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Investigating the effects of engine flue gas on dielectric strength of air gaps

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Abstract

South African diesel locomotives travel under electrified railway lines that use the IEC 60913:2013 clearances. It has been identified that the IEC standard does not cater for the diesel locomotive exhaust pollution in the air gap clearance design, and this may have unknown electrical implications. This research aims therefore to investigate the effects of engine flue on the dielectric strength of the air gaps and contribute to the knowledge needed to safely operate diesel locomotives under the railway high voltage catenary system. The research is executed through computer simulations and laboratory experiments. The Wits High Voltage laboratory is used for air breakdown tests in normal air and in engine flue polluted air conditions. Breakdown simulations are implemented in MATLAB^{TM} using a fluid gas discharge model to represent the discharge process taking into account gas composition through Townsend coefficients. Experiments have shown that there is a linear relationship between breakdown voltage and gap sizes for the tested range of 1 cm to 30 cm. It is observed that for gap sizes less than 25 cm, the DC voltage breakdown strength of air is enhanced by the presence of engine flue gas by a maximum of 26 %. Beyond 25 cm the flue gas reduces the breakdown strength of air by as much as 21 % in petrol flue and by 36 % in diesel flue. The enhancement is attributed to the increased flue humidity and the corona stabilization effect. For the gap sizes greater than 25 cm the corona mechanism is different, thus the humidity and corona stabilization cease to be influential. Lightning impulses were used to observe the extent of the corona stabilization, tests showed a similar trend to that of DC voltage but most importantly, the difference between flue and normal air breakdown voltages was less than that of DC voltage results by 8 %. This is attributed to the decrease in corona stabilization effect due to the reduced space charge in impulse tests. The simulations predicted the actual breakdown voltages observed in the experiments and it showed the same trends for gap sizes less than 25 cm for DC voltages. The research concluded that the presence of engine flue enhances the dielectric strength of air for the gap size range 3 cm to 25 cm under the tested environmental conditions. This is due to the increased humidity of the flue. No differences were observed for 1 cm and 2 cm.