Study Committee A3

Transmission and Distribution Equipment

Paper 10401_2022

METAL VAPOR DEPOSITION PATTERNS AND CHARACTERISTICS ON ALUMINA CERAMIC INSULATORS IN VACUUM

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Motivation

- Conventional vacuum interrupters use a metal shield around the contacts to protect the alumina ceramic insulator from metal vapor depositions from the inter-contact arc. These metal vapor depositions can degrade the insulating capability of the insulator along its surface.
- This study investigates the metal vapor deposition pattern and HV degradation via metal vapor depositions without the use of metal shields.

Method/Approach

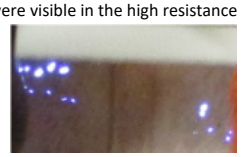
- Physical prototypes are fabricated and exposed to one half-cycle of power frequency arcing up to 15 kA peak for 10 total switching operations.
- Samples are tested under high voltage conditions.
- Samples are then sectioned and the metal vapor patterns are measured dimensionally, for bulk resistance along different regions of the deposited vapor, and microscopically.

Objects of investigation

- Brazed and sealed vacuum device with alumina ceramic insulator and copper chromium arcing contacts.
- Vapor grading shields arranged at both ends of the ceramic tube with varying clearances to ceramic inner diameter.

Experimental setup & test results

- HV testing exhibited microsecond voltage collapses, after which the VI would recover dielectrically.
- Sectioned samples show discrete sections of deposited metal vapor with varying resistance along its length.
- During resistance measurements, discrete regions of arcing were visible in the high resistance regions.

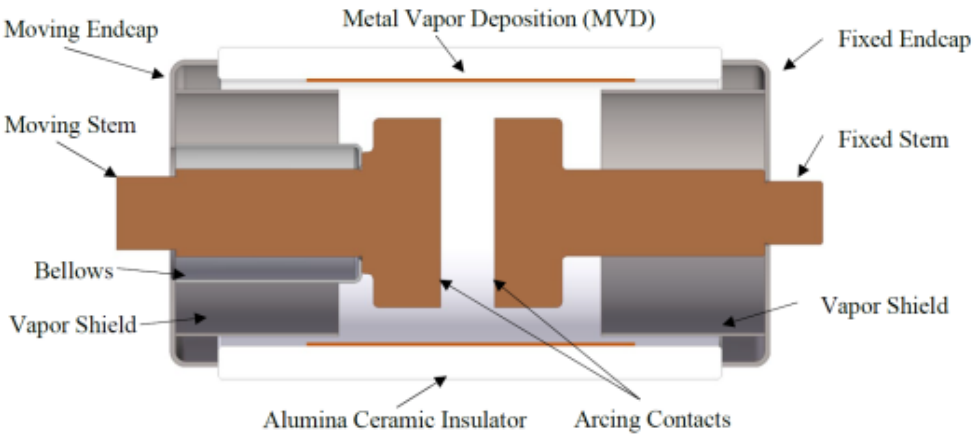


Discussion

- Metal vapor travels and condenses beyond the “line-of-sight“ from the contacts
- Transition region from high conductivity deposits to high resistance ceramic insulation can result in a high electrical stress leading to dielectric breakdowns.

Conclusion

- Metal vapor depositions must be sufficiently controlled and the electrical stresses reduced such that the device can reliably withstand applied voltage.
- Short HV discharges may be indicative of dielectric stress in the device.



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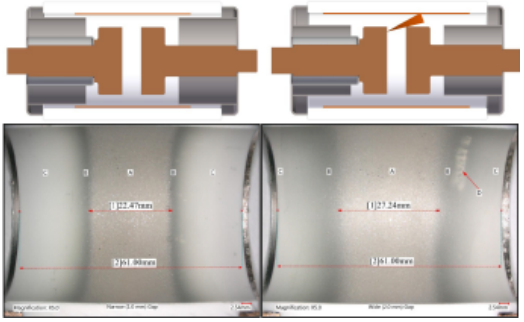
continued

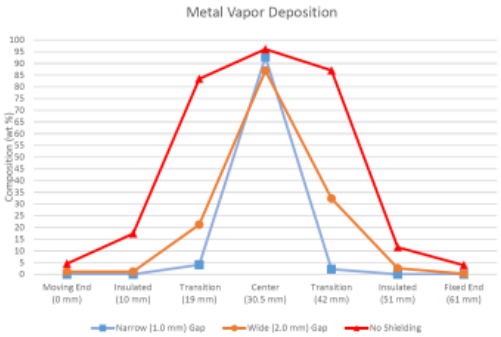
Visual Characterization

- Deposited metal vapor distribution extends beyond the line-of-sight of the contact arcing surfaces and is modified by the proximity of the metal end shields to the ceramic inner diameter.



Metallographic Characterization

- Distribution of metal deposits (of copper and chromium) appear to match the visual record and measured bulk resistances.



Addressing the Questions of the A3 Special Report

- *"…advancement of basic technologies contributes to the challenges targeting decarbonisation, decentralisation, and digitalisation in power grids. In addition, integration and coordination of such knowledges would play an important role for it. Can specialists give any prospective views of new technologies applicable to T&D equipment?"*
    - Generally vacuum interruption can replace other mode of switching which may adversely affect the environment. This trial tried to establish if VIs for very small current or limited number of operations can reduce number of parts and making it slimmer and compact and thus reducing the material content for the VI and circuit breaker.
    - This phenomenon of volage collapse for microseconds may generate a pattern based on depositions and number of times it is exposed to high voltage. The pattern of discharge – frequency, intensities may indicate distress. More studies can be carried out to capture such data with controlled variations and establish alarms or alerts for any potential distress for remote and predictive maintenance of the system. This would then be applicable for all types of Vacuum Interrupters considering different patterns of depositions – then capturing the data and processing with algorithms to provide meaningful feedback to the users.