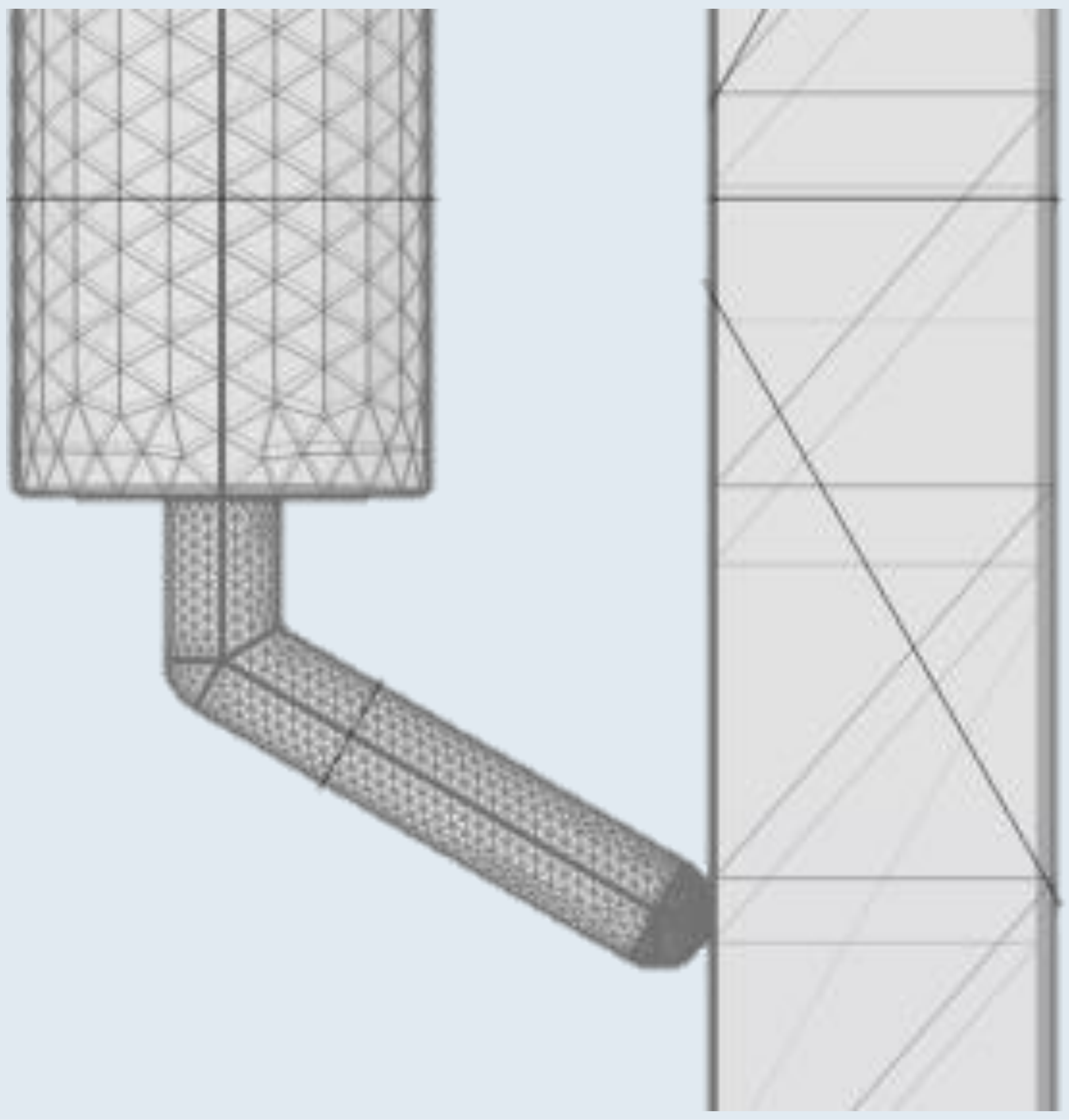

3D Electric field calculation in hybrid insulation for electrotechnical equipment design

Surface flashover at the gas/solid interface in electrotechnical equipment is a critical issue. This research investigates such flashovers by examining the pre-breakdown and breakdown mechanisms through experimental studies and numerical simulations using COMSOL® Multiphysics to gain a deeper understanding of the phenomenon.

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Introduction

The triple point, where two insulators with different electrical properties and a conductor intersect is the most vulnerable part of an insulation system due to electric field ($\vec{E}$) enhancement in this region. Understanding pre-breakdown and breakdown at this triple point is crucial for designing gas/solid insulation systems. Factors influencing surface discharges and surface breakdown (surface flashover), include gas parameters, solid properties etc. [2].

This study focuses on the calculation of the electric field in transient and in static regime.

1- determining **the characteristic time** of the voltage step at which $\vec{E}$ becomes governed by conductivity (σ) instead of permittivity. 2- the influence of **surface charge density** (σ_q) and **relative permittivity** (ε_r). Existing experimental data [1] shows that in solid dielectrics with a $\varepsilon_r < 3$, the discharge behavior is similar to that of air alone. As ε_r increases, the mechanism shifts possibly due to the opposition of the electric field created by the accumulated surface charge in response to the applied field.

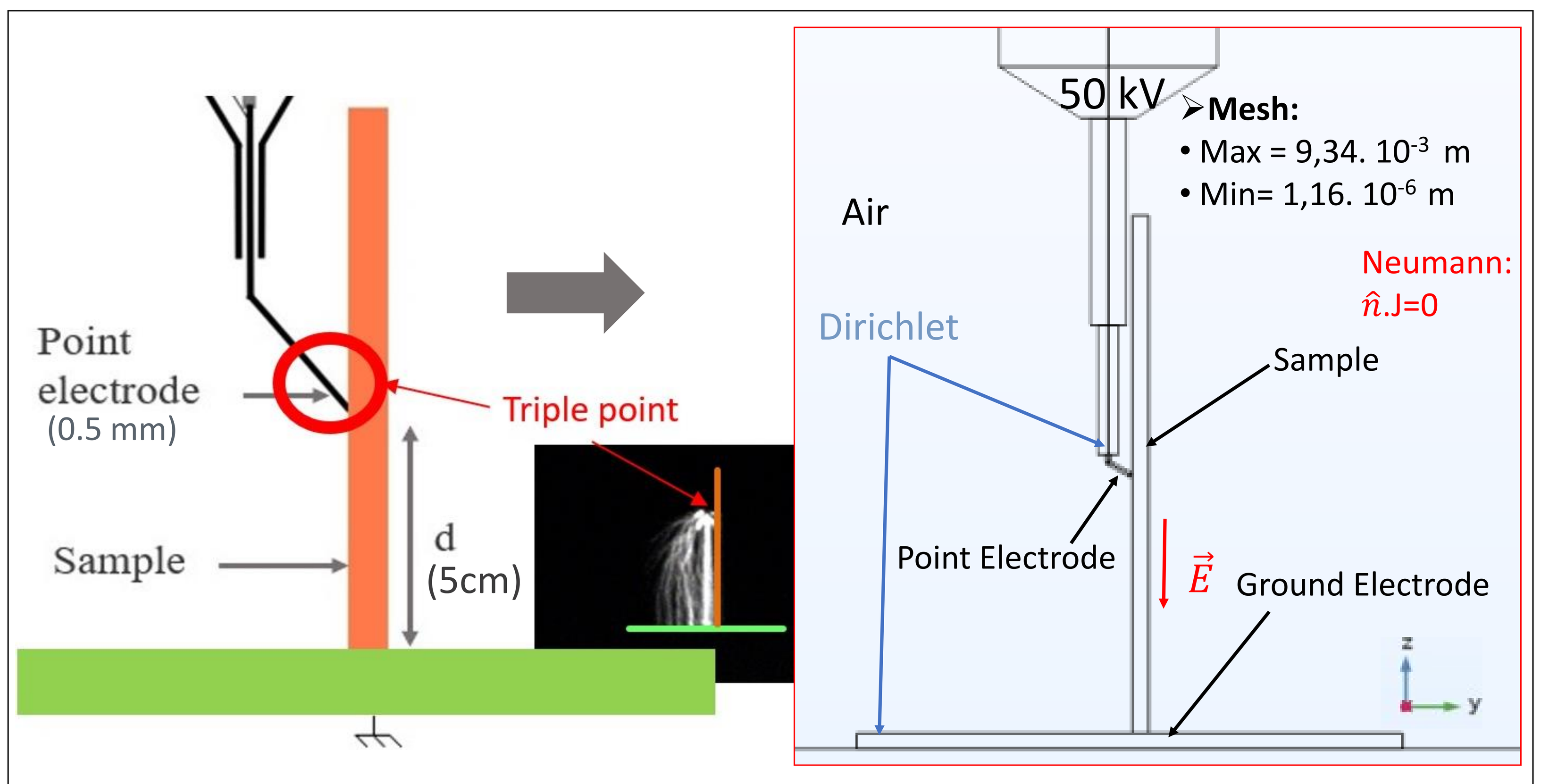


FIGURE 1. Pre-breakdown and breakdown geometry of the point-plane electrode system with the dielectric placed perpendicular to the grounded plane electrode, where the surrounding medium is air.

Methodology

* J_e: Current density
Q_s: External current source
ρ_q: Volume charge density

➢ 3D electric field calculation via COMSOL® Multiphysics

Study 1	Study 2
➢ Electric current physics : $-\nabla.(\sigma\nabla V - J_e) = Q_s$	➢ Electrostatic physics: $\nabla^2 V + \frac{\rho_q}{\varepsilon} = 0$
➢ Combined parametric study to determine τ for the system's transition at 50 kV calculation done between 10^{-3} - 10^{8} s:	➢ Combined parametric study to determine the required σ_q, ε_r and voltage to replicate discharge behavior in air:
→ σ= 10^{-11} & 10^{-12} S/m → ε_r = 2 & 9	→ ε_r= 2 to 9 → + and homogenous σ_q = 0.1 to 8 μC/m²

Results

- **Study 1: Near the triple point** (in the solid at : 100μm of the triple point)

➢ 10^{-12} S/m for ε_r = 2 → τ= 2.5*10^2 s

➢ 10^{-11} S/m for ε_r = 9 → τ= 1.5*10^2 s

Under lightning impulse voltage (1,2/1200 μs) the system is primarily governed by permittivity.

- **Study 2:** Electric Field **near the triple point** (in the solid at : 100μm of the triple point) is at the same order of magnitude of the electric field in air without a solid for :

➢ 5 μC/m² for ε_r = 3.2

➢ 7 μC/m² for ε_r = 5.2

The surface charge density significantly influences the discharge mechanism by opposing the applied field.

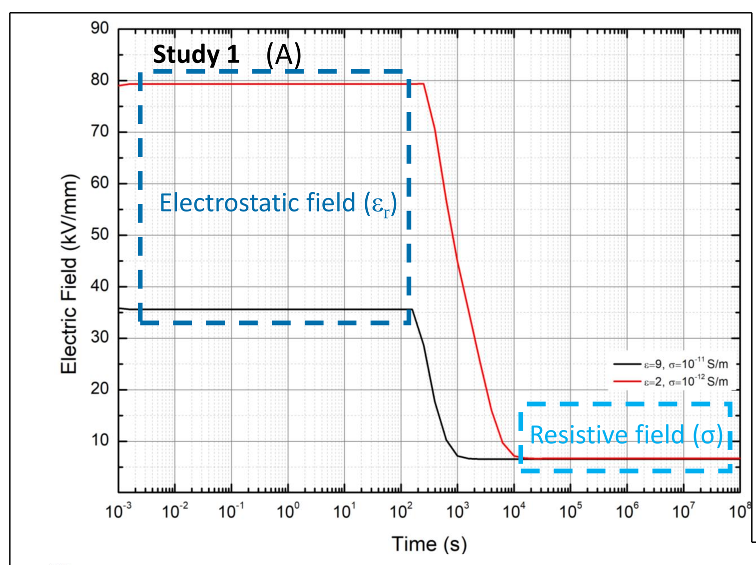
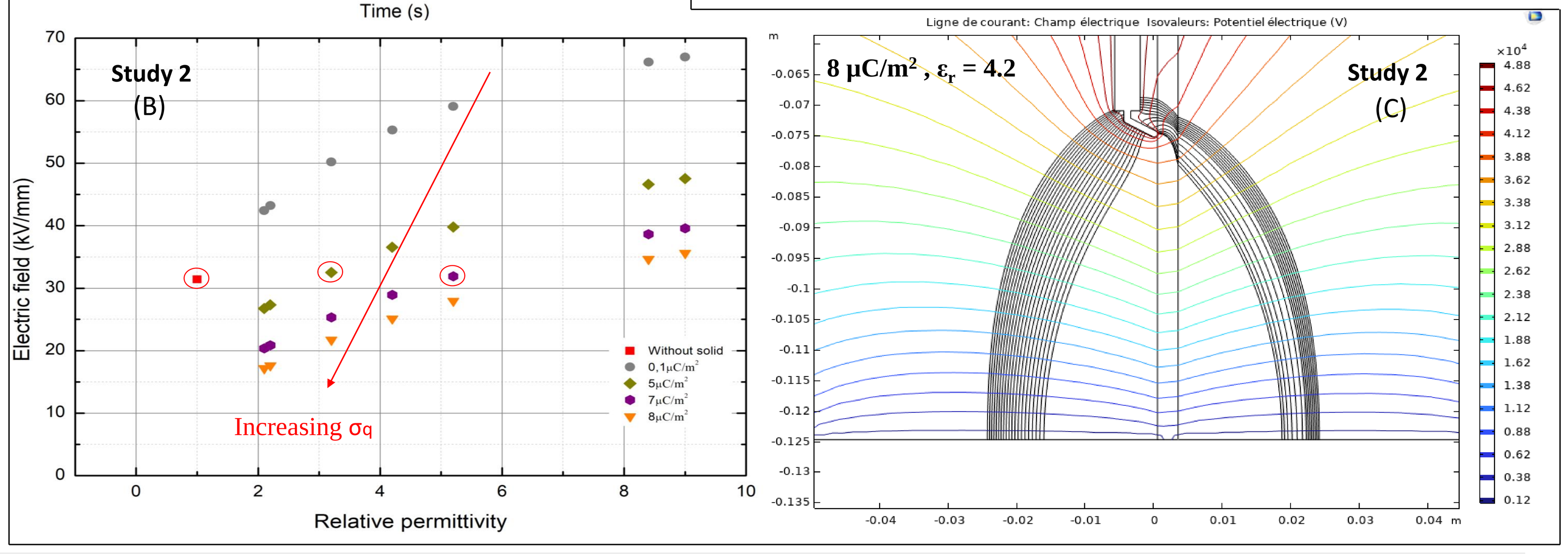


FIGURE 2. Results for a 50 kV point electrode.

(A) **Study 1:** Electric field as a function of time
(B) **Study 2:** electric field as function of permittivity and charge density
(C) **Study 2:** Electric field distribution at 8 μC/m² , ε_r = 4.2



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