Assessment of insulation technology for overhead line equipment using finite element analysis to validate experimental setups

acm's women in computing
acm-w
Europe

Lauren Deeth-Kelt*, Paul Lewin*, Neil Palmer*, Charlie Reed*, Liz Tillotson*, Paul Naylor**, Richard Stainton**
***University of Southampton** and **Network Rail

Introduction

Electrifying rail networks bring challenges for overhead equipment. **High-voltage lines need enough clearance** to prevent lightning strikes or surges from discharging to the train or nearby structures. On existing rail lines, this requires **demolishing and rebuilding** bridges or other structures, which **leads to higher construction costs and disruption** for local transport and businesses.

Here we assess two insulated bridge arm designs that help reduce the required clearance between high-voltage lines and grounded structures. **We used computer modelling and testing to confirm the minimum safe working distances.** These results are essential for safe and cost-effective rail electrification, especially on existing infrastructure.

Results

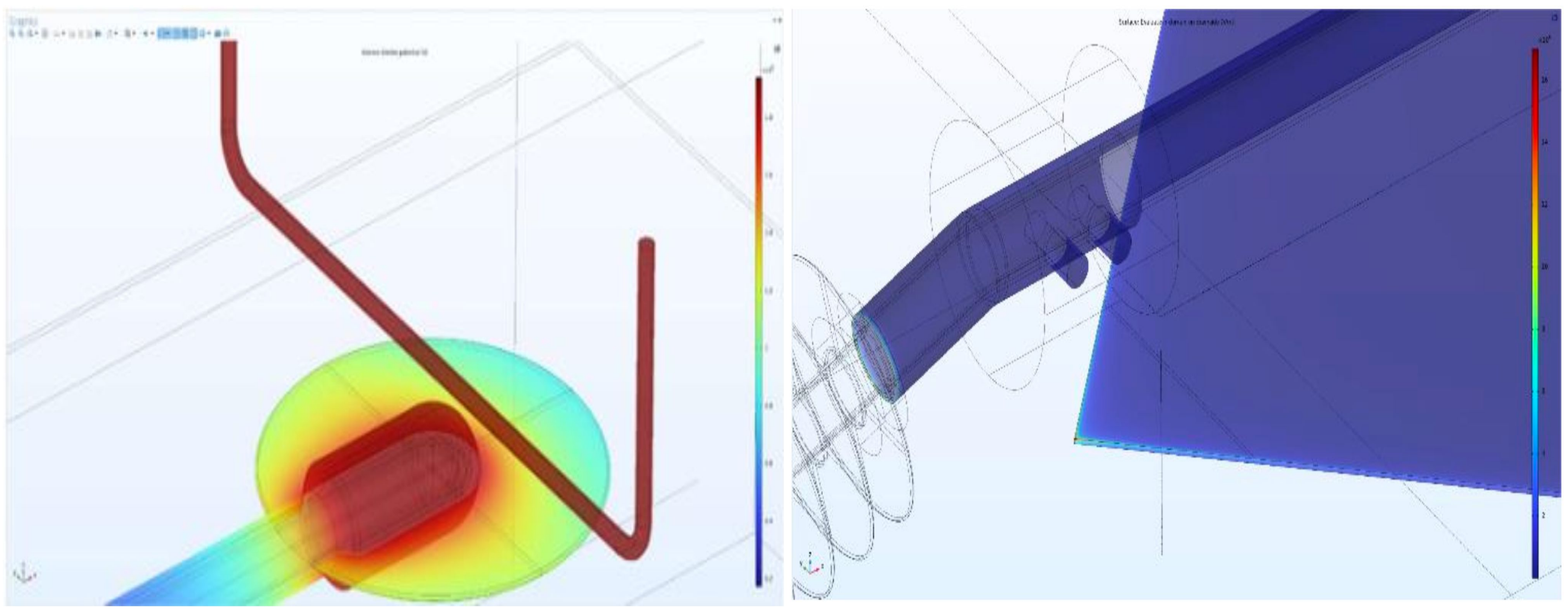
Table 1 records results from wet impulse testing and confirms withstand distances of 280mm for Arm A arm and 340mm for the Arm B. The addition of the surge arrestor reduces these distances to 0mm and 60mm for Arm A and Arm B arms respectively. The dry test results produced distances of 260mm and 300mm for Arm A and Arm B without a surge arrestor. Connecting the surge arrestor reduced these distances to 0mm and 60mm as in the wet tests.

Table 1: Impulse testing withstand results

Wet/dry test	Surge arrestor used?	Withstand distance (mm)	
		Arm A	*Arm B*
Wet	No	280	340
	Yes	0	60
Dry	No	260	300
	Yes	0	60

Table 2: Power frequency testing withstand results

Wet/dry test	Withstand distance (mm)	
	Arm A	*Arm B*
Wet	80	100
Dry	5	80



Figures 1 and 2: COMSOL models of Arm A and Arm B

Analysis and Conclusions

We used COMSOL models of Arm A and B, respectively (in Figures above), to explain various electromagnetic phenomena observed during testing.

- **Arm A**

➔ Rounded design and thick insulation make Arm A more resistant to breakdown.

➔ Testing showed surface charge build-up, causing some back discharges.

➔ An earlier version of Arm A had a puncture and permanent damage.

➔ Forensic analysis revealed an aluminium fixture inside the glass-reinforced plastic core, connected to the contact wire.

➔ Partial discharges likely weakened the insulation, leading to a puncture as the aluminium was at the same potential as the contact wire.

- **Arm B**

➔ Needs a larger clearance because of its design, especially due to two large hexagonal M16 bolts mounted on the sides.

➔ The bolts create high electric field points, increasing the risk of breakdown.

➔ Testing with a 1m² earth plate revealed reverse polarity effects at higher voltages due to the arm's geometry.

➔ Finite Element Analysis (FEA) showed the earth plate and bolt edges created a discharge path at 193kV.

References

1. Ministry of Transport. Electrification of railways advisory committee: Iterim report, 1920.
2. Peter Stainton. Overcoming the clearance issue, rail engineer, https://www.railengineer.co.uk/overcoming-the-clearance-issue/ , June 2021, accessed 02/02/2025.
3. British Transport Commission. Modernisation of British Railways: The System of Electrification for British Railways. British Transport Commission, 1956..

12th ACM Celebration of Women in Computing: womENcourage™
Brașov, Romania
17-19 September, 2025
Theme: Computer Science: a Catalyst for Educational Change

womENcourage 2025, Romania

acm