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 interpret 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

COMSOL Conference Milan 2009
Correlation between Cable Load and PD Activity

From the same ‘Utility Company’
Two Models

- A long time scale (hundreds of hours) thermal model..
  
  \textit{..will provide the background conditions for a..}

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

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

\[E = -\nabla V\]

Subject to BC

Sheath : \[V = 0\]

Conductors : \[V(t) = V_0 \cos(wt + 2n\pi/3) \quad n = 0, 1, 2\]
Electric Field in PILC Cable

Time=0.002  Streamline: Electric field
Increased Field in Insulator Void

Electric field: Effect of Void

Electric field x component (V/m) vs. x
Thermal Model

\[ \rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (k \nabla T) = Q \]

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: \( T_{\text{boundary}} = 288 \) K
Response to Real Load over One Week

Response to a Load with Diurnal Variation

Load Data from the usual ‘Utility Company’
Comparisons require 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