The use of Non Linear Metal Oxide Resistors in Transformer Tapping Windings

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Background - Use of Non-Linear Resistors in Transforme Windings

Non-linear resistors have been in use for limiting transient over voltages from lightning impulses, switching impulses and at times resonant over voltages for more than 40 years. They are mostly installed across tapping windings and across series reactors in the tertiary windings, but only in a very small percentage of all transformers. When used across the tapping windings, then it is mostly where the tapping winding is at the line end of a medium or high voltage windings with a relative large tapping range.

In the earlier years, non-linear resistors were mostly made from Silicon Carbide [SiC] elements. However, in the last 30 years non linear resistors made from metal Oxide blocks, often Zinc oxide blocks (ZnO's) have become more common and have gradually replaced the SiC non linear resistors. The ZnO blocks used inside transformers to protect transformer windings are basically the same type as used in polymer or porcelain surge arresters, to protect transformers windings at the line end near the transformer terminals. The ZnO used internally are immersed in insulating oil, so they do not need the porcelain or polymer insulator/housing. There are other differences in the construction arising from the requirement that the ZnO assembly has to be compatible with transformer oil over a temperature range from below 0 ^{o}C to above 100 ^{o}C. The clamping structure for ZnO's used inside transformers is also different, as it has to suitable for being immersed in transformer oil, and be reliable and able to maintain the clamping pressure over a wide temperature range during 40+ years service life without need for inspections and maintenance.

The use of non-linear resistors for protection of transformer windings can be summarised as follows:

- ZnO began to replace SiC varistors from late 1970-ties due to their superior Volt/Current characteristic which give better protection to the transformer windings.
- The in-service experience with the use of non-linear resistors in transformer windings reported in 1991 was; 25 years for SiC varistors and 10 years for ZnO with no in-service failures reported then, although there has been reports of a few cases where remedial maintenance work were required.
- The main use inside transformers was for overvoltage protection of tapping windings, series reactors in tertiary windings, and also mounted within the OLTC diverter switch compartment for protection of over voltages between the selected and the pre-selected tap and less frequently to protect windings from resonant overvoltages.
- The benefit of using ZnO elements is that it allows the designer to avoid the use risky and complicated winding arrangement in favour of a simple and more reliable winding arrangement protected by ZnO's and in some applications also the use of a less costly on load tap changer.

Some user reluctance was found and has been reported. Their main concerns were:

- Access for periodic inspection is difficult and not possible unless considered and provided for at the design stage. This concern does not apply for ZnO mounted directly in the diverter switch tank.
- Increased difficulties with interpretation of impulse fault detection oscillograms.
- It was generally accepted by both manufacturers and transformer users that the ZnOs provide a valuable tool for protection of transformer windings against transient overvoltages and that there is almost no restrictions on their use, as long as:
  - ✓ The ZnO elements are selected from reputable suppliers,
  - ✓ The ZnO block stack clamping structure is designed and manufactured so it will maintain adequate clamping pressure on the block stack after dry out and throughout the service life transformer.
  - ✓ Inspected and clamping pressure checked tested after transformer dryout/vapour phase processing.
  - ✓ The ZnO block stack should mounted so they can be accessed for inspection, maintenance or replacement if it should be required.

It is Interesting to note that at least one OLTC manufacturer has ZnO's fitted across some of the contacts in vacuum type OLTC's.

To learn from the experience of other transformer users and manufacturers, a questionaire was sent to SCA2 members and other transformer experts to obtain feedback on their views and experiences with the use of ZnO's in transformers.

Replies from some of the experts were as follows:

1) One major utility reported: ZnOs' are "not preferred" but we will accept their use if no other practical solution is available. This utility has accepted approximately 20 units with ZnO's over 25 years. This user has experienced loose blocks on 2-3 in service transformers. These defects were detected from DGA results and remedied prior to catastrophic failures. This user considers ZnO's should always be mounted in a location where accessible for inspection and replacement if required.

2) One major international transformer manufacturer stated that they have supplied transformers with ZnO's for approximately 15 years and they are now used in 5-10 % of their transformers, but only if not avoidable by normal design measures. However, they have some clients which insist on ZnOs be fitted as overvoltage protection inside their transformers irrespective of whether needed for design purpose not. They summarised their view as follows:

- The key benefit of ZnO's is that they make it possible to use OLTC in applications where this would otherwise be difficult or impossible.
- The disadvantage is that there are extra parts and additional connections which need to be made carefully.
- The assembly should be housed within fibreglass pipes with copper plates for contacts between discs and connecting leads and blocks should be mounted under spring pressure to ensure contact pressure is maintained throughout the life of the transformer.
- The design should be conservative, with low AC stress and redundancy, so one ZnO block can fail without compromising voltage withstand characteristic. [Other manufacturers mounts the ZnO blocks within a slotted pipe made from transformer Board]. Open mounting arrangement also exist but also the higher AC voltages which occur during long and short duration induced voltage tests.
- Good cooling should be provided around the ZnO blocks.

3) A 2nd major transformer manufacturer reported that they had recently changed from using SiC to ZnO"s and have used ZnO stacks in a in Large 400/275 kV Quad boost transformers.

4) A 3rd major transformer manufacturer reported that it had supplied more than 100 transformers with ZnO's fitted across tapping windings over the last 30 years, without any failures having occurred to date. Their design was based on ZnO blocks with spring loaded mounting within an insulating cylinder supported from the tank wall. This manufacturer considered the only disadvantage with using ZnO's across the windings was the more difficult interpretation of impulse test oscillograms.

Moreover, many years experience in Australia with use of SiC and more lately ZnO's fitted across the 132kV line end tapping windings in number of 200-375 MVA 275/132kV transformers shows that none of these transformers have ever had any in service problems related to the use of Non Linear resistor within the transformers.
(It should be noted the expert views of the individual expert not the necesrily the authors view.)

Advantages of using ZnO

- Allows the use of OLTC's with lower insulation level, lower cost and less insulation within tapping winding than would be required without ZnO's for some transformers, especially auto transformers with line end tapping windings and/or relative large tapping range.
- Can at times allow simpler tapping winding arrangement, than without ZnO's.
- Reduces risk of winding or OLTC failure from transient overvoltages or resonant voltage build-up within tapping winding.

Disadvantages of using ZnO’ in Transformers WIndings.

The only real disadvantages are:

- Impulse oscillograms more difficult to interpretate.
- A few more critical components.

Example of arrangement of ZnO's Installed across a tx tapping winding

Conclusion

The advantages of using this technology outweigh it disadvantages. More than 30 years in-service has proven that transformer with this technology does not have higher failure rates than transformers without ZnO’s (possibly even lower failure rates).

However, it is crucial the ZnO arrestor stack be designed correctly. The design of the block assembly must be robust and it is considered that the blocks should be clamped under spring pressure that ensures the clamping force on the blocks and the contact plates is maintained over the total service life of the transformer.

The voltage rating of the blocks should be such that they are able to withstand induced and other power frequency tests with a reasonably safety margin, yet still prove adequate protection for fast transient and potential oscillation and high frequencies.

It may also be considered prudent that the arrestors be mounted and inspection covers be provided, so the arrestors can be inspected or even replaced without untanking or lifting the bell of the transformer.

procedures should include specific records of inspection checks on the ZnO blocks, the correct assembly and installation of the ZnOs twithin the transformer, including the re-tightening and check on clamping pressure after the vapour phase dryout.

References:

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