Moisture in Power Transformer: *How to Manage It?*

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MOISTURE is a major problem for the paper insulation system of a transformer. The effect of moisture on the paper insulation is the change in the dielectric constant. The sources of moisture in transformers are residual moisture in the bulk paper insulation which is absorbed from the atmosphere and the ageing decomposition of cellulose and oil. When this happens, it will affect the dielectric property of the transformer oil. Poor dielectric properties will result in electrical and thermal breakdown of the oil. It also reduces the oil flow because the density of the oil increases. This will increase the temperature of the transformer due to poor heat dissipation.

The following chart shows the effect of the dielectric breakdown voltage with respect to temperature at different moisture level. It can be seen that the dielectric breakdown voltage of the insulation reduces as the moisture content increases. On the other hand, the breakdown voltage increases when temperature increases. The chart explains why transformers often fail in the mornings or evenings, and why highly loaded transformers with high moisture content are less likely to fail.

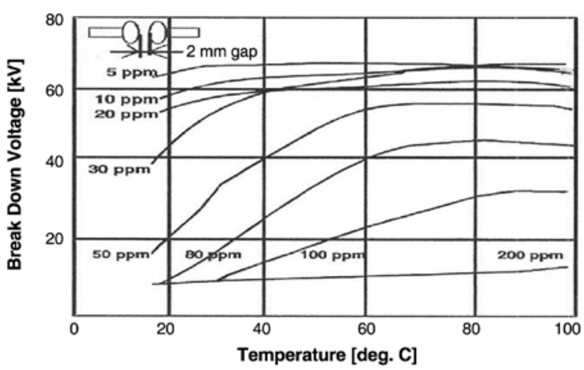


Figure 1: Effect of the breakdown voltage with respect to the temperature at different moisture levels (Source: Nynas)

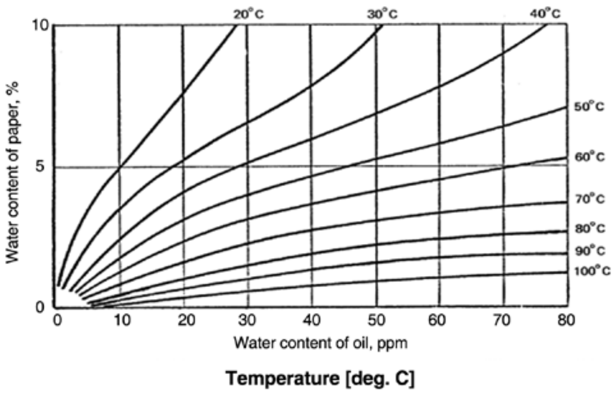


Figure 2: Piper curves equilibrium between water in oil and in paper

MOISTURE MONITORING TECHNIQUES

Moisture in the transformer can be monitored by using on-line and offline methods. The online method is carried out by taking an oil sample from the transformer and sending it to the lab for moisture content measurement. When there is indication of abnormality from the online test, it is important to carry out offline tests diagnostics to ascertain the overall integrity and assessment to avoid unscheduled outages, financial and environmental damages.

a) Online Monitoring

As mentioned earlier, monitoring for moisture is done in two ways. The first is by taking an oil sample and sending it to the lab for moisture measurement. Alternatively, the moisture content measurement could be done at site by installing the online moisture detection equipment to the transformer drain valve. It is advisable to install the moisture detection equipment at the drain valve as a better reading can be obtained. Equilibrium curves have been developed to relate absolute water content in oil to water content in paper (Figure 2). The curve is called Piper curve and is established by plotting the relationship between the water content in paper (%) with respect to the water content in oil (ppm) at different temperatures.

In order to use the chart, the temperature during the oil sampling is recorded. The moisture content in the oil is measured. The moisture content, parts per million (ppm), is plotted on the Piper chart and an estimated value for the moisture content in paper can be determined. However, this will give an estimated value of moisture in paper and it is dependent on the moisture equilibrium of the transformer. The moisture migration from the oil to paper and back to oil is dependent on the temperature of the transformer.

b) Offline Monitoring

Normally, offline monitoring techniques are an indirect way of estimating the moisture effect in the transformer. The most popular methods are dissipation factor (tan delta), polarisation and depolarisation currents (PDC), Frequency Domain Spectroscopy (FDS), and return voltage (RVM) in the frequency and time domain. For an example, tan delta is used to determine the insulating capacitance of the oil. If the insulating capacitance is low, it shows that there is high moisture level in the oil.

MOISTURE MANAGEMENT IN A TRANSFORMER

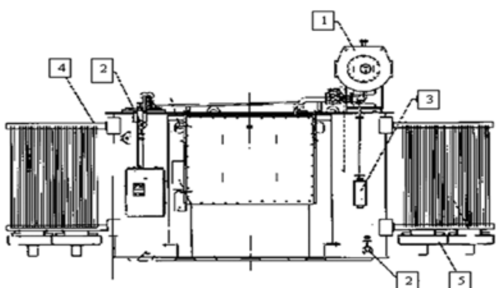
Moisture in transformer always exists. This is because the cellulose chain in the paper insulation will break over time, thus releasing moisture in the oil. However, the amount of moisture in the free breathing transformers can be minimised by considering the following solutions. The most popular moisture management devices are silica gel, vacuum filtration, air bag and diaphragm sealed conservator tank. Figure 3 shows the location on the transformer where the devices are installed.

a) Silica Gel

Silica Gel (Figure 4) breathers are installed by default on transformers with a conservator tank. Breathing is the process of oil expansion and contraction. During the breathing process, the external air will flow into the conservator tank through the breather where the silica gels are installed. The silica gel will absorb the moisture in the air and this will change its colour from blue to pink. The disadvantages of silica gel are:

a) It requires frequent monitoring of its colour
b) Some moisture may escape through a moisture saturated path in the breather
c) It cannot remove the moisture in the oil

As a solution for items (a) and (b), a self dehydrating breather (Figure 5) can be used. A dehydrating breather differ from a conventional breather by a heating element.



1) Conservator Tank (Air Bag)
2) Oil Fill and Drain Valve (Vacuum Filtration Equipment)
3) Breather (Silica Gel or Self Dehydrating Breather)
4) Radiator
5) Fan

Figure 3: The installation locations of the moisture management devices on a power transformer

Figure 4: Breather with silica gel

Figure 5: Self-dehydrating breather

A heater is mounted within the container to heat the desiccant at selected intervals. The heater within the container is supplied with electrical power to heat the desiccant and condense the moisture and discharge it through the vent valve. The voltage supply to the self-dehydrating breather needs to be connected to the alarm system so that it can trigger the alarm if the supply failed.

b) Vacuum Filtration

Moisture filtration in paper and oil can also be done using a vacuum medium. This technology is taking advantage of the moisture migration inside the oil-paper insulation. Most of the vacuum filtration equipment in the market nowadays have integrated particles filter (Figure 6). A continuous flow of oil is supplied from the transformer to the filtration equipment. The oil will be heated and passed through the vacuum chamber. Under high vacuum and temperature, the oxygen and moisture content will be removed from the transformer oil. Then, the oil will pass the particles filter before flowing back to the transformer.

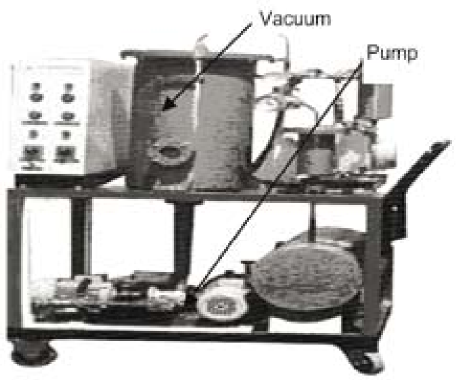


Figure 6: Vacuum filtration equipment

The advantage of using the vacuum filtration technique is that it offers the ability to remove moisture down to very minimum levels. On the other hand, the cost of the filtration equipment is comparatively high. In addition, the moisture in the oil is removed at a slower rate. The equipment cannot be pushed to filter at extra speed because it will lose its efficiency and may cause oil surge in the transformer which will eventually trip the transformer.

c) Air bag

The air bag is installed inside the conservator tank to prevent the insulating oil and surrounding air from coming into contact (Figure 7 and Figure 8). It is filled with air and connected to a breather.

The air bag will prevent undesirable elements in the atmosphere, such as water and oxygen; and prevent the contamination of the transformer oil within the conservator. This will also prevent condensation and oxidation activity inside the transformer and suppress gas bubble

Figure 7: Air bag

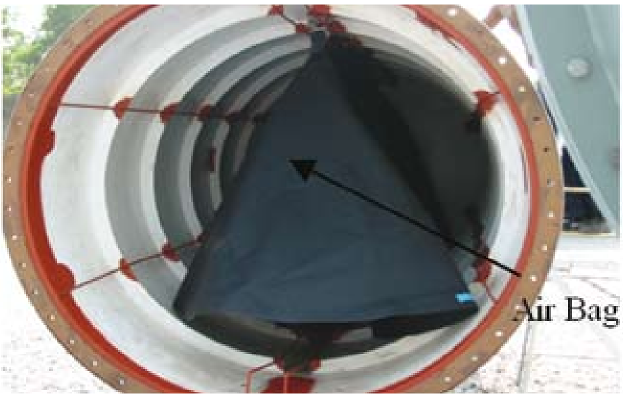


Figure 8: Air bag inside the conservator tank

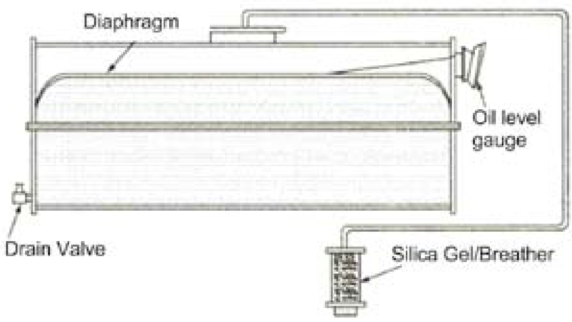


Figure 9: Diaphragm sealed conservator tank design

formation in the transformer oil. On the other hand, an air bag is expensive and the installation for the in-service transformers will require retrofitting.

d) Diaphragm Sealed Conservator Tank

The diaphragm sealed conservator tank is similar in concept as the air bag, which is to prevent the insulating oil and surrounding air from coming into contact. A thin rubber-like material is put across the conservator tank (Figure 9). However, it has a limited flexibility over a period of time. The rubber can get torn due to internal pressure from the transformer main tank.

OTHER OPTIONS OF SOLVING THE MOISTURE ISSUE IN A TRANSFORMER

The user of the free breather transformers can upgrade their transformers to a hermetically sealed transformer. The hermetically sealed transformer does not have any conservator tank. This type of transformer requires low maintenance. The only maintenance that is required for this transformer is to release the gasses stored in the Bucholz relay (if any) and the pressure relief valve. The advantages of the hermetically sealed transformers are:

- Less oil and cellulose ageing due to less oxidation
- No dehydrating breathers thus no maintenance is required

However, these types of transformers have several limitations:

- The capacity of the transformer is limited to distribution capacity (up to 15MVA). Research works are ongoing to increase the capacity to a higher level.
- Incipient fault inside the transformer cannot be diagnosed by Dissolved Gas Analysis (DGA). The DGA is like a blood test for the transformer.

For hermetically sealed transformers, oil sampling cannot be done. On the other hand, users can also consider Cast Resin Transformers. The cast resin transformers encase the windings in the epoxy resin materials. It needs less fire protection because the fire hazard has been minimised with the absence of insulating oil. The windings are completely sealed, so it is free from moisture and dust. In addition, it requires less maintenance thus reducing the running cost. However, these types of transformers have several limitations:

- Most designs are for indoor use only
- Larger in physical size compared to hermetically sealed transformers of the same capacity
- Initial purchasing cost is high

CONCLUSION

The lifespan of a transformer could be increased if the moisture level in it is managed effectively. This could be done by monitoring the moisture level via online or offline methods, installing silica gel, air bag, diaphragm or filtration equipment. Users have the option to upgrade the transformer to a hermetically sealed type or cast resin type. ■

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