Comparison of off-line and on-line vacuum dehydration of power transformers

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Any standard maintenance of a wet power transformer is primarily focused on the decrease of its water content **in its solid insulants.** In its cellulose materials, 95-99% of water is always deponed, and only a residual amount of water 1-5% is diluted in its oil filling. Simultaneously with the reducion of the water content in the oil, the dielectric strength of the oil will be improved.

There are two basic vacuum dehydration methods:

- **the off-line** dehydration
- **the on-line** dehydration

By the standard **off-line process,** the transfomer is normally shut-down. The maintenance process is performed by **big dehydration units** (ABB-Micafil, Hering, Filtervac, Fluidex…) with the hydraulical power over 3000 l/hour. The oil is heated to over 80 C and the vacuum is kept under 0.1 kPa, which accelerates the whole process and shortens the procedure as much as possible.

Advantages : short procedure

Disadvantages : **very poor dehydration efficiency** - only the water from the oil filling can be removed, due the very slow diffusion of the water from the cellulose materials where more than 95% water is deponed. Inevitably, the water content in the cellulose will remain basically the same as before the dehydration.

This problem of any off-line dehydration is demonstrated very convincingly by a time-related reading of the water content in the oil (Cw-value) and the dielectric strengh of the oil (Ud-value) as shown in the Fig. 1.

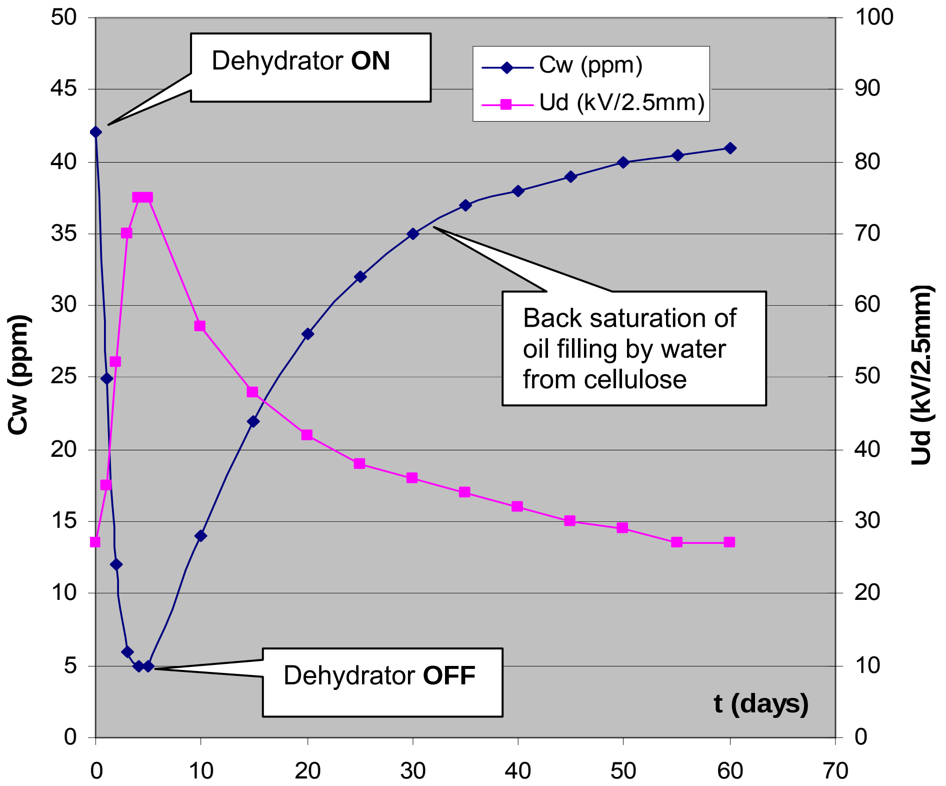

Fig. 1 An example of a typical dynamic response of a transformer during and after off-line dehydration

The effect of the off-line dehydration (as shown in Fig. 1) is following :

- immediately after the connecting of the big dehydrator (say 5 m3 of oil per hour) to the transformer, the water content in its oil (Cw-value) rapidly decreases, from initial 43 ppm-level and stabilise at 4 – 5 ppm level. Simultaneously, the dielectric strength of the oil (the Ud-value) rapidly increases from the Ud ≈ 26 - 28 kV/2.5 mm at a value about 75 – 80 kV/2.5mm or even more.
- Shut-down of the dehydrator always means the start of natural and spontaneous back -saturation of the oil filling with the water from the cellulose insulants. The water content in the oil slowly increases and its dielectric strength corespondingly decreases. In 50 – 70 days of the back saturation, the Cw- and Ud-value is basically the same as before the dehydration (at the same temperature).

During, say, a 5-day dehydration period only the diluted water in the oil filling is removed (which represents no more than 1 – 2% of the whole water deponed in a transformer). The final effect of this reduction of the water content in the transformer is therefore insignificant (and very often non-measurable).

Conclusion :

⇒ a long-term solution of the moisture problem of any transformer by means of short-term off-line dehydration is an illusion regardless of the hydraulic power of a dehydrator

⇒ short–term off-line dehydration generally represents a waste of time and money

⇒ the short-term (high vacuum, high temperature) off-line dehydration method, if repeatedly used, will always deteriorate the oil filling and subsequently reduces the life-expectancy of a transformer

Remember, the most frequent systematic errors are caused by

the sampling of oil immediately after the shut-down of a dehydrator.

This often used measuring & evaluation practice is absolutely wrong and highly misleading – See the Fig. 1 – position „Dehydrator OFF“, because this time-point doesn´t represent neither the real amount of water deponed in a transformer nor the real dielectric strength of its oil.

The recommendation for users of short-term off-line dehydration :

⇒ the main goal of the dehydration of a transformer is always the dehydration of its cellulose insulants, **never only the dehydration of its oil filling**.

It means

⇒ why pay for the amount of dehydrated oil and not for real results ? The real results means :

- known amount of removed water
- long-term improvement of the Cw-value and the Ud-value of the oil has to be always based on the comparison of two readings (at approx. the same temp of transformer):
  - the reading of both values before a dehydration
  - the reading of both values ca 60 – 80 days after dehydration

There is very little evidence (if any), that short-term, off-line dehydration is really effecient. Any payment for this kind of dehydration (considering its potential harmful effect) is simply absurd.

The standard **on-line maintenance procedure** (dehydration, degassing, filtration) if performed by a small vacuum unit has following pro and cons:.

Advantages : easy installation and low operational costs, good efficiency

Disadvantages : slow process

continuous, undesirable and the unallowed removal of light fractions in the oil from the oil filling due to the long-term application of the high vacuum

slow but undavoidable deterioration of the oil inventory due to high vacuum and high temperatures

To avoid any deterioration of the oil filling of a transformer and subsequently the deterioration of its hard insulants, fa. Ing. Altmann has developed the vacuum separator VS-06.

The basic principle of the VS-06 strictly avoids a high vacuum and high temperature scenario. The liquid piston principle effectively eliminates any harm to an oil filling of a transformer during dehydration.

For more details See www.ars-altmann.com / /Product Range /VS-06.

The basic advantage of any off-line dehydration of a transformer convincingly shows again and again the time-related reading of the water content in the oil (Cw-value) and its dielectric strength (Ud-value) as shown in Fig. 2.

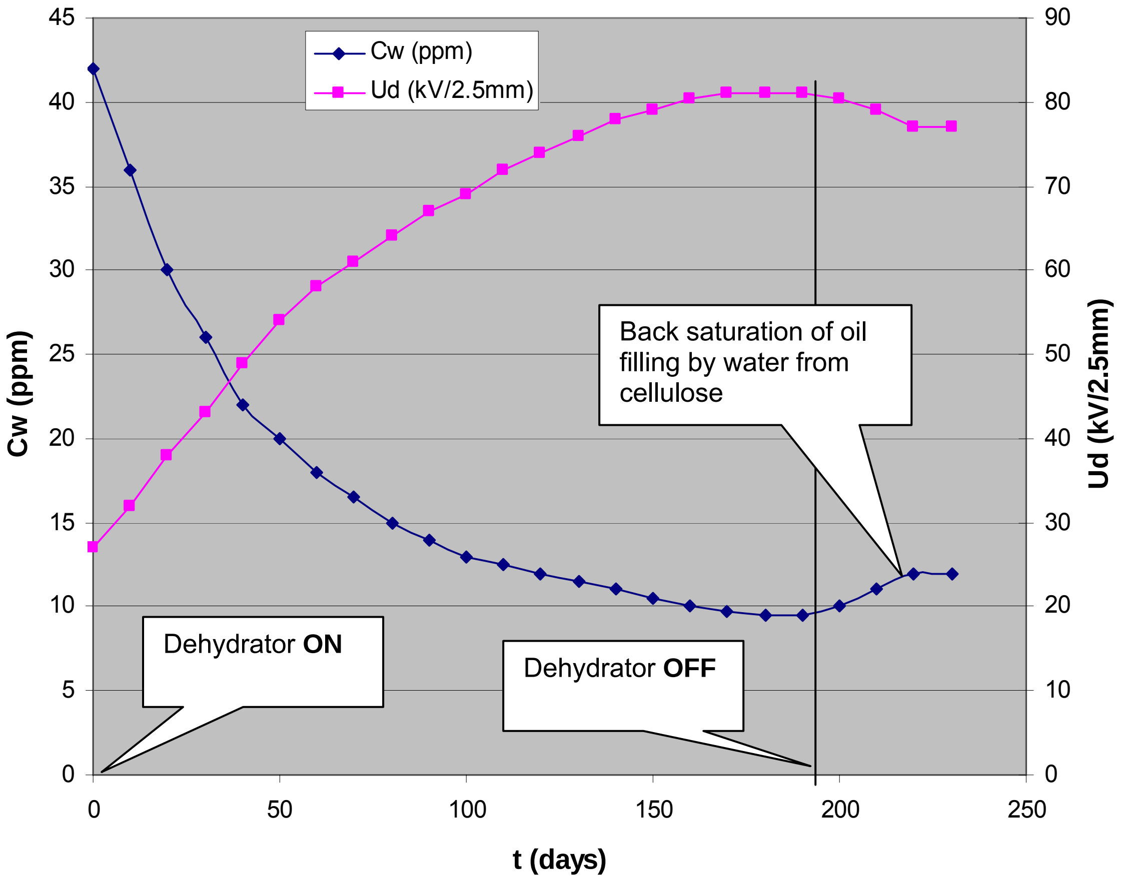

Fig. 2 An example of a typical dynamic response of a transformer during and after on-line dehydration

The mutual comparison of Fig. 1 a 2 shows the basic distinction between both methods.

The off-line method shows a very rapid drop of the water content in the oil and the rapid increase of its dielectric strength but this improvement is only virtual. After the termination of the dehydration procedure there always follows a strong back saturation of the oil filling by the water from the cellulose. Both Cw- and Ud-values will be basically the same after ca 50 – 70 days as before.

On the other hand, the typical feature of an on-line dehydration method is the relatively slow decrease of the Cw- value and the „slow" increase of the Ud-value.

Neverthless, the required improvement of the Ud-value (from , say, 16 – 22 kV/2.5 mm above 30 kV/ 2.5 mm – the minimal Ud- level requested by the IEC norm) is normally undertaken in a week. The Ud-value is then permanently increased up to maximal attainable value over 70 – 80 kV/2.5mm.

The back saturation of the oil filling by the water from the cellulose, after the termination of dehydration is inevitable regardless of any kind of procedure.

After properly performed on-line dehydration, this effect is very small and the corresponding decrease of the dielectric strength is small as well.

Moreover, the real effectiveness of VS-06 dehydration proces can be very well documented and verified by:

- the volumetric reading of removed water by remote monitoring
- **the amount of removed water is accumulated in the external water trap (the very best evidence of dehydration efficiency).**
- the reading of Cw- and Ud-values after after the termination of dehydration, the proper time-period is usually 60 days or thereabout.

Summary

The present, short-term off-line dehydration method is :

- **quick but ineffective** – basically only the water diluted in the oil filling is removed
- **dangerous** – if repeatedly used, the deterioration of the oil filling and the decrease in the life-expectancy of a transformer is inevitable
- **highly misleading** – the readings performed ***immediately after the termination of a dehydration campaing*** camouflages the ineffectiveness of the dehydration

Properly performed on-line dehydration is:

- **slow but effective -** water is permanently removed from the celllulose an not only from the oil filling
- **safe –** oil is in no way stressed by high temperatures and high vacuum. No light fractions of oil are removed
- **exact proof -** the efficiency is **precisely** documented by the volumetrically measured amount of removed water