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Temperature Distribution in High Voltage Dummy Cable

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High Voltage Cable

- **Highest power ~ 2500 MVA**
- **High voltage ~ 1000 kV**
- **High current ~ 1000 A**

Energy Loss in High Voltage Cable

- **Voltage-dependent**

  for AC power system

  $P_v = U^2 * \omega * \varepsilon_0 * \varepsilon_r * C * \tan\delta$

  U: voltage, ω: angular frequency

  ε_0: permittivity of vacuum, ε_r: relative permittivity of insulator

  C: capacity of insulator, $\tan\delta$: dissipatien factor of insulator

- **Current-dependent**

  $P_l = I^2 * R$

  I: current, R: resistance of conductor

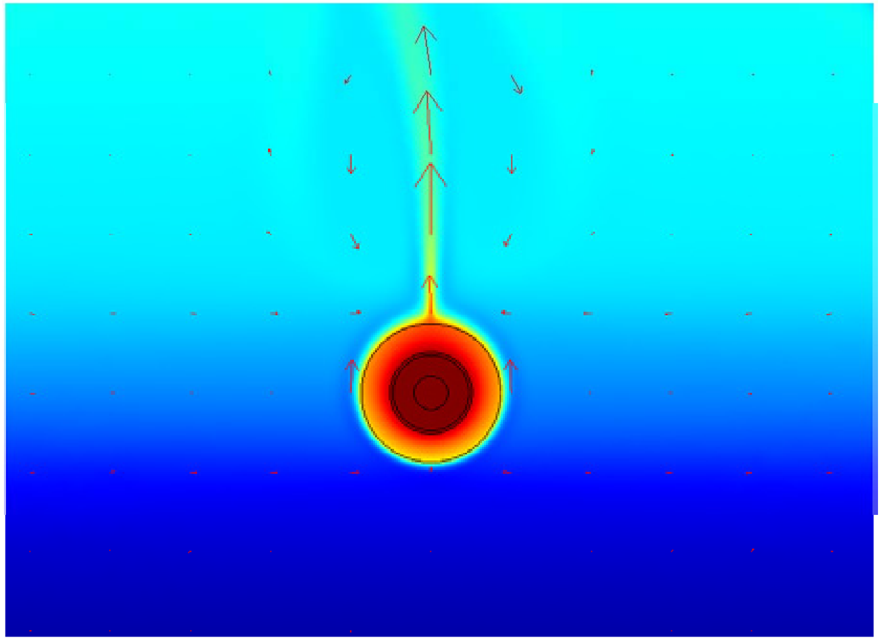
Limited Operating Temperature of High Voltage Cable

- **High temperature**
  → increases energy loss
  $\rho = \rho_0 * (1 + \alpha * (T - T_0))$
  → accelerates thermal ageing of cable

- **Permissible operating temperature**

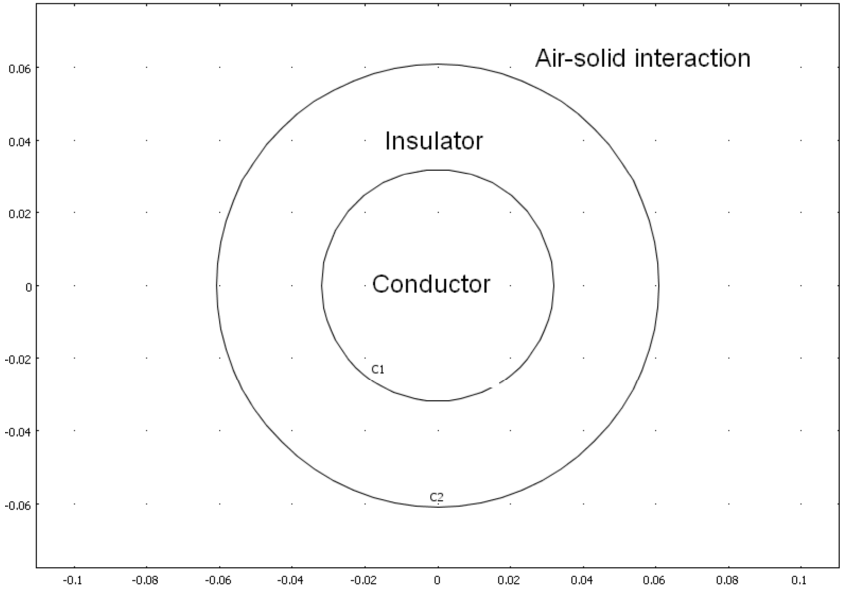
Insulator	**Impregnated Paper**	**HDPE**	**XLPE**	**EPR**
Temperature °C	**85/90**	**80**	**90**	**90**

Temperature Distribution in Dummy Cable Laid in Free Air



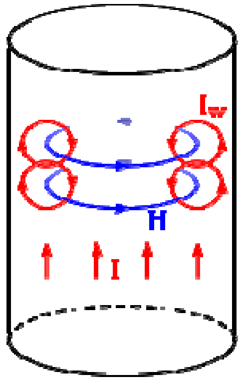
- **Dummy cable**
  no voltage applied, $P_V=0$
- **Heat source**
  resistive loss $P_I=I^2*R$
- **Natural convection cooling by free air**
- **Steady-state reached when heat balances**

COMSOL Modelling



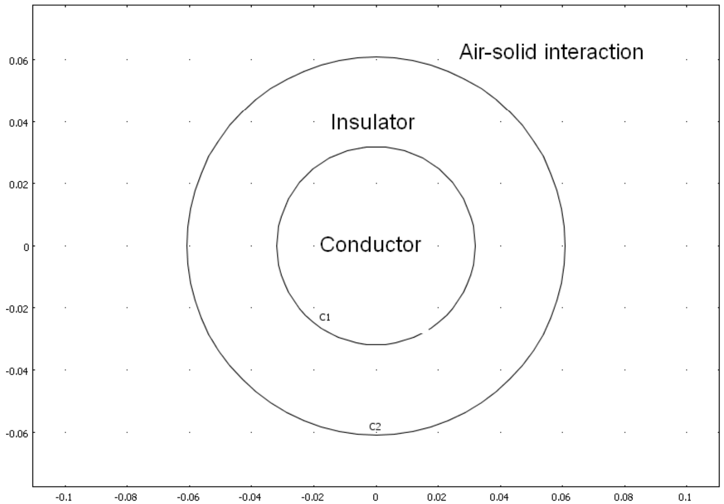
- **2D model**
  temperature change in
  cable direction neglected
- **Coupled electric-thermal problem**
  heat source $Q=J^2* \rho(T)$
  actual temperature T depends on
  heat source and natural convection
  cooling

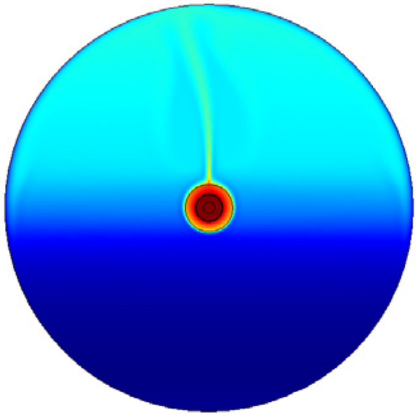
Perpendicular Induction Current, Vector Potential Mode



- **Analysis type: Transient**
  heat source $Q(\rho(t))$
- **Skin effect**
  enhances the current density near conductor surface, the effective resistivity increases
  $\rho_{AC}(T) = (1+Ys)^* \rho_{DC}(T_0)^*(1+\alpha^*(T-T_0))$
- **Skin effect factor**
  $Ys = Xs^4/(192+0.8^*Xs^4)$
  $Xs = \sqrt{(Ks^*\omega^*\mu/(\pi^*R_{DC}(T_0))}$
  μ: magnetic permeability
  Ks: correction factor for segmented cable

Heat Transfer by Conduction Mode





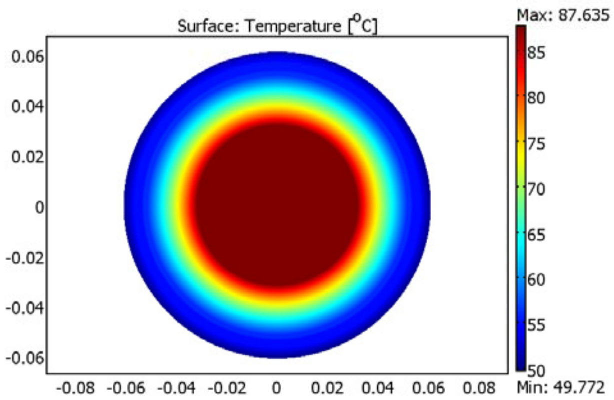
- **Analysis type: Transient**
  $T(t)$
- **Conductive inside cable**
  $\rho\, C_p\, \partial T/\partial t - \nabla\cdot(k\nabla T) = Q$
- **Heat transfer coefficient for air-solid interaction**
  $Q_{transfer} = Hc^*(T_{inf} - T)$
  Hc: coefficient for natural convection around a cylinder
  $Hc = \kappa/D^*f(\theta)^*Gr^{1/4}$
  Grashof number
  $Gr = \beta^*g^*(T - T_{inf})^*D^3/\nu^2$
  COMSOL Library Model "Cooling Flange"
- **Thermal radiation**
  $\varepsilon^*\sigma^*(T_{inf}^{\ 4} - T^4)$

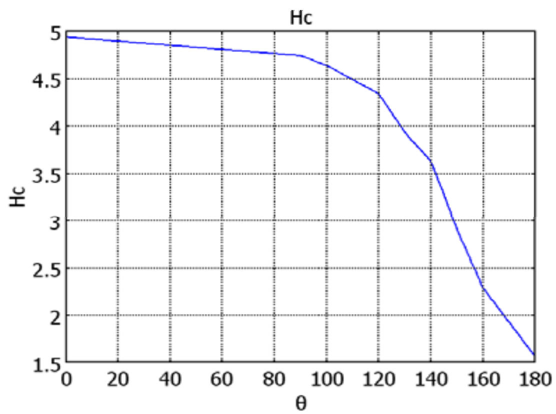
BRUGG CABLES
Well connected.

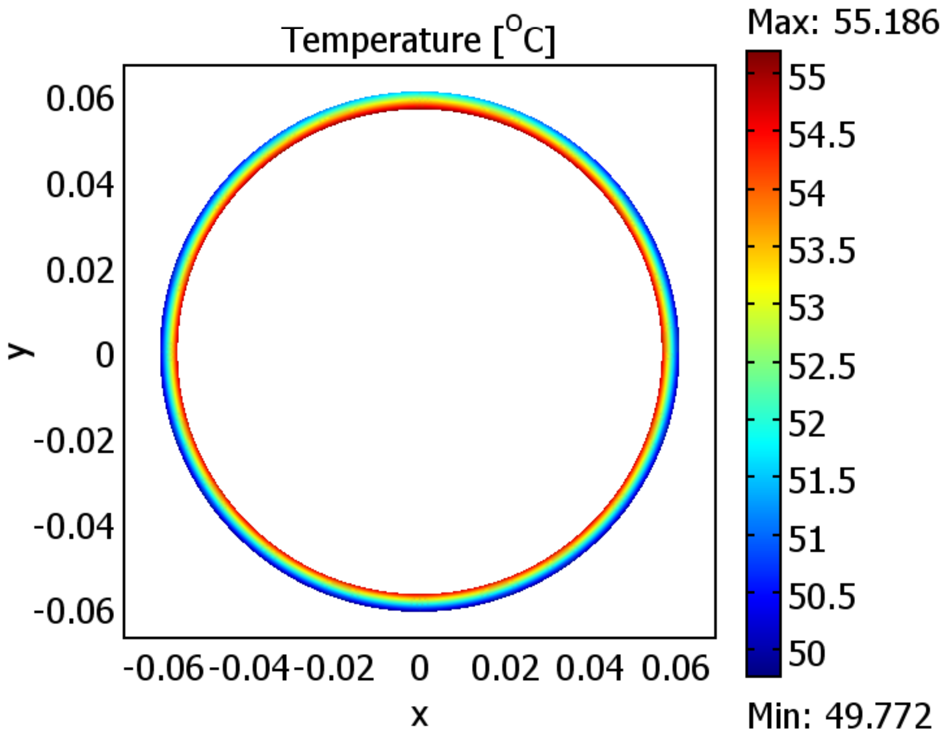
Experimental

- **2500 mm^2 XLPE insulation segmented cable**
- **AC current, 50 Hz, 2900 A and 2000A separately**
- **Temperature measured and recorded by using a 6-Channel-Pointprinter from company Eurotherm Chessell**

Simulation Results

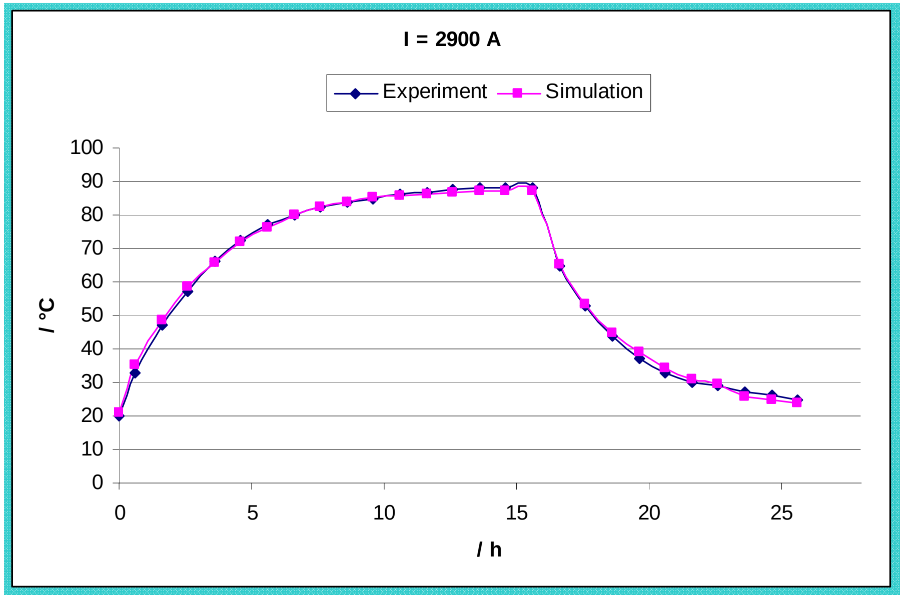


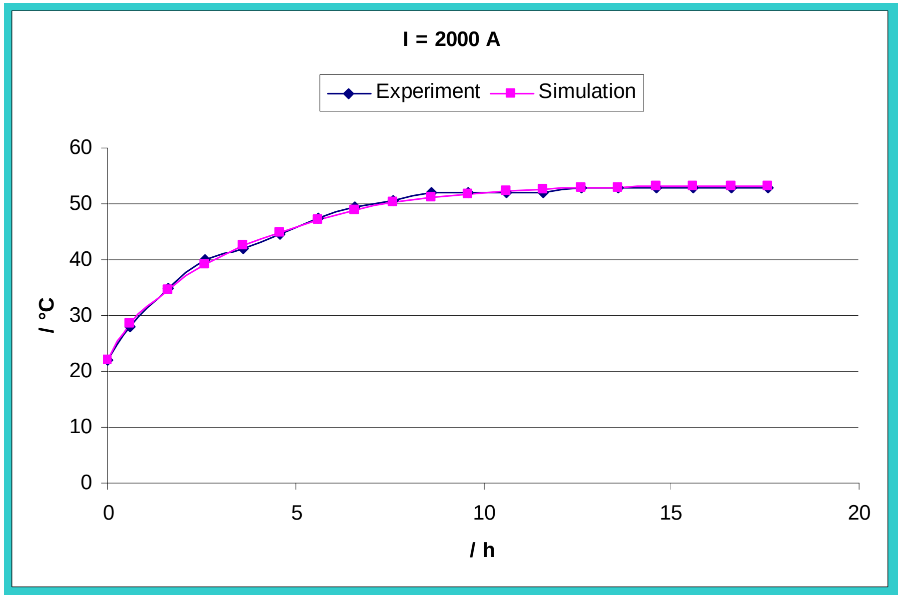




Temperature in the outer layer, T-sheath

Comparison of Simulation and Experimental Data





- **Results influenced very much by Ks:**

  the skin effect correction factor for segmented cable, should be individually defined

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Thank You
for Your Attention