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Corona in Mines

Corona discharge plays a major role in the reliability condition of the electrical apparatuses used in mines. The USA NIOSH conducts continuous research studies on the performance and safety of mine electrical cables, including conductive tests of insulation resistance, corona generation, surface tracking and dielectric strength. The Hipotronics 100-kV AC and DC high voltage sources are two electrical power supply systems with adjustable outputs capable of up to 100 kV that are operated from within the Mine Electrical Laboratory control room.

But, corona might also be involved with a safety issue - ignition that leads to explosions in coal mines. Explosions in underground mines and surface processing facilities are caused by accumulations of flammable gas and/or combustible dust mixed with air in the presence of an ignition source. While much progress has been made in preventing explosion disasters in coal mines, explosions still occur, sometimes producing multiple fatalities.

Following a series of explosions of coal mines in Western Virginia during 2003, a study funded by the National Institute of Occupational Safety and Health (NIOSH), was done by H. K. Sacks and Thomas Novak, *Senior IEEE Members*, offering possible ignition mechanisms, including corona. The explosions took place in abandoned areas of underground coal mines. In all instances, steel-cased boreholes were located in the vicinity of the explosions. The study that was published in 2004 as “Corona Discharge Initiated Mine Explosions”, suggested that corona discharges from steel borehole casings, which are used to sample mines’ air, was the most likely mechanism responsible for these ignitions. The study used computer simulations were performed with using data collected at the mine sites. CDEGS™ software from Safe Engineering Services & Technologies, Ltd (SES) and MaxwellSV™ from Ansoft Corporation were used for the simulations. Strong circumstantial evidence suggested that lightning had initiated methane explosions in abandoned

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and sealed areas of underground coal mines. Data from the National Lightning Detection Network indicated a strong correlation between the times and locations of the explosions with those of specific lightning strikes. The study claimed that the conditions for corona ignition at the bottom of a borehole casing were induced from the lightning strikes.

An explosion can occur if lightning dissipates sufficient energy in a methane/air mixture with methane content between 5-15%, provided the oxygen content is at least 12%. The minimum energy requirement of only 0.3 mJ occurs with a methane concentration of 8.5%, and pockets of explosive methane/air mixtures can occur in abandoned, and even sealed, areas of coal mines.

According to the authors, lightning can penetrate underground mines either by propagation through the overlying strata or through conductive metallic structures extending from the surface to the mines. A lightning strike at the surface can propagate downward through the earth with enough energy to detonate explosives. The depth of penetration is proportional to soil resistivity. The second lightning-penetration mechanism results from a direct strike or a nearby strike that couples to a metallic structure that extends from the surface to the mine, such as cables, conveyor structures, water pipes, and borehole casings. This mechanism is far more likely in the deep mine incidents of West Virginia. The attenuation of such a strike depends on the surge impedance of the structure and how effectively the structure is grounded. The third optional ignition mechanism that should be considered is corona discharge. If corona ignition is possible, an actual spark gap is not necessary to create an explosion. Any conductor which is elevated in potential relative to remote ground will be the source of an electric field. If this field exceeds a critical level within the surrounding gas, corona discharge will occur. In air, spark discharge is generally considered to occur at approximately 30 kV/cm. The actual critical field at which corona forms is a function of the surface geometry, whether the potential is DC or time varying, and properties of the surrounding gas. Experimental research reported in a paper by Liu, J.B., Ronney, P.D., and Gundersen, M.A., "Premixed flame ignition by transient plasma discharges," (The 29th International Symposium on Combustion, Sapporo, Japan, July 21-26, 2002.) reported that short-duration corona discharges of 50 ns are capable of igniting methane/air mixtures at atmospheric pressure. In fact, such discharges are more efficient than spark discharges (i.e. requires less expended energy) and can form the basis of an efficient internal methane/air combustion engine.

Finally, using the simulations it was demonstrated clearly that corona discharge is likely to occur except for extremely weak lightning strikes and extremely low overburden resistivities.

- http://www.cdc.gov/niosh/mining/topics/Explosions.html

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