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Investigation of Insulated Wire Breakdown Under DC and Lightning Impulse Conditions

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An investigation into the breakdown characteristics of a dielectric-coated wire-plane electrode system in atmospheric air is presented. Simulating the scenario in which standard utility wiring in close proximity to a grounded conductor is excited by a lightning strike, the wire is insulated while the plane electrode is a bare metal surface. At sufficiently high fields, greater than ˜30 kV/cm, ionization of the air in the gap results in charge accumulation on the wire dielectric surface. The combination of this pre-breakdown ionization and redistribution of charge effectively collapses the field in the air gap region. Thus, as observed, and supported by 3D field simulations, the size of the air gap plays a minor role in determining the overall breakdown threshold of the system. For instance, for 12 AWG solid-core THHN copper wire (600 V manufacturer rating), the breakdown threshold voltage increases only slightly from ˜81 kV with a small air gap of 5 mm to ˜94 kV with an air gap of 50 mm. Hence, the breakdown threshold is primarily dependent upon the dielectric strength of the wire coatings.

Overall, tests were conducted with air gaps ranging from 0 to 50 mm between the grounded, bare conductor and standard THHN copper wire of varying gauge (coated with PVC and covered with a nylon sheath) under both lightning impulse and direct voltage excitation. A 4-stage, 40 kJ, 400 kV open-circuit output Marx generator is used to generate lightning currents in the range of interest, with risetimes from 500 ns to 5 µs and peak currents from 2 –5 kA. A smaller 750 J capacitor bank, with a peak voltage of 200 kV, is used to perform DC tests with a slow voltage ramp of ˜20 kV/s. Results elucidating polarity, wire defects, and waveform dependence will be discussed.

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