Investigations of lightning impulse voltage on vacuum circuit breakers and comparison of effects between industry and research

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ABSTRACT

To avoid the use of insulation gasses besides air especially “sulphur hexafluoride” (SF_6) as an insulating and interruption gas it´s important for the goal of reducing greenhouse gas emissions from energy production and distribution. Particularly switchgears equipped with vacuum interrupter (VI) technology are suitable to be replaced by SF_6 interrupter due to their climate neutrality and non-toxicity. Vacuum circuit breakers (VCB) have been established for decades in medium-voltage systems, and research and development for high-voltage applications. In addition to the needed short-circuit interruption currents and larger gap distances [1], the electric strength of vacuum insulation for high voltage is an important issue. Due to the degressive curve of the electrical strength of the vacuum atmosphere, multiple contact gaps (VI´s) are used for high voltages [2]. As the highest voltage occurring in the electrical grid, the lightning impulse voltage (LIV) is decisive for the investigation of the electric strength. Giere [3] has compared some publications to show which lightning impulse voltage is possible at which gap distance. It is shown that the conversion of electric field strength from basic experimental set-up´s to the complex design of a vacuum circuit breaker is challenging. [3]
In this publication, measurements will be made on industrial VCB´s by the up-and-down method using the withstand procedure according to Powell and Ryan [4]. A LIV generator is used to generate the LIV and a Zaengl voltage divider is used to measure the applied voltage and breakdown voltage. The measurements on a test field of the research are carried out after LIV conditioning. The experimental results are compared with lightning impulse withstand levels of industrial devices.
The common research is dominated by experiments on electrode set-up´s with investigation of the influence of the gap distance, the area effect, and the electrode surface. Usually the up-and-down method is used to determine the 50 % breakdown voltage [4]. In contrast, industry relies on tests to determine the lightning impulse withstand voltage when investigating more complex VI´s. In the case of vacuum circuit-breakers with contacts, metal vapor condensation shields and ceramics for use in the power grid, the internal electric strength is just as important as the external electric strength [5]. Here, the focus is on the reliability of the insulation for a long-term application. When comparing the measurements from research and industry, the differences in the possible conditioning processes are also obvious. Here, conditioning processes with high AC voltage, LIV pulse or glow discharge as well as various surface treatments and bakeout processes can be used. [6]

References

[1] Weber, B.; Kühn, B.; Gentsch, D.; Kurrat, M. (2021): Investigation of vacuum arcs between with varying gaps up to 40 mm. In: 2021 29th International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV). Padova
[2] Horn, A. (2009): Schaltverhalten der Reihenschaltung zweier Vakuumschaltstrecken in einem Gefäß. Zugl.: Braunschweig, Techn. Univ., Diss., 2009.
[3] Giere, S. (2004): Vakuumschalttechnik im Vakuumeinsatz. Zugl.: Braunschweig, Techn. Univ., Diss., 2002. Als Ms. gedr. Göttingen: Culliver Verlag
[4] Hauschild, W.; Mosch, W. (1984): Statistik für Elektrotechniker. Eine Darstellung an Beispielen aus der Hochspannungstechnik. Berlin: VEB Verlag Technik.
[5] Meyer, T.; Kühn, B.; Gentsch, D.; Kurrat, M. (2021): Lightning impulse conditioning of a combined field grading and shielding arrangement for vacuum double break. In: 2021 29th International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV). Padova.
[6] Slade, P. G. (2008): The Vacuum Interrupter. Theory, Design, and Application. Boca Raton: CRC Press Taylor & Francis Group.