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# An Investigation of Thermal Ratings for High Voltage Cable Crossings through the use of 3D Finite Element Analysis


**Z.Y.Huang , J.A.Pilgrim and P.L.Lewin**

University of Southampton, Southampton, UK


## DEFINITION OF RESEARCH PROBLEM

### The Importance of Cable Crossings

- Cable crossings are inevitably found in urban areas as a result of growing complexity of underground cable systems
- Dangerously high temperatures can occur at crossing points, resulting in premature aging of cable insulation and potentially cable failures
- The only existing explicit rating method is IEC60287 (analytical), but its application/accuracy is restricted by idealistic assumptions

**QUESTION – Are there any alternative methods which can be applied to accurately rate cable crossings with more realistic environmental parameters?**

Figure 1 - sample cable crossing in North America

(www.dstar.org/research/project-desc/UG-cable-ampacity)

### Research / Economical concerns

**Project interests**

- Effect of ground conditions
- Mutual heat reduction / optimize thermal performance
- Accuracy of IEC 60287

**Technical Factors**

- Deeply buried
- Large vertical spacing between crossing circuits
- Redesign both circuits for best performance

**Economical Factors**

- Minimize risk
- Minimize ageing
- Minimize capital expenditure

**against**

**Need to find a compromise between maximisation of power transfer and economical concerns**

## DEVELOPMENT OF 3D FEA MODEL

### Example Cable Crossings

- Conductor size: 800 mm$^2$
  Copper conductor: Dc=34.7 mm
  XLPE insulation: Di=72.6 mm
  Lead alloy sheath: Ds=78.5 mm
  PE serving: De=86.8 mm
- 2 x 132 kV single-core armour-free cables crossing at 90 degrees
- 2 x 132 kV three-phase circuits crossing at 90 degrees
- Burial depths:
  (**upper cable**) 0.5 m &
  0.75 m, 1.5 m, 1.25 m (**lower cable**)
  (**upper cable**) 1m &
  1.25 m, 1 m, 2.25 m (**lower cable**)

### Numerical Modelling

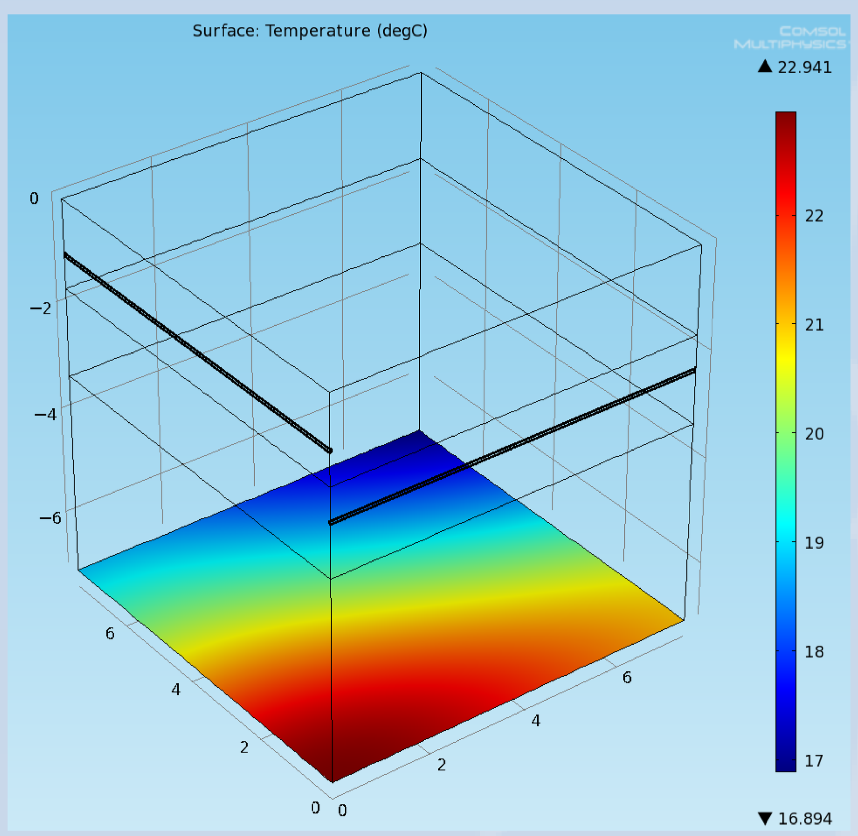



Figure 2 – example temperature plot on bottom boundary

- Model size: 7.5 x 7.5 x 7 m (LxWxH) homogeneous soil, Ps=1.2 Km/W
- Ground surface conditions: isothermal at 12 / 15$^0$C, still air convection, 1 m/s air convection, 10 m/s air convection
- Bottom boundary condition: locally fixed temperature(surface)

$$T(local) = T(\infty) + \frac{Ps}{2\pi} \times \mathrm{Wt} \times \ln\frac{d'}{d}$$

Ps = soil thermal resistivity, Km/W

Wt = total losses inside the cable, W/m

d = distance between the point under consideration and actual buried cable, m

d' = distance between the point under consideration and image cable above the ground, m

- Side wall boundary condition: thermal insulation/symmetry
- Heat sources : Joule loss, dielectric loss, sheath loss

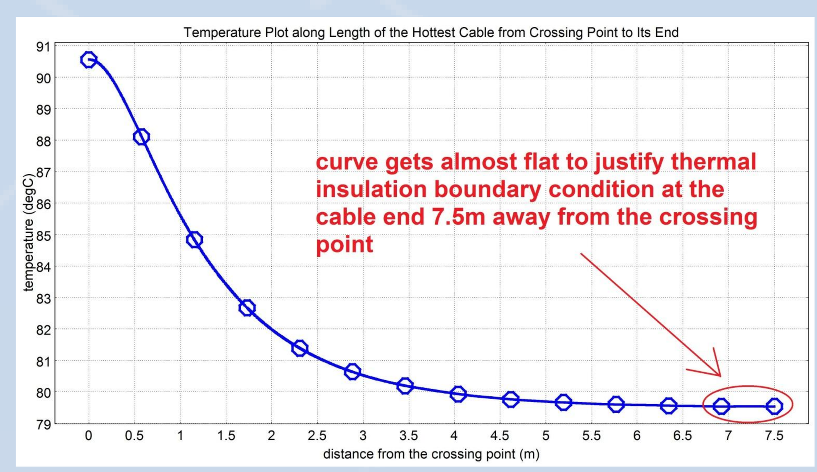



Figure 3 - temperature plot along length of the hottest cable

## RESULTS AND IMPLICATIONS

### Single Cable Modelling Results

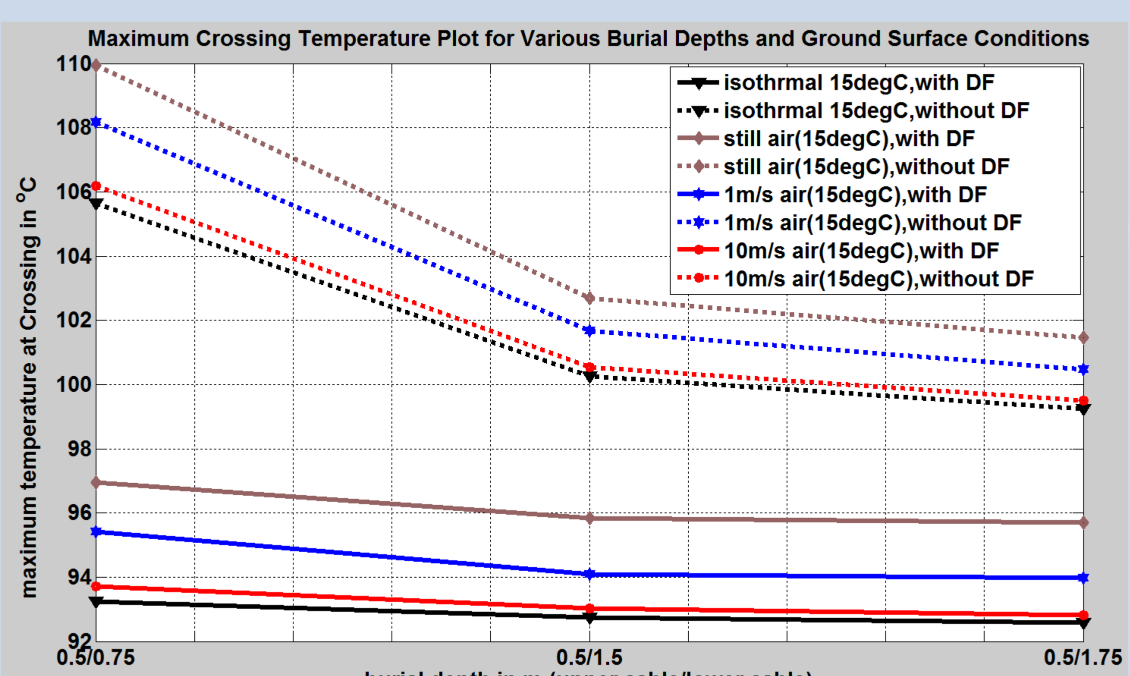



Figure 4 - crossing temperature plot for various burial and ground surface conditions part 1

- Applying Derating factor (DF) from IEC60287(Std) reduces temperatures, but still above 90$^0$C
- The magnitude of the excess temperature depends on ground boundary conditions

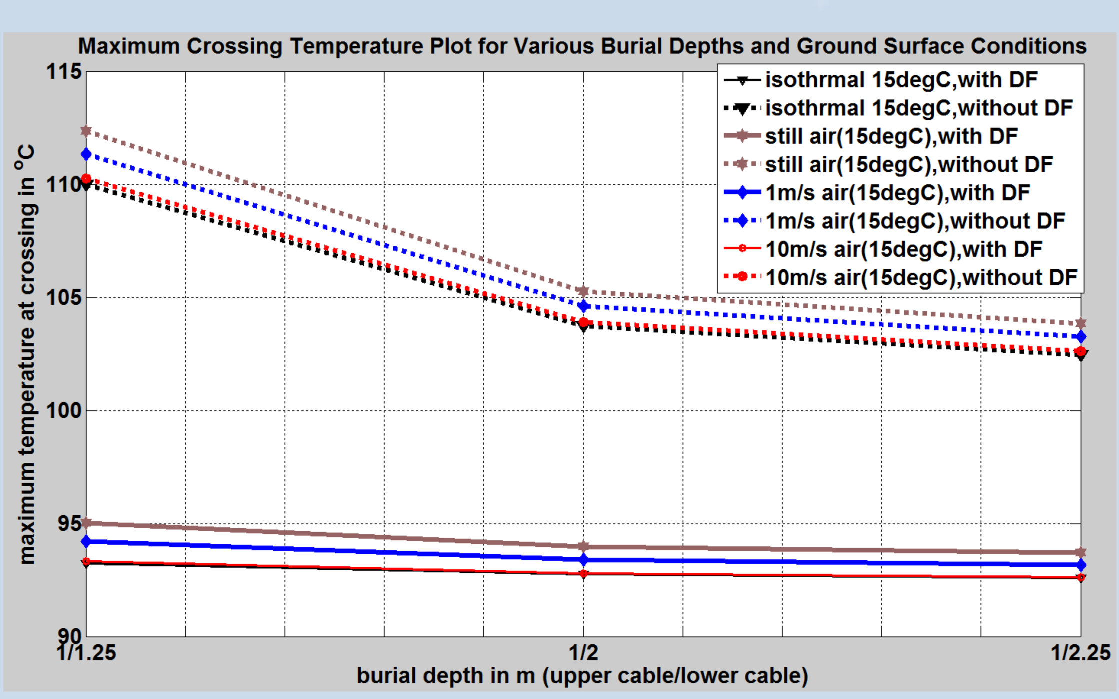



Figure 5 - crossing temperature plot for various burial and ground conditions part 2

- The match between FEA and IEC 60287 results improves with increasing burial depth and vertical spacing between two crossing circuits
- This is due to the reduced effect of the ground condition surface with increasing burial depth

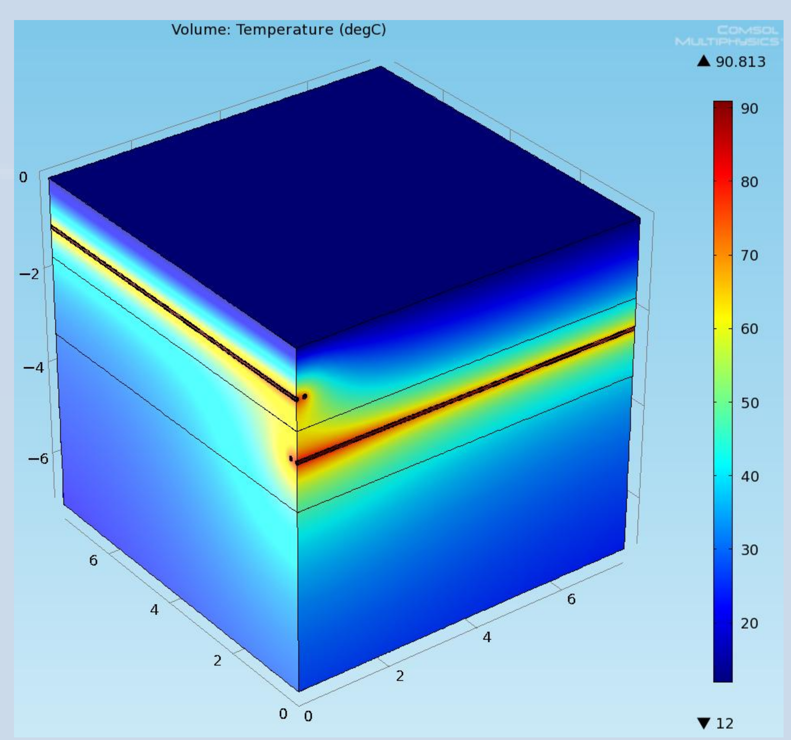



Figure 6 – volume temperature profile of two three-phase cable crossing at 90 degrees

- Extend single cable crossing model to three-phase circuits crossing
- Trends match single cable case but over-rating increases
- Because the total heat generated is increasing, ground condition imposes a stronger effect on the overall crossing thermal performance

### Implication & Further research

- The isothermal ground boundary assumption in IEC60287 for crossing rating calculation is necessary for quick analytical calculation. However, it reduces the accuracy of calculations for practical applications.
- Ground surface condition has a strong effect on crossing thermal performance so that an understanding of its effect is vital for accurate rating strategy.
- Further study will focus on how good is IEC60287 can be applied in crossing rating problems quantitatively.


Contact details : zh2g09@ecs.soton.ac.uk

University of Southampton, Highfield, Southampton, SO17 1BJ, UK