot oil and the current heating ensures that all parts of the transformer attain the required temperature levels in short time. Once the target temperature is reached and the temperatures inside the transformer are stabilized, the oil is drained into a separate tank and vacuum is applied.



Low Frequency heating method

Vapor Phase

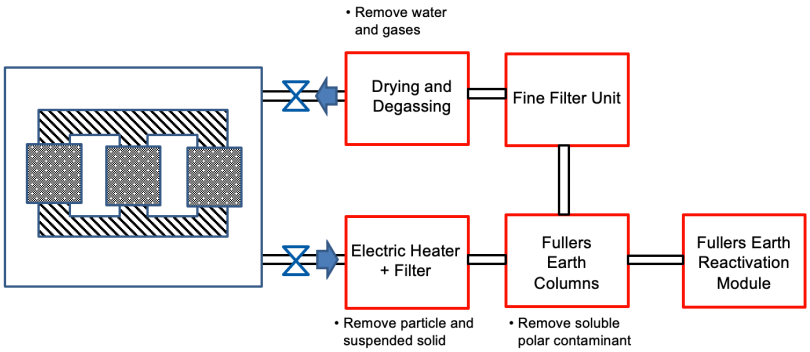
Vapor phase drying plant

Vapor phase drying method provides the fastest drying process and effective to clean the active part especially during the manufacturing process. The active part is placed in a vacuum chamber (for VPD at site, the transformer tank is used as vacuum chamber). The liquid solvent, a kind of kerosene oil, is adopted as the heat carrier and is vaporized into solvent vapor by an evaporator. The applied solvents are more efficient for water absorption compared to transformer oil which leads to shorter process periods.

Reclamation / Regeneration Process

IEC defined reclamation as "a process that eliminates or reduces soluble and insoluble polar contaminants from the oil by chemical and physical processing". These contaminants are mostly oxidation products from the solid insulation, and especially the oil. Chemical and physical processing is typically a combination treatment using sorbent material and oil filters.

Transformers may be regenerated off-line or on-line using a mobile unit containing a Fuller's Earth mixture, or clay. The oil is warmed and pumped through this media. The clay is a highly polar, granular matrix made from natural bentonite, sepiolite or montmorillonite, mixed with metal oxides, and "activated" (which may involve thermal dehydration and partial dehydroxylation) in order to increase the polarity, surface area and catalytic activity of the material. During oil reclamation, the material removed from the oil in approximate order, are any solids, polar material such as acids, then alcohols, aldehydes, ketones, esters, soaps and aromatic material.



Oil reclamation process

Next Issue

Transformer Transportation and Handling: Beginning of Future Reliability

Its Coming Back !

TNB Labs MasterClass Training

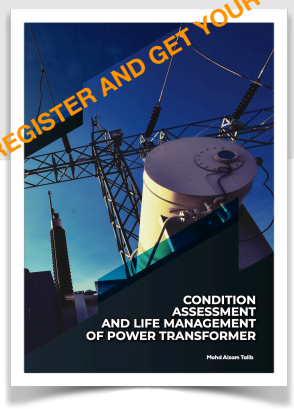
'Life Management of Power Transformer'

7-10 August 2023, Le Meridien Hotel, Putrajaya

This 4 days training will helps the participants to understand the principle design and construction of transformer, operation and maintenance, diagnostic testing, condition and life assessment of transformer as well as failure prediction.

Other than classroom theory and case studies, the participants will experienced hands-on session and lab tour of TNB Labs facility@TNB Research Centre. The participants will also receive one copy of technical book entitle "Condition Assessment and Life Management of Power Transformer".

For more detail information, please contact:
nawal.azhar@tnb.com.my / aizam.talib@tnb.com.my



Editor:

Ir. Ts. Dr. Mohd Aizam Talib
aizam.talib@tnb.com.my

TNB Labs Sdn Bhd
No.1, Lorong Ayer Hitam,
Kawasan Institusi Penyelidikan,
43000, Kajang Selangor