Study Committee A2

Power Transformers & Reactors

Paper A2-10122_2022

Impulse Testing of Power Transformers - Impact of Internal Varistors built into On-load Tap Changers

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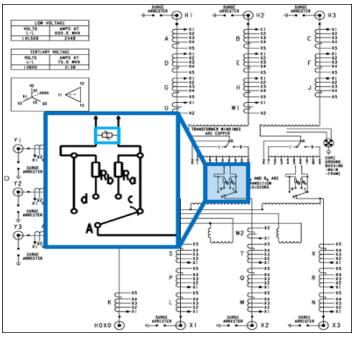
Motivation

- During Impulse test, voltage and current waveform mismatch usually indicate a failure. Through this study we concluded that may not always be the case
- Finding the cause of such mismatch can be a challenging task
- Two such unusual discrepancies noticed during factory impulse test are discussed in this paper
- The cause of these mismatches were found to be partial conduction of varistors built into the tap changers and not due to any dielectric failure

Case Studies

- The first case was 417 MVA, 345/115/13.8 kV autotransformer and the second one was 600 MVA, 345/141.5/13.8 kV autotransformer
- Standard IEEE test protocols for designs were followed as acceptance criteria for successful dielectric test which was assumed to be a fault because of waveform mismatches
- During investigation we found that both designs used On Load Tap Changers that have built in varistors in tap changer diverter assembly



Varistors

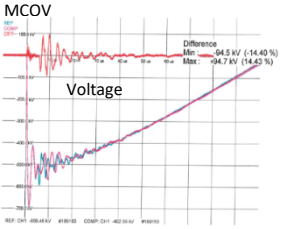
- Varistors are non linear protective devices made from metal oxide elements like ZnO
- Their resistance is very high under normal operating voltage but reduces to a small value in overvoltage conditions
- The protection level is determined by the Current-Voltage curve of the varistor where the conduction process is gradual and not abrupt

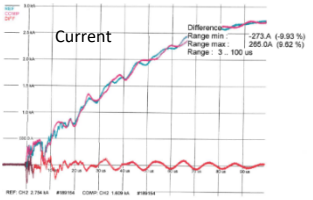
Case study 1 - 417 MVA, 345/115/13.8 KV Autotransformer

- During the Full wave test, the voltage waveform at reduced voltage did not match the waveform at full voltage on X3
- X3 reduced-to-reduced and full-to-full voltage waveforms matched
- Physical examination and other electrical testing did not reveal issue with the windings
- It was found that varistors were used in the tap changers, which can cause waveform mismatches
- Conduction of varistor was confirmed with RLC circuit model as well
- Re-tested after bypassing varistors and waveform mismatches were no longer present
- The unit underwent full dielectric testing with varistors connected and using the modified IEEE test protocol for varistor designs
- All tests were successful and impulse tests performed as expected

Case study 2 - 600 MVA, 345/115/13.8 KV Autotransformer

- During the Full wave impulse testing, the transformer showed voltage and current mismatches on X3
- Mismatch seen at 5-7 microseconds was due to gradual conduction of varistors before reaching MCOV





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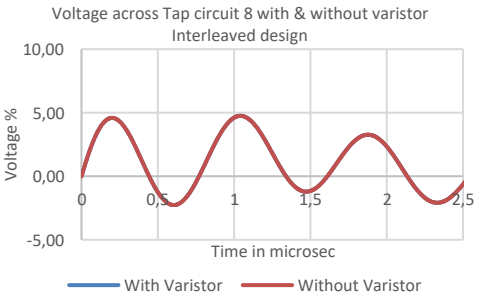
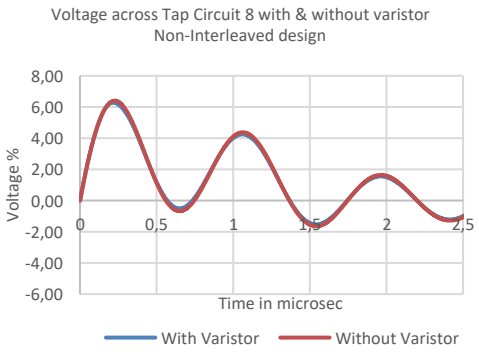
continued

Case study 2 – Corrective action

- The RV coils were redesigned changing lead numbering to achieve interleaving of cables
- This helped to reduce the step voltage between tap changer selector and pre-selector such that the varistor internal to the tap changer may not activate
- RLC based circuit simulation and RSO test was performed to confirm effect of interleaving RV
- The simulation results for the voltage across tap circuit , with and without varistors, for interleaved and non-interleaved designs are shown below





- For non-interleaved designs, there is a small voltage mismatch with and without varistor indicating that the varistors are triggered
- For interleaved designs, there is no voltage mismatch with and without varistors indicating that the varistors are not triggered
- Full testing of the transformer as per standard IEEE protocol was performed after the corrective action and it passed all tests

Recommendations

- When selecting tap changers it is important to ensure if they have built-in varistors
- If such tap changers are used, the test plans should reflect the appropriate test protocols as in Case study 1
- The other choice is to eliminate the operation of varistor during test by appropriate tap winding design as in Case study 2
- When the varistors are taken into account, troubleshooting becomes easy in case of a real impulse failure
- Accounting for the presence of built-in varistors in tap changers during design can also avoid introduction of secondary failures that can happen when trying to find the root cause of mismatches.

Conclusion

- IEEE allows different acceptance test sequence for units with and without varistors
- IEEE Impulse test protocols for varistors were usually assumed only for cases with explicit varistors used by designers to limit the voltage across tap winding
- When varistors are part of tap changer, they can go unnoticed and may result in test time surprises and delay troubleshooting
- By bringing this to attention, this paper helps alleviate such problems in future
- Varistors in tap changers are used as a safety measure against any unforeseen transients rather than optimizing the size of the tap changer