Potential Distribution Along a 500kV Polymer Insulator in Presence of a Pollution Layer

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Abstract: The objective of this study is to assess polymeric insulators subjected to polluted environments. The study cases were conducted on polymeric insulators of 500 kV lines. All analyses were carried out with computer simulations, employing the software COMSOL Multiphysics® to calculate the voltage distribution on the surface of the insulators with deposits of pollution layers. Pollution in the presence of moisture generates partial discharges that can lead to the total collapse of these units, causing great concern to the electricity sector regarding the system.

Figure 1. 500kV Polymer Insulator

Computational Methods:We used the interface for equation modeling in the coefficient form to insert our PDE of interest:

$$(\sigma_v + j\omega\varepsilon)\nabla^2 V + j\omega\rho_s = 0$$

Where:

σ_v- Material Conductivity [*S/m*]

ε - Material Permittivity [*F/m*]

ρ_s - Surface charge density [C/m^2]

ω - Service frequency [rad/s]

V - Electric Potential [V]

According to others authors we can consider the surface charge density along the insulator equals zero, resulting to solve a modified Laplace's equation:

$$(\sigma_v + j\omega\varepsilon)\nabla^2 V = 0$$

Due to the symmetry of our problem we use the 2D axisymmetric space dimension and model the presence of pollution as a thin conductive layer of 1 millimeter uniformly distributed over the insulator and applied the service peak voltage (407 kV), to evaluate the voltage distribution. We varied the values of conductivity and permittivity of pollution according to Table 1:

	Clean	Slightly Polluted	Moderately Polluted	Highly Polluted
Permittivity[F/m]	1.02	15 and 80	15 and 80	15 and 80
Conductivity[S/m]	0	10^{-8}	10^{-6}	10^{-3}

Table 1. Pollution Parameters

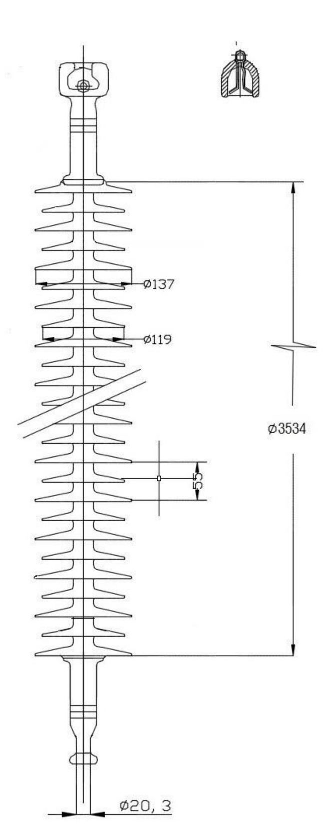

Figure 2. Insulator CAD Drawing

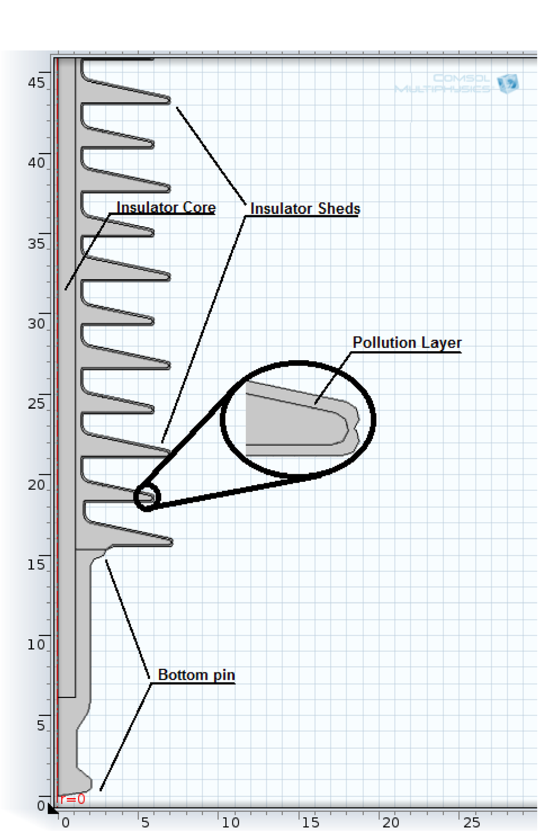

Figure 3. Pollution Modeling

Results: Under a volume conductivity of 1μS/m, the influence of the thin layer permittivity increases as the conductivity decreases. For low conductivity, the potential distribution obtained is close to the potential distribution of the clean insulator which is only governed by the capacitive regime, as the conductivity increase, the influence of the permittivity decreases and becomes neglected for a volume conductivity greater or equal to 1 μS/m. In fact, the thin layer becomes a better conductive layer entering in resistive regime making the potential distribution uniform.

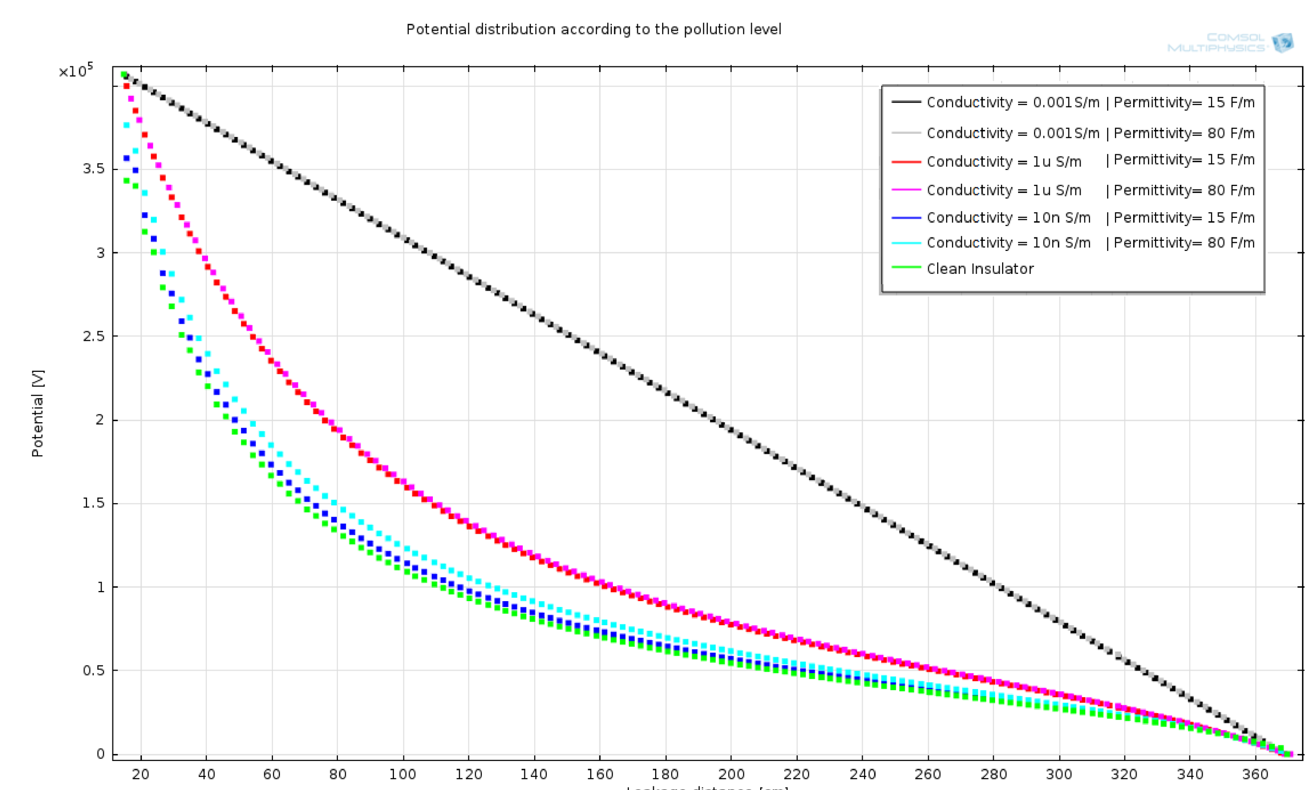

Figure 4. Potential distribution according to the pollution level

Material	Conductivity[S/m]	Permittivity[F/m]
Air	0	1.02
Silicon Rubber	0	3
Fiberglass	0	6.5
Metal fittings	10.2x10^6	10^{-6}

Table 2. Material Parameters

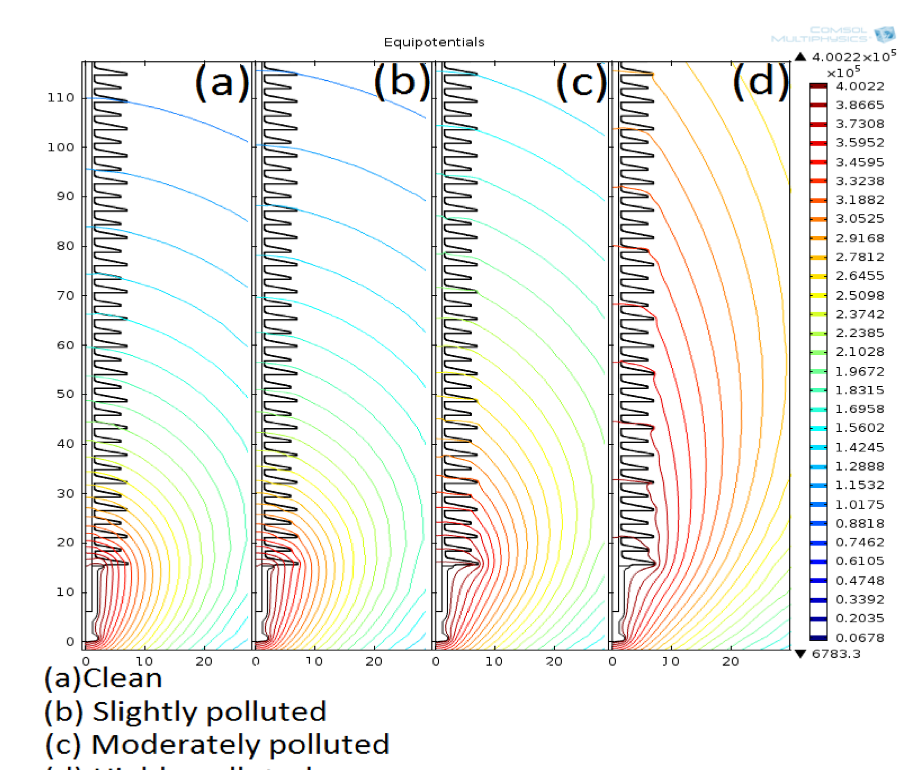

Figure 5. Equipotentials

Conclusions: It is important to register how the efficient performance of insulators heavily depends on the level of pollution, and depending on this level, some units may still be subject to intermittent discharges, causing the gradual degradation of the dielectric and leading the insulator to bad functioning. COMSOL Multiphysics is a powerful tool that helps the understanding of this problem and, in the future, the results could be used to develop some device to monitor the insulator performance when operating in polluted environment.

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