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Partial Discharge Characteristics of Free- Moving Particles in HVDC-GIS

Authors : Philipp Wenger, Michael Beltle, Stefan Tenbohlen, Uwe Riechert

Abstract : The integration of renewable energy introduces new challenges to the transmission grid, as the power generation is located far from load centers. The associated necessary long-range power transmission increases the demand for high voltage direct current (HVDC) transmission lines and DC distribution grids. HVDC gas-insulated switchgears (GIS) are considered being a key technology, due to the combination of the DC technology and the long operation experiences of AC-GIS. To ensure long-term reliability of such systems, insulation defects must be detected in an early stage. Operational experience with AC systems has proven evidence, that most failures, which can be attributed to breakdowns of the insulation system, can be detected and identified via partial discharge (PD) measurements beforehand. In AC systems the identification of defects relies on the phase resolved partial discharge pattern (PRPD). Since there is no phase information within DC systems this method cannot be transferred to DC PD diagnostic. Furthermore, the behaviour of e.g. free-moving particles differs significantly at DC: Under the influence of a constant direct electric field, charge carriers can accumulate on particles' surfaces. As a result, a particle can lift-off, oscillate between the inner conductor and the enclosure or rapidly bounces at just one electrode, which is known as firefly motion. Depending on the motion and the relative position of the particle to the electrodes, broadband electromagnetic PD pulses are emitted, which can be recorded by ultra-high frequency (UHF) measuring methods. PDs are often accompanied by light emissions at the particle's tip which enables optical detection. This contribution investigates PD characteristics of free moving metallic particles in a commercially available 300 kV SF_6-insulated HVDC-GIS. The influences of various defect parameters on the particle motion and the PD characteristic are evaluated experimentally. Several particle geometries, such as cylinder, lamella, spiral and sphere with different length, diameter and weight are determined. The applied DC voltage is increased stepwise from inception voltage up to U_{DC} = ± 400 kV. Different physical detection methods are used simultaneously in a time-synchronized setup. Firstly, the electromagnetic waves emitted by the particle are recorded by an UHF measuring system. Secondly, a photomultiplier tube (PMT) detects light emission with a wavelength in the range of λ = 185...870 nm. Thirdly, a high-speed camera (HSC) tracks the particle's motion trajectory with high accuracy. Furthermore, an electrically insulated electrode is attached to the grounded enclosure and connected to a current shunt in order to detect low frequency ion currents: The shunt measuring system's sensitivity is in the range of 10 nA at a measuring bandwidth of bw = DC...1 MHz. Currents of charge carriers, which are generated at the particle's tip migrate through the gas gap to the electrode and can be recorded by the current shunt. All recorded PD signals are analyzed in order to identify characteristic properties of different particles. This includes e.g. repetition rates and amplitudes of successive pulses, characteristic frequency ranges and detected signal energy of single PD pulses. Concluding, an advanced understanding of underlying physical phenomena particle motion in direct electric field can be derived.

Keywords : current shunt, free moving particles, high-speed imaging, HVDC-GIS, UHF
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