Failure Modes of Underground MV Cables: Electrical and Thermal Modelling

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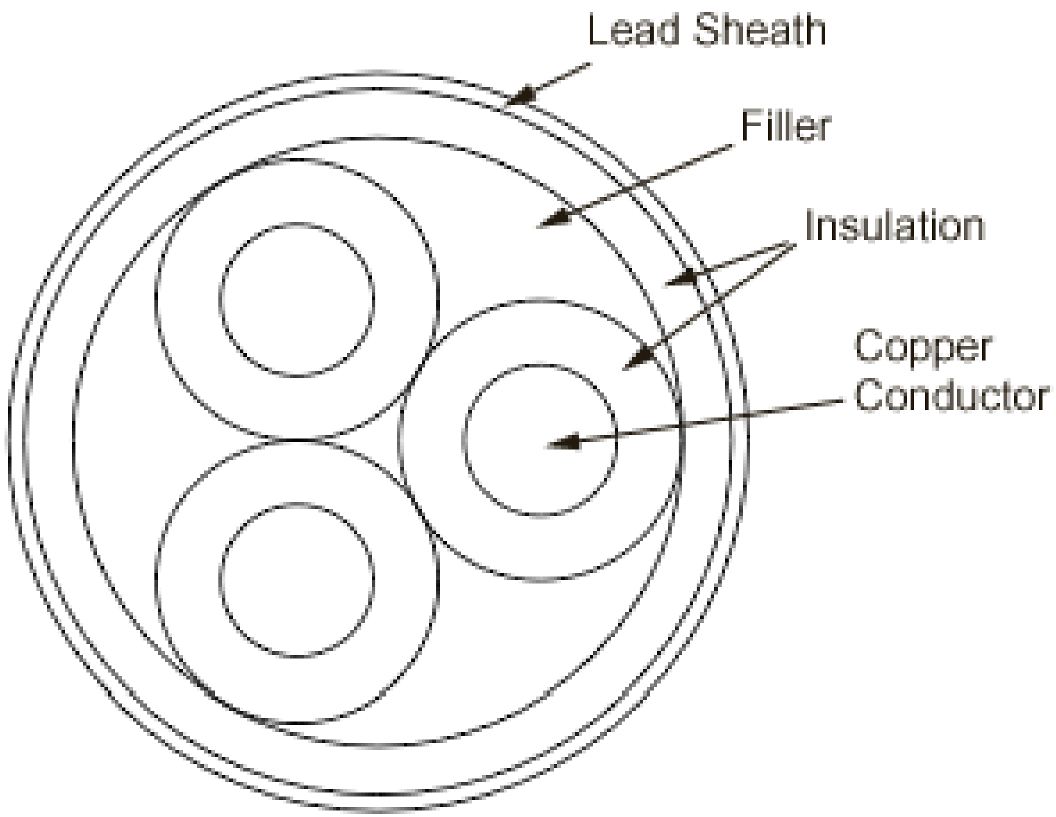
What is This Nasty Looking Object?

3 Phase Paper Insulated Lead Covered (PILC) Cable



Medium Voltage Distribution Network

- Between the HV transmission network..

  (long distance, 100s kV, frequently overhead)

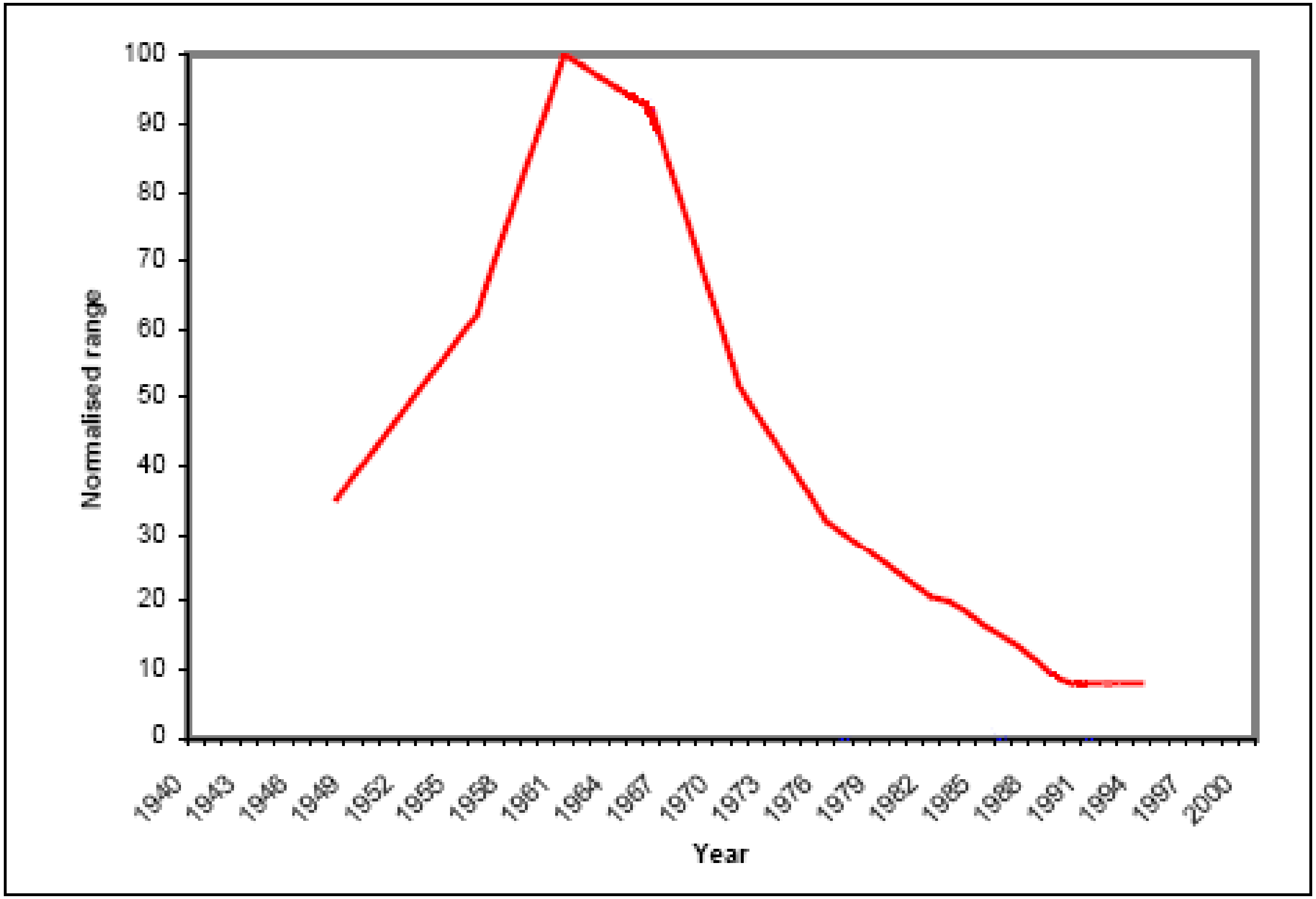
- ..and the household electricity supply..

  (230 V, domestic)

- ..lies the MV distribution network.

  (moderate distances,10s kV, frequently underground)

Inventory of MV cables by Year of Installation

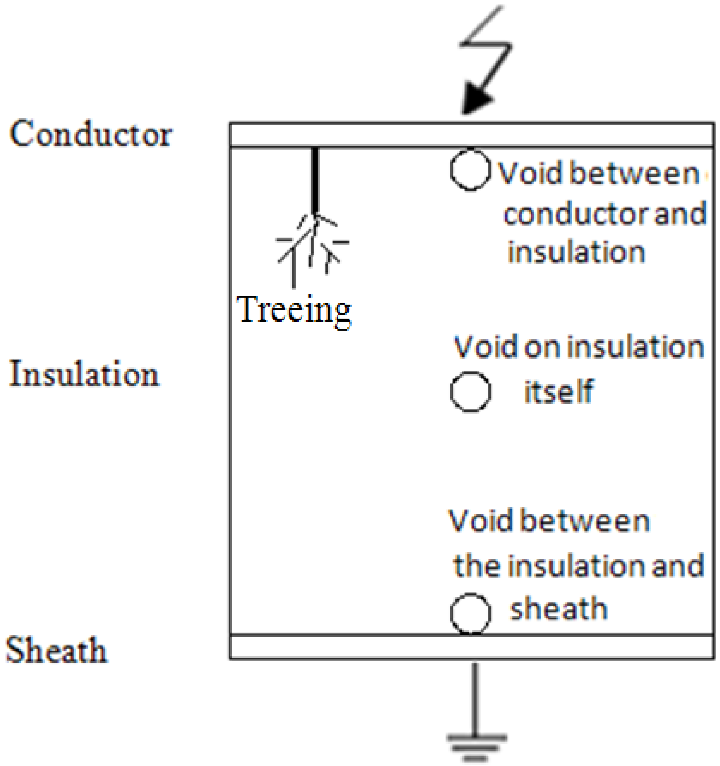


Supplied by ‘ a Utility Company’

A Legacy Infrastructure (in large Part..)

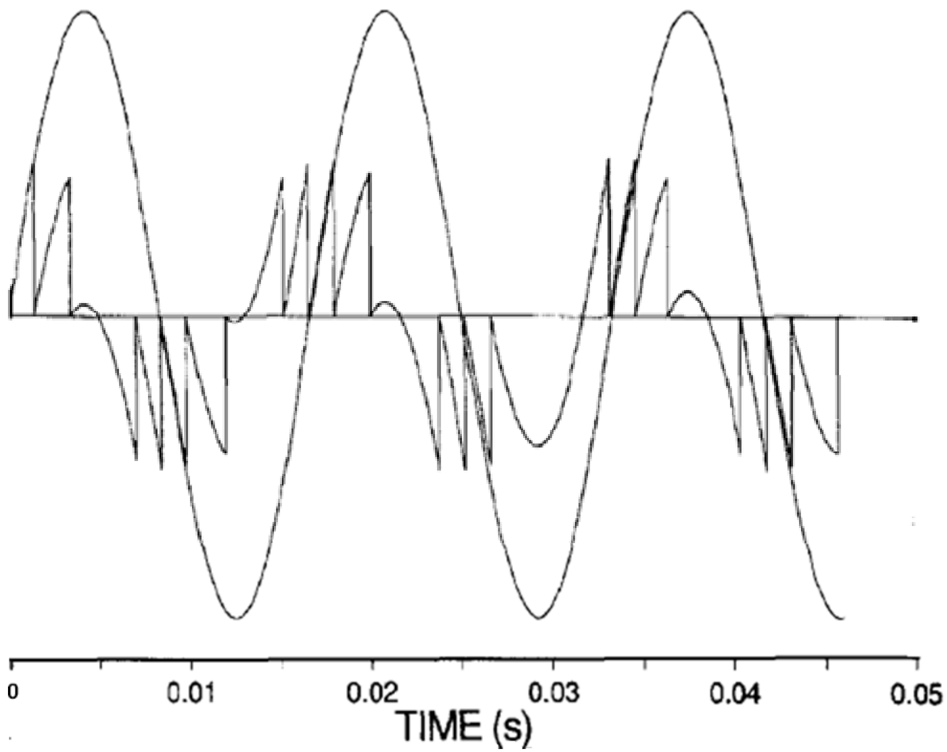
- A ‘utility company’ has 38000 km of MV cable within its area of operation.
- Much of the cable infrastructure is operating beyond its design life expectancy.
- The current rate of replacement is 100 km/year
- On-line condition monitoring sensors are being installed to detect Partial Discharge (PD) activity..
- ..but how to interprete the data?

Partial Discharge



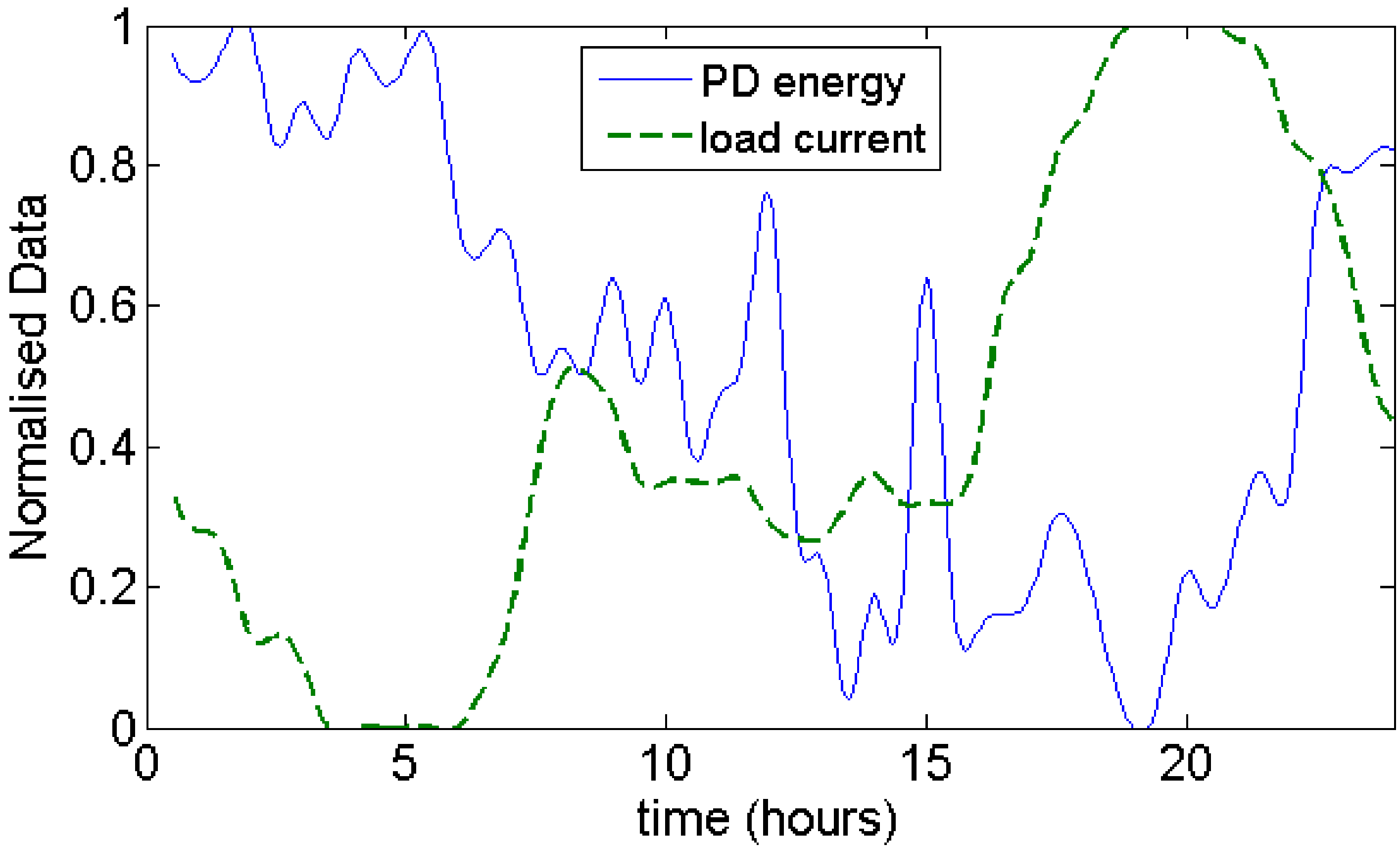
PD is a localized electrical discharge that only partially bridges the insulation between conductors which may or may not occur adjacent to a conductor.

Partial Discharge – E Field in Discharging Void



from
Boggs, S. A. (1990) Partial Discharge - Part 111:Cavitv-Induced PD in Solid Dielectrics. IEEE Electrical Insulation Magazine, 1990-Vo1.6, No.6

Correlation between Cable Load and PD Activity



From the same 'Utility Company'

Two Models

- A long time scale (hundreds of hours) thermal model..

..will provide the background conditions for a..

- ..short time scale (20 ms!) electrostatic model.

Electrostatic Model

$$-\nabla \cdot \left(\varepsilon_0 \varepsilon_r \nabla V\right) = \rho$$

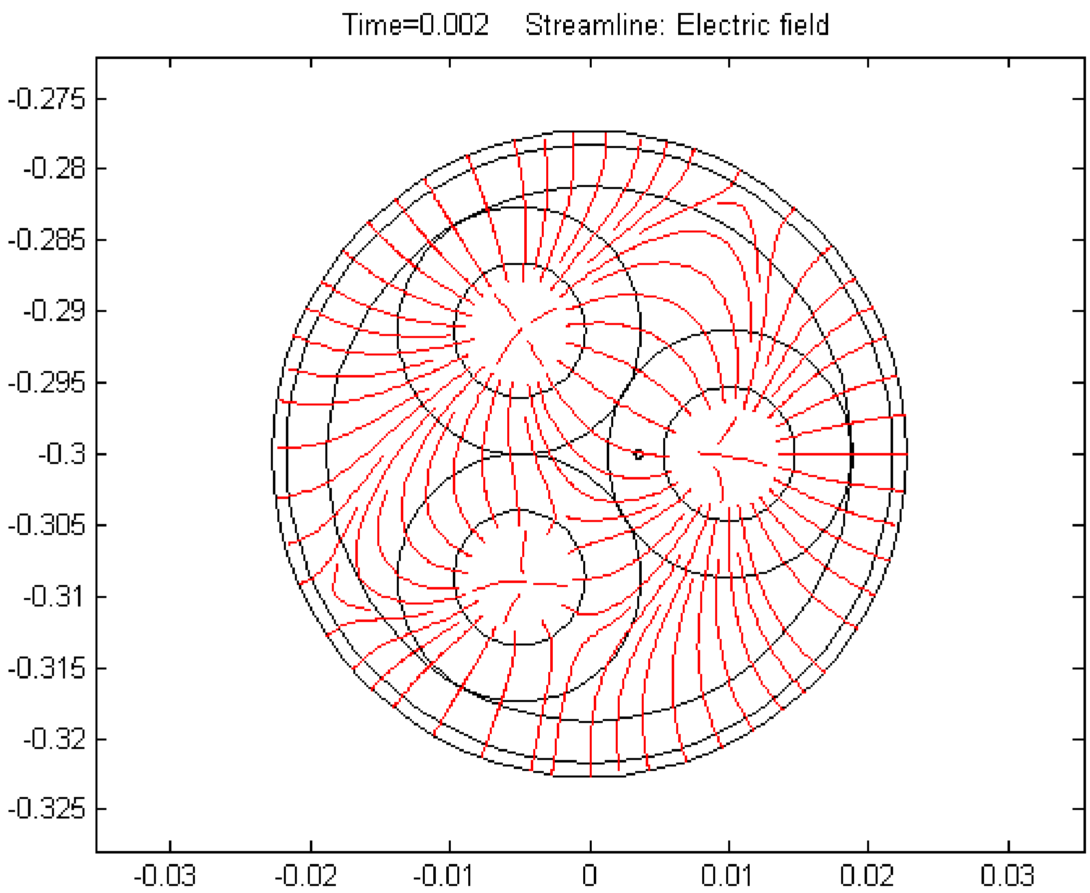
$$\mathbf{E} = -\nabla V$$

Subject to BC

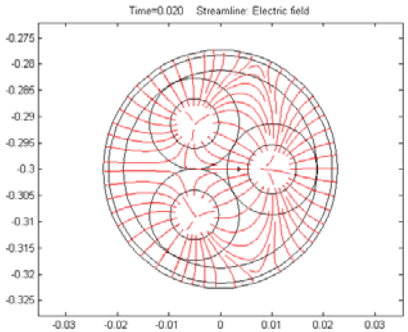
Sheath : $V = 0$

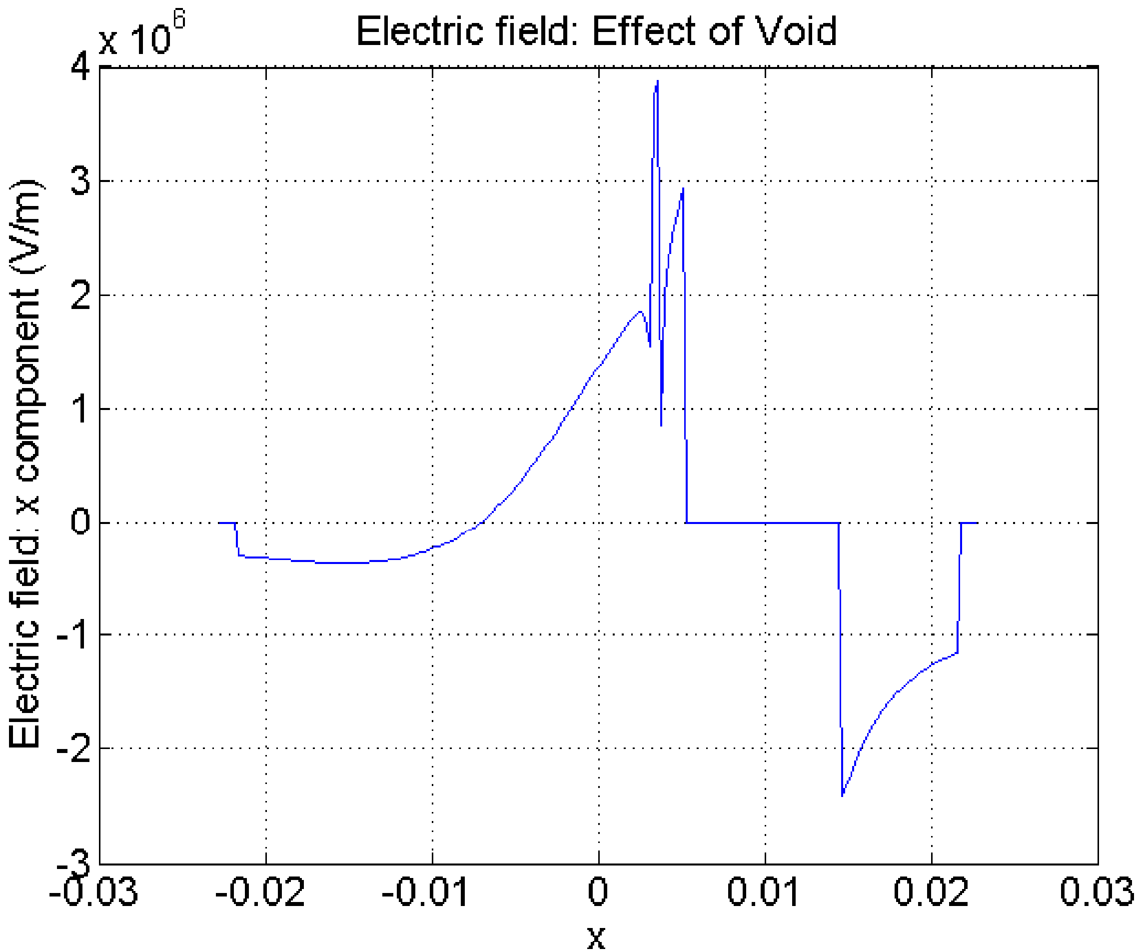
Conductors : $V(t) = V_0 \cos(\mathrm{w}t + 2n\pi/3) \quad n = 0,1,2$

Electric Field in PILC Cable

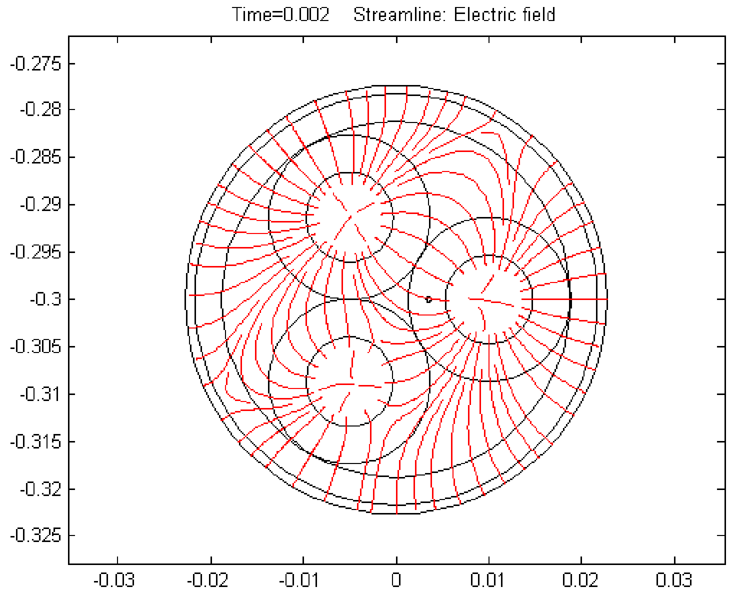


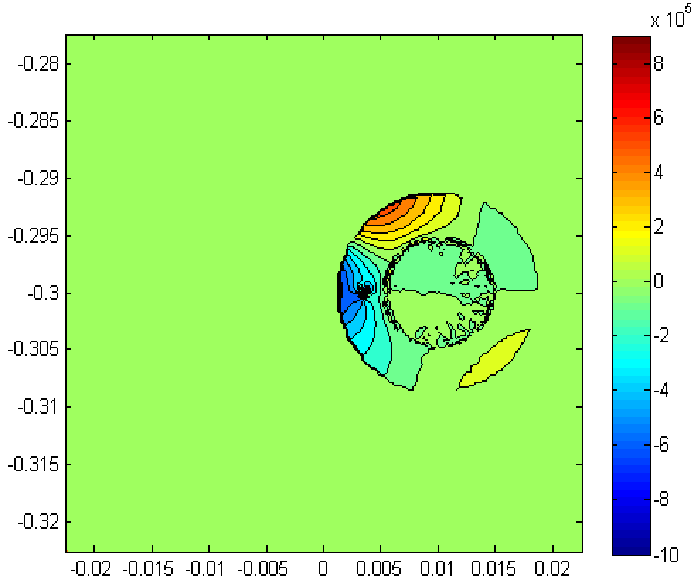
Increased Field in Insulator Void





Tangential Component of Field within Insulation Belt





Thermal Model

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot \left(k \nabla T \right) = Q$$

where $Q = Q_c + Q_s$ (conductor and sheath contributions)

$$Q_c = \frac{I^2 R}{A_c}$$

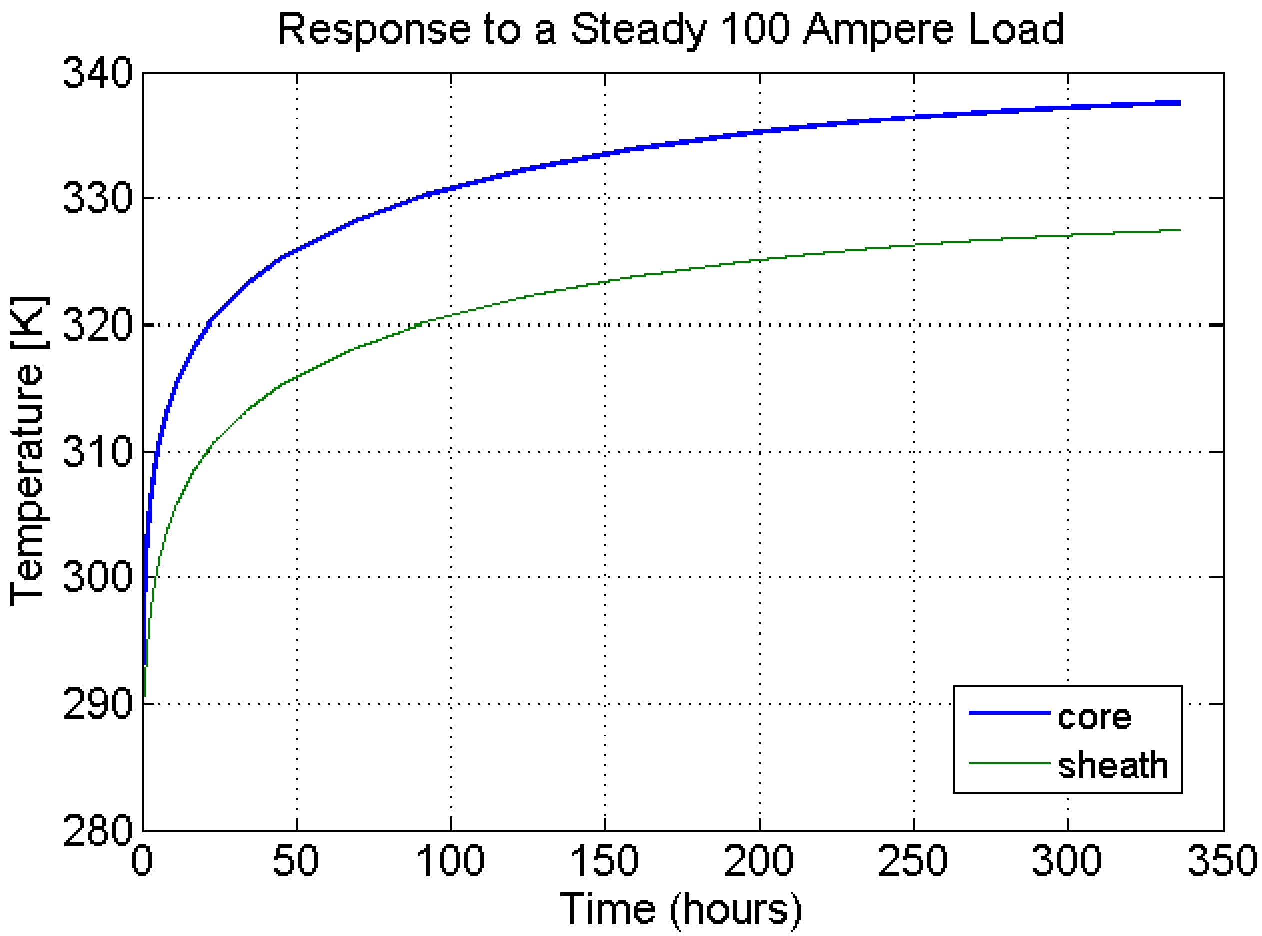
$$Q_s = \lambda \frac{Q_c}{A_s}$$

following BS IEC 60287 -1-1: 2006

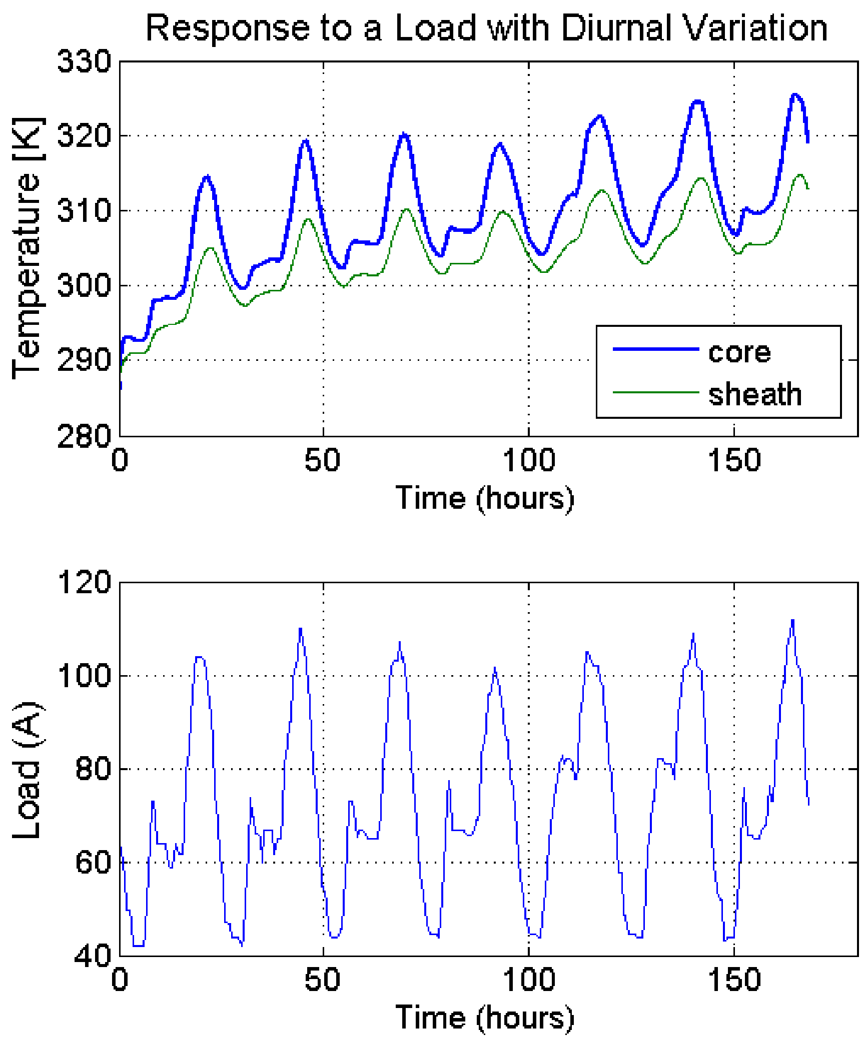
Subject to IC: $T(t) = 288\ K$

Subject to BC: $T_{boundary} = 288K$

Step Reponse

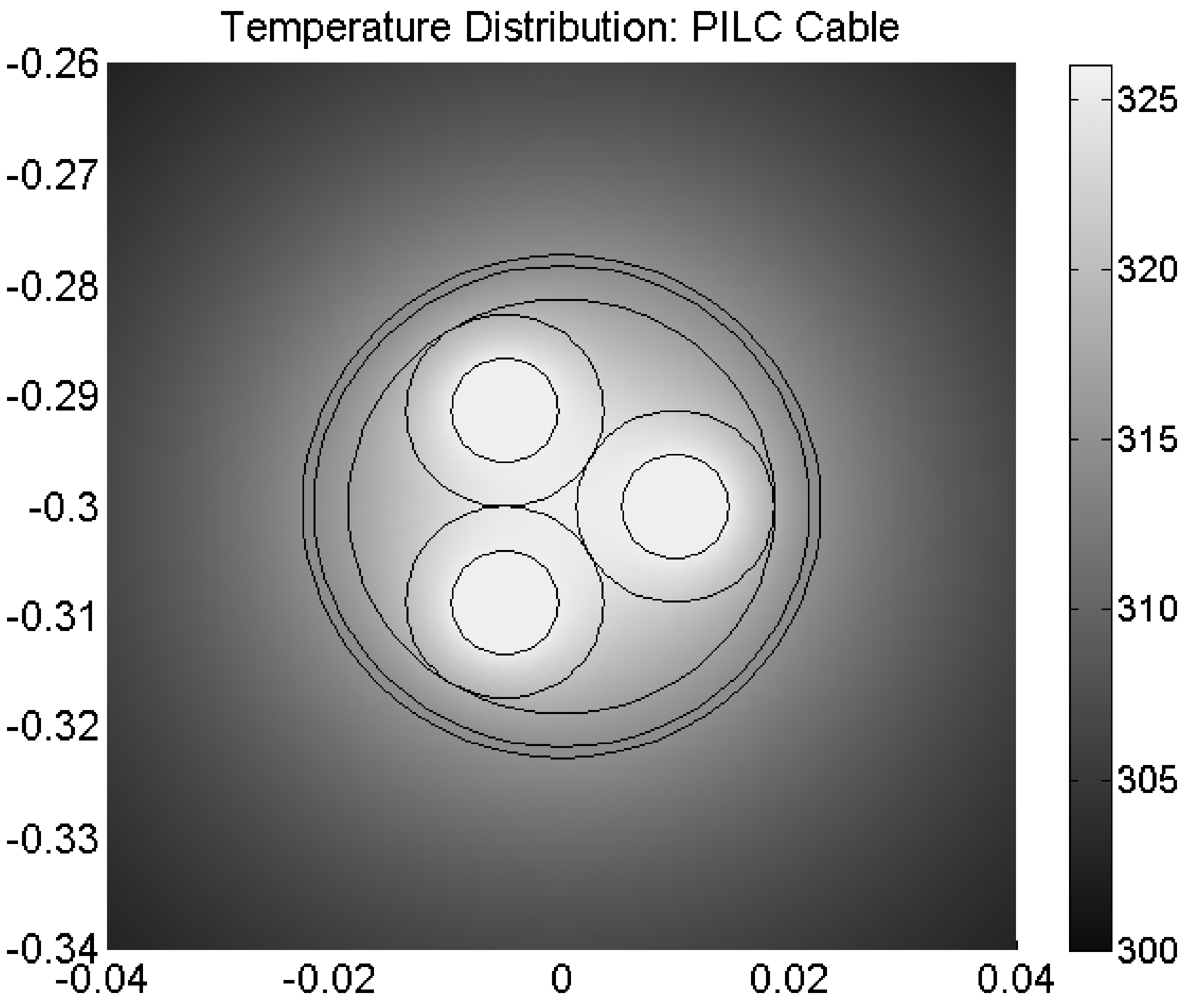


Response to Real Load over One Week

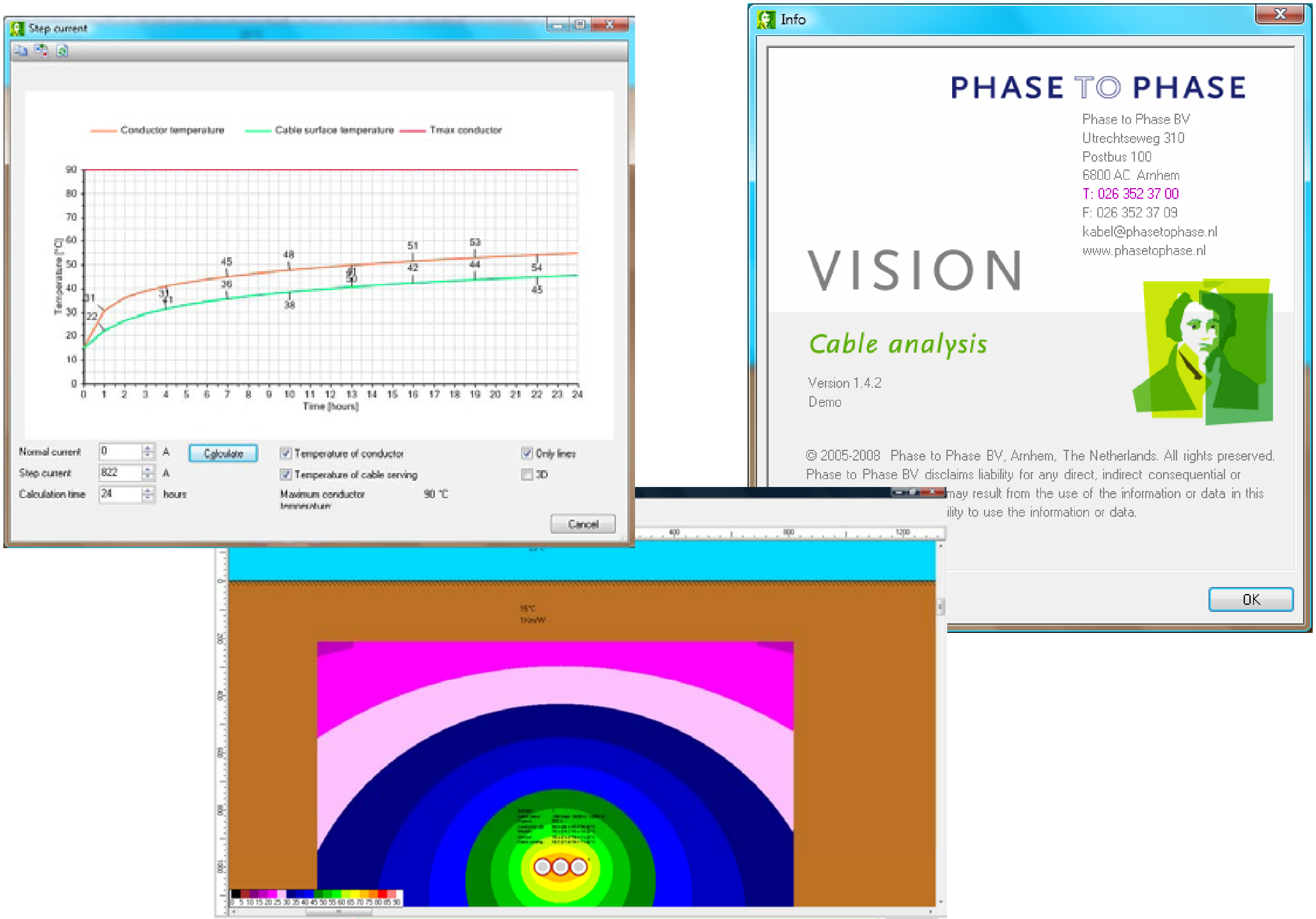


Load Data from the usual 'Utility Company'

Temperature Distribution within Cable



Comparisons requires with existing commercial products, for example..



Future Work

- Incorporate Thermo-Mechanical Effects into the long term model.
- Run the short time scale model using the background conditions of temperature and deformation established by the long term model

THANK YOU

FOR YOUR ATTENTION