# Performance Optimization of Underground Power Cables using RTTR

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## Introduction

### Distributed Temperature Sensing (DTS)

- Measures temperature profile at screen, sheath or outside
- No safe alarm thresholds because of thermal inertia of cables

### Real-Time Thermal Rating (RTTR)

- Basic models defined by IEC standards and Cigre guide
- Calculates conductor temperatures and cable rating on I, T, or t

### Advantages of our solution

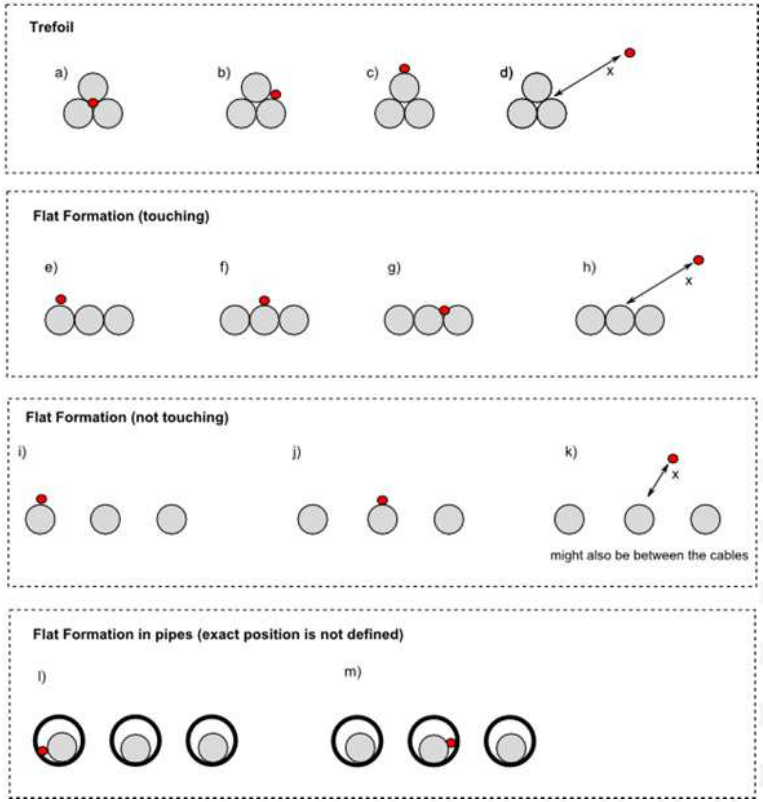
- Enhancements of models over standards (multilayer soil model, …)
- Conductor temperature profiles
- Non-cyclic loads / predictions using load profiles
- FEM validation of models / real-time rating accuracy
- Enhanced visualization

# Introduction – Fibre Positions

- Fibre integrated in the screen or at the sheath is perfect for RTTR
- Other fibre locations as shown in the picture may be used in our engine

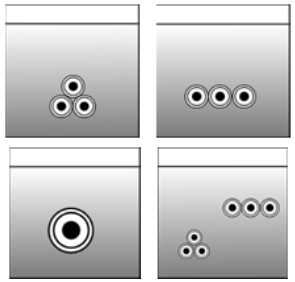
Reduced accuracy in case of:

- Soil in between cable and fibre with less accurately known thermal parameters
- Cables without fibres

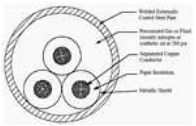


# Introduction – Installations

- Buried group

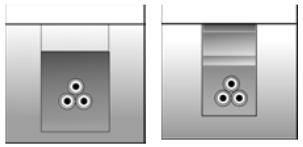


- Buried pipe

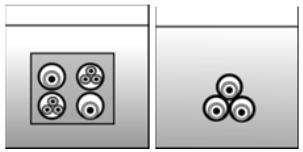


- Pipe

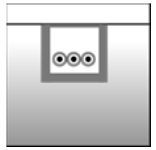
- Thermal / back-fill



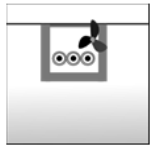
- Multiple ductbanks



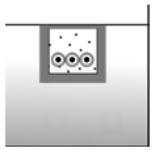
- Unfilled trough



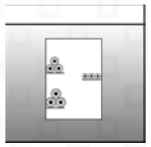
- Unfilled trough forced



- Buried trough sand

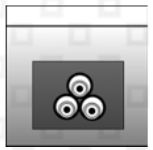


- Tunnel



- Tunnel forced

- Encased pipe

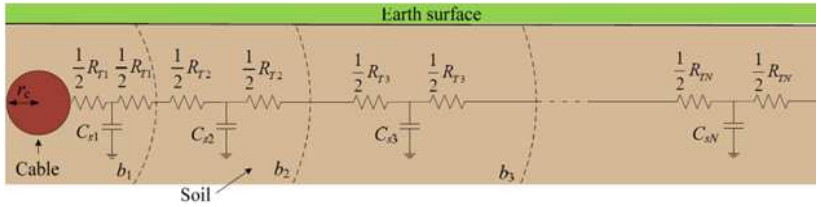


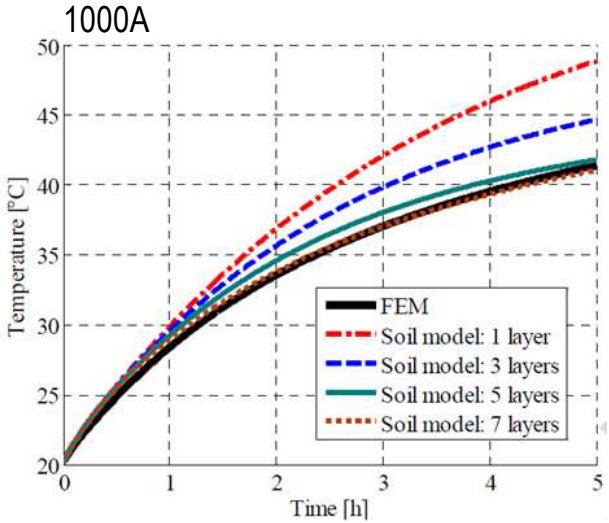
## Introduction – RTTR Procedure

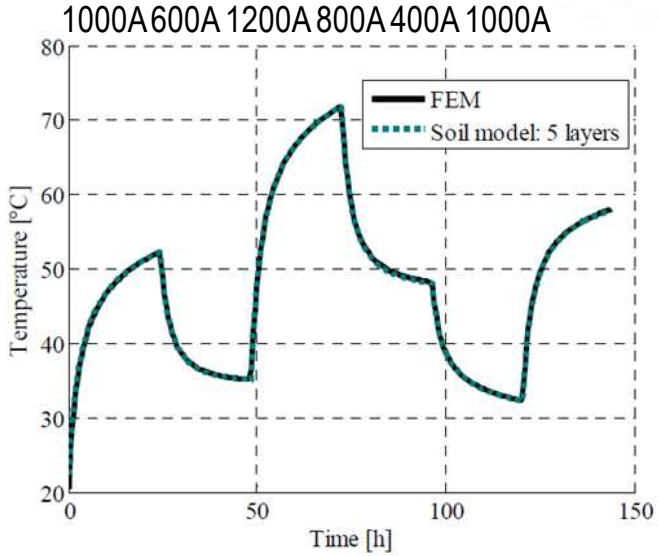
- Calculation of conductor temperature profiles along the cable
  - DTS temperature and load histories (no cyclic approximations)
  - Thermal models of cables
  - Optional point temperature sensors
- Calculation of ambient parameters (Tamb, Rho_soil)
- Predictions on conductor temperature, time and ampacity
  - Constant or variable load
- Triggering of pre-alarms and alarms
- Transmission to SCADA
- Visualization of measurement and rating results / alarms

# Multilayer Soil Model

- No equivalent circuit for soil definded by IEC 60853, but time-dependent resistance with different approximations depending on duration
- RC-ladder soil models developed by the Polytech Institute of NY University
- Transients from 5 layer model agree well with FEM simulations

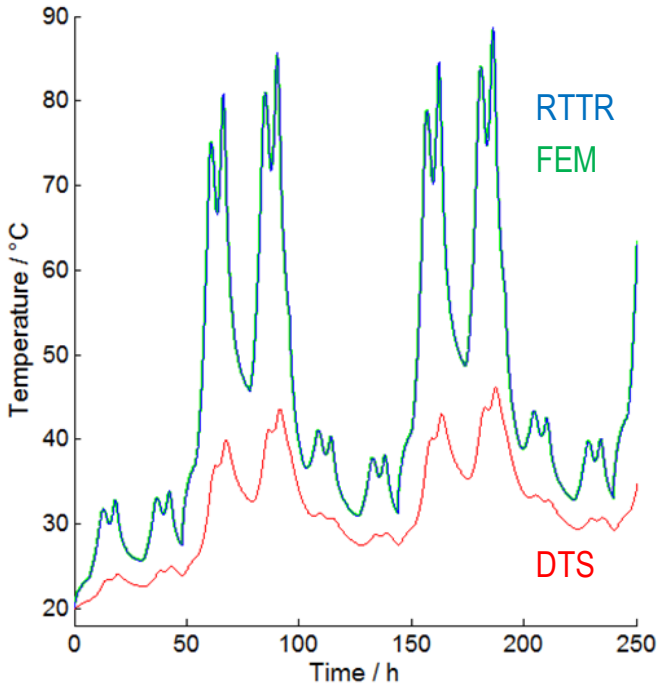



Figures: M. Diaz-Aguilo, F. de León, S. Jazebi, and M. Terracciano, IEEE Trans. Power Deliv., 2014

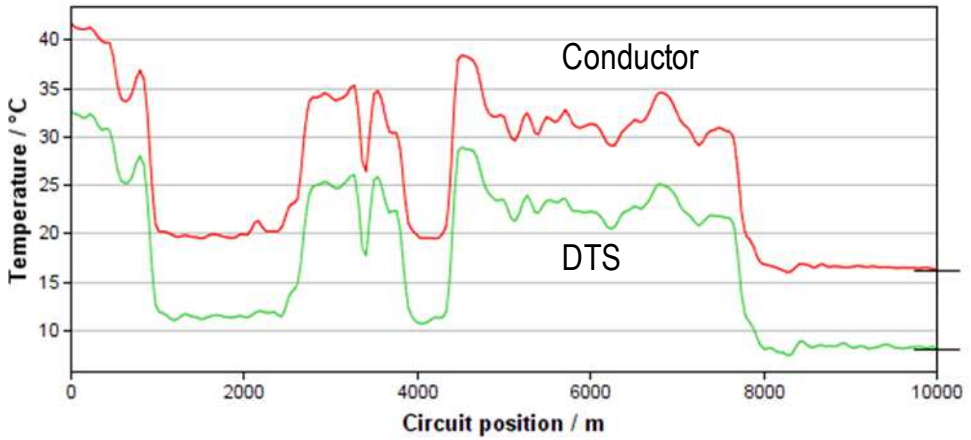
# FEM Validation of Thermal Models



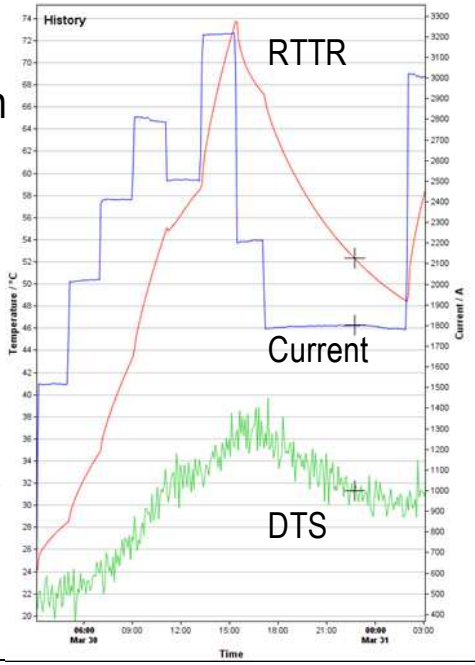

- Finite element method (FEM) allows precise modelling, but is to slow for real-time
- Thermal modells of RTTR are validated by comparison with FEM for various load scenarios
- Comparison of conductor temperatures shows no significant difference

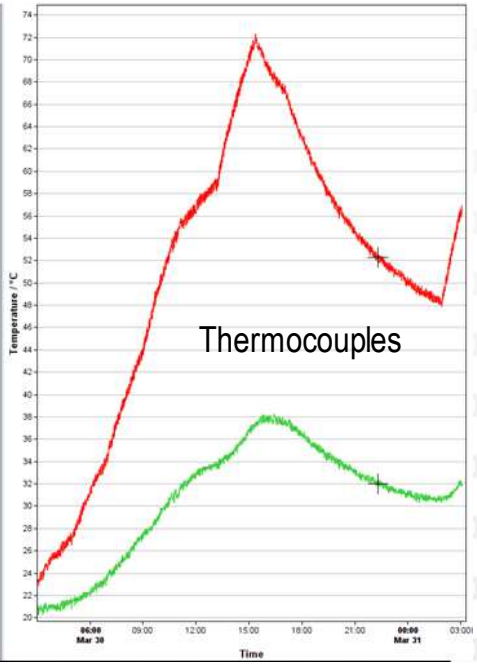
# Conductor Temperatures

- Tc profiles along entire length of cable
- Locations of maximum DTS and conductor temperatures may be different
- (external heat, cable, installation,..)
- Positions with maximum Tc per thermal section used for safe predictions



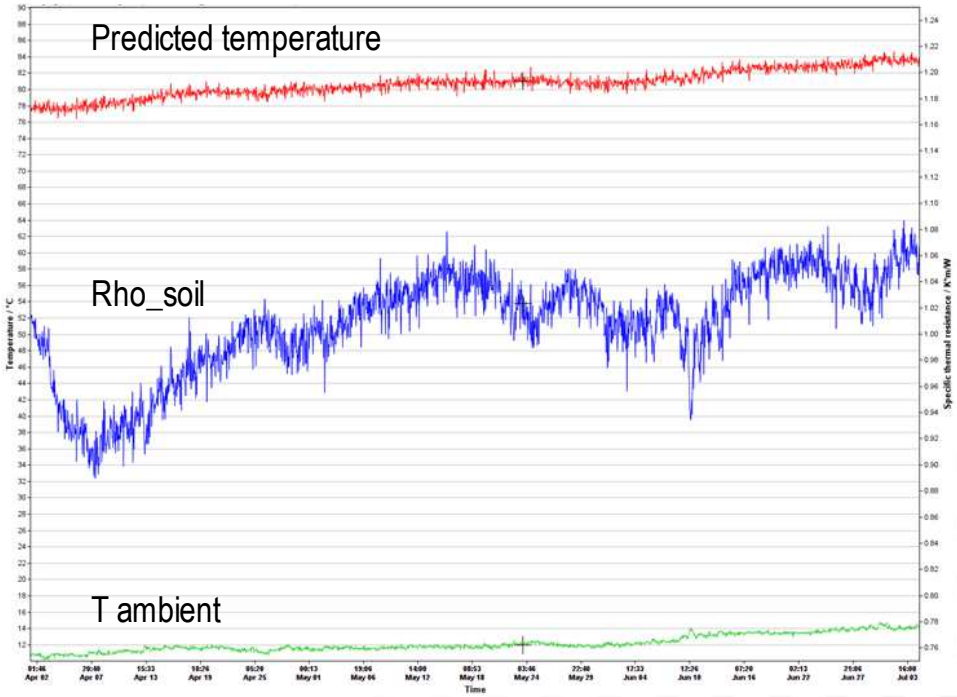

- Accuracy of Tc confirmed by compariton with measured Tc
- Differences between measured and calculated Tc mainly related to
  - Inaccuracy of DTS and thermocouples
  - Deviations of cable and laying from model
- No significant difference between RTTR and FEM results



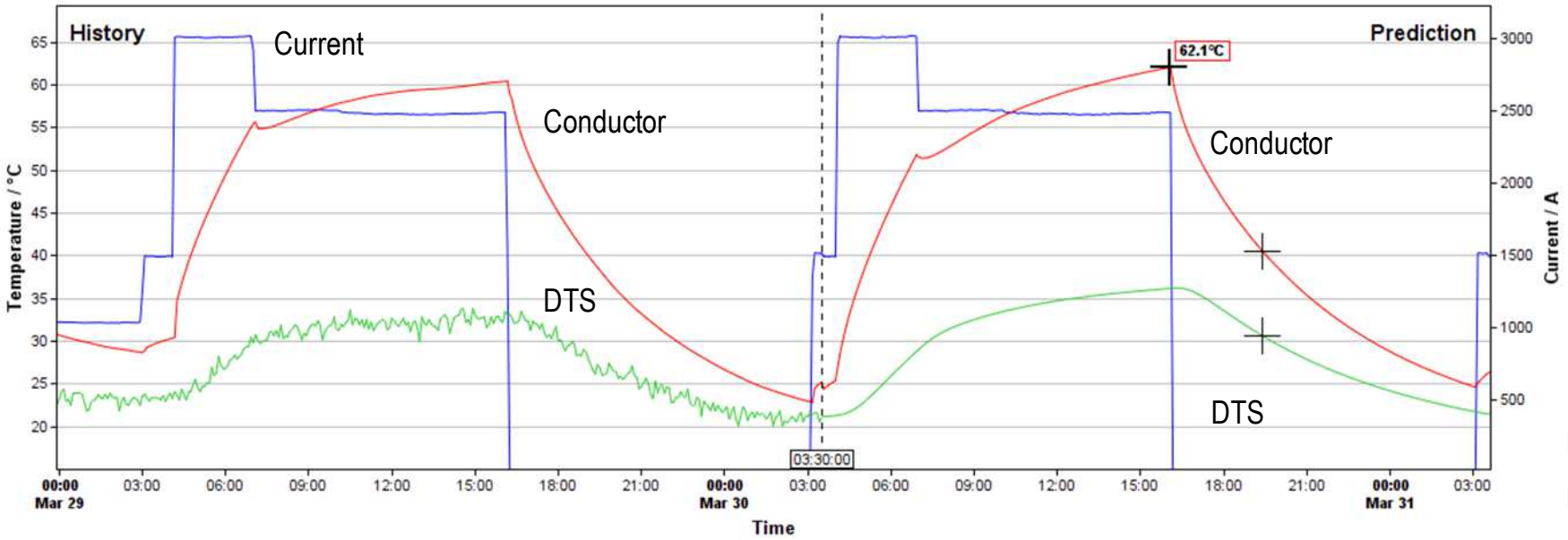



# Fitting of Ambient Parameters

- Ambient temperature and thermal resistivity of soil not precisely known
- Both parameters vary considerably with the seasons
- RTTR engine determines parameters from temperature and load histories before calculating predictions
- Measured ambient temperatures can be considered as starting point of fit



# Temperature Prediction using a Current Profile



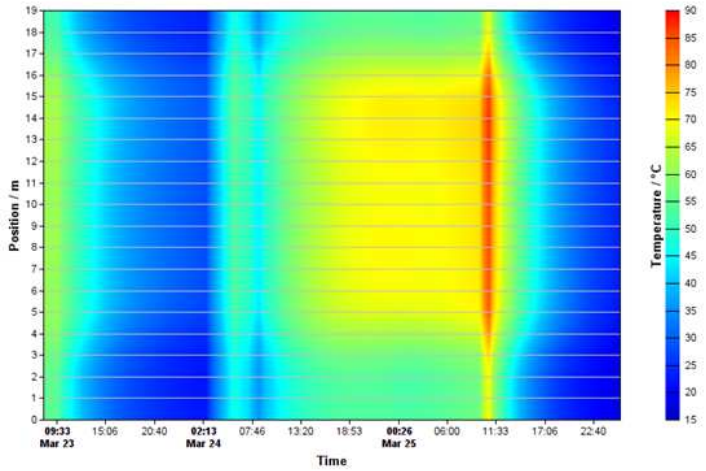

- Current profiles from last 24 hours or from database may be used
- Tc is predicted as function of time
- Alarming is triggered based on maximum Tc within prediction period

# Visualization of Rating Results

Rating summary


Enhanced view

Contour plot



## Conclusion

DTS/RTTR enables safe operation of power cables at high load by

- Monitoring conductor temperatures for all locations
- Predictions using arbitrary load curves
- Triggering of pre-alarms and alarms