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On-load tap-changer (OLTC) are indispensable parts of regulating power transformers. There are different types of on-load tap-changer like selector switches and a type which consists of selector and diverter switch insert (DSI). Here only the second type will be considered, more precisely mainly only the DSI. The explanation for that is given at the end of this document.

Generally spoken transformers are exposed to various electrical stresses during testing and in service. Transient over voltages caused by switching operations and lightning impulses can result in severe stresses on the internal insulation. As the OLTC is connected to the regulating (or tap winding) of the transformer it can result in a high dielectric stress to the OLTC in general and the DSI in particular.
The DSI will be stressed by the voltage which occurs between the tap in service and the pre-selected tap. This stress will vary depending on the specific transformer design, the position of the OLTC during the test and whether the test voltage will be applied to the line-end terminals or to the star point.

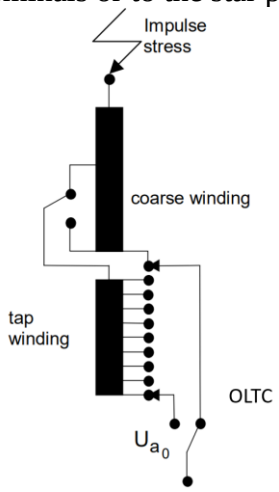

Figure 1 : Winding arrangement (coarse/fine) with OLTC in mid position

Especially in winding arrangements with a coarse and tap winding extremely high voltage stresses occur at this insulating distance during impulse testing when the OLTC is in mid position. Fig. 1 shows the principal winding arrangement. Under chopped wave stress a maximum of 40% of the incoming wave can appear across the distance between the tap in service and the pre-selected tap.
There are different measures to avoid a too high dielectric stress within the DSI:

1. Option: large geometric dimensions: Design such large geometric dimension inside the diverter switch that it can cope with any possible dielectric stress that might occur in any kind of transformer, winding arrangement, and test setup.
   It is clearly seen that this is not an economic solution.
2. Option: Limiting the max. dielectric stress: Limiting the dielectric stress can be done in two different ways
   - Spark gap: spark gaps were mainly used in the past for small and medium power transformers.
   - Varistor made of Zinc Oxide (ZnO): Varistors are currently used in almost all power transformer classes.

The advantage of very fast reacting varistors compared to spark gaps is, that the response characteristic is independent from the breakdown behaviour of the insulation liquid. The breakdown behaviour of the insulating liquid will differ from liquid to liquid and will change over its lifetime. When using spark gaps to limit the voltage stress this needs to be considered during dielectric layout of the DSI at development stage.
Additionally, the response characteristic will not change when using varistors even after several times of responding. In case of spark gaps the characteristic most likely will change as the spark will change the initial geometry of the gap.

There is an excellent long-time experience of ZnO varistor application in OLTCs. During the last 40 years non-linear resistors have been in use in OLTCs for power transformers without any problems. For an excellent long-time behaviour of varistors a design rule and continuous quality monitoring of the ZnOs elements is very important.

In OLTC application the varistor is easily accessible during regular maintenance work, see Fig. 2. The 1 mA DC voltage can be measured and compared to the initial values.

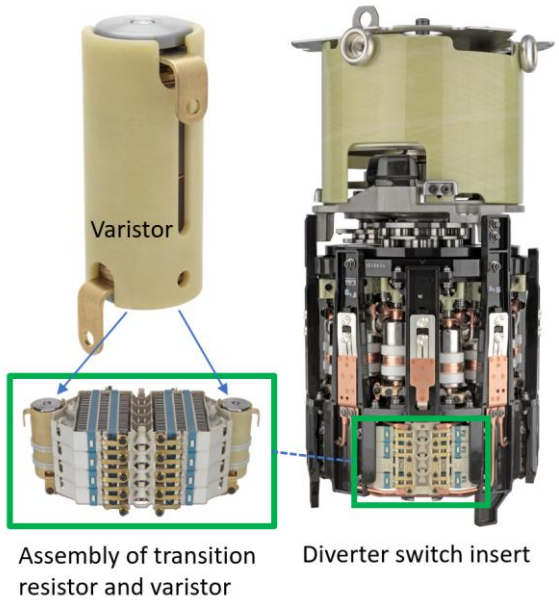

Figure 2: diverter switch insert with varistor

Selector switches are not mentioned here because in stationary position they only contact one tap of the regulating winding. The selector switches principle does not have a pre-selected tap in stationary position. Therefore, they a are not affected by an a_0-voltage stress (stress between the tap in service and the pre-selected tap) which only can be limited by a varistor inside the diverter switch.

The voltage stress in other parts of the winding (other than a_0), which affect the selector and the selector switch are limited by varistors which are implemented in parallel to sections of the regulating winding. These varistors are integrated directly inside the transformer tank. If necessary, these varistors are layouted and integrated by the transformer manufacturers and not by the OLTC manufacturer.

A much more detailed Paper regarding this topic is available: P. Heinzig, A. Krämer, et al. „Long-Time Experiences of ZnO Varistor Application in Power Transformers and OLTC's" (Cigre 2006, A2 – 303)