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Engineering GmbH

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Ampacity simulation of high voltage cables

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(1) Introduction

- Cable ampacity typically depends largely on the cross-section of ist conductor
- Due to cost reduction it is of interest to keep the conductor cross-section low
- Usually semi-empirical methods, including larger safety margins, are used to determine ampacity
- Here COMSOL Multiphysics is used to determine the temperature distribution

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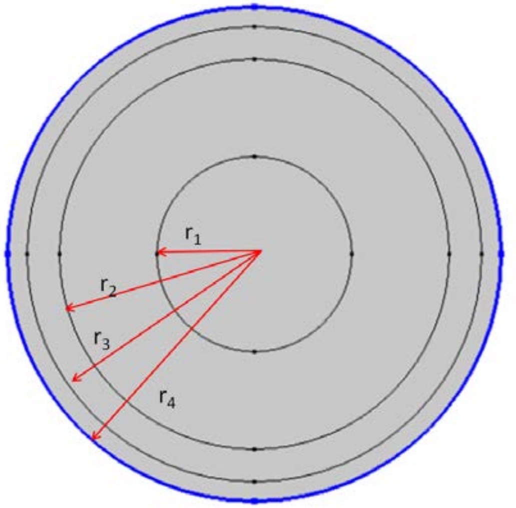
(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

- Comparison of IEC-standard ampacity calculation with COMSOL Multiphysics simulation for:
  - single-conductor cable
  - three bundled single-conductor cable

(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

- A single-conductor cable is implemented to evaluate the maximum allowable current, while keeping the conductor temperature at a defined maximum temperature
- The cable consists of a conductor material as well as different isolating layers and armour



(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

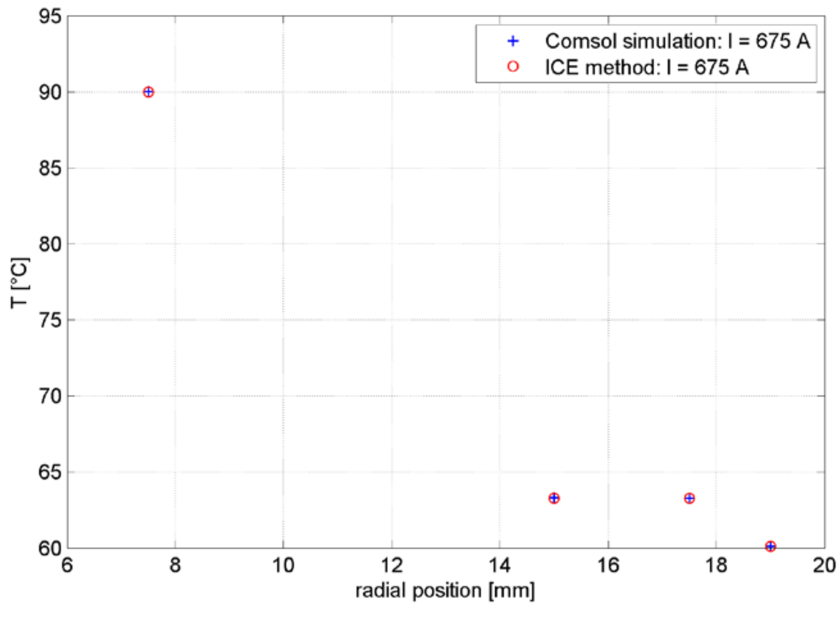
- IEC standard ampacity calculation:
  - Simple calculation of radial heat conduction
  - Aim is to limit the conductor temperature to 90°C
  - The conductor generates heat, depending on the current according to the suppliers information
  - The maximum allowable current is determined via a iteration algorithm
  - The outer surface is cooled via radiation as well as convective cooling for which the heat transfer coefficient is estimated by adequate correlations

(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

- COMSOL Multiphysics ampacity calculation:
  - A equivalent model is defined in COMSOL
  - The heat source is defined according to the IEC calculation method
  - The same cooling parameters on the outer surface are used
  - An iteration is carried out by using a Global equation iterating towards the maximum allowed conductor temperature

(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

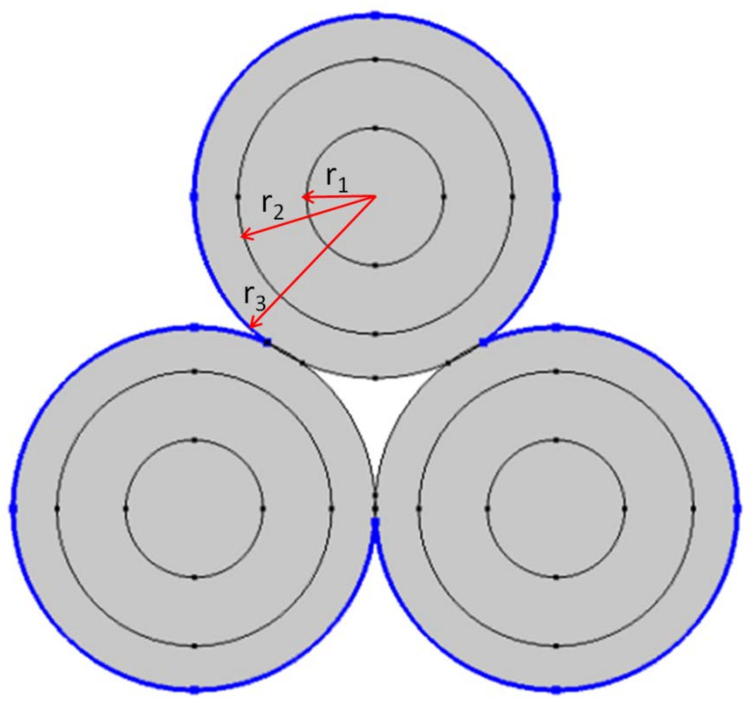
- Single-conductor cable, comparison of temperature distribution and iterated ampacity



- As expected for a simple radial heat conduction problem the results agree with each other

(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

- The same procedure is carried out for a bundled geometry of three single-conductor cables



(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

- IEC standard ampacity calculation:
  - Simple calculation of radial heat conduction is amended by a factor considering the bundled geometry
  - Heat source and cooling is implemented according to the first case
- COMSOL Multiphysics ampacity calculation:
  - The exact geometry is implemented in COMSOL
  - Heat source and cooling is implemented according to the first case

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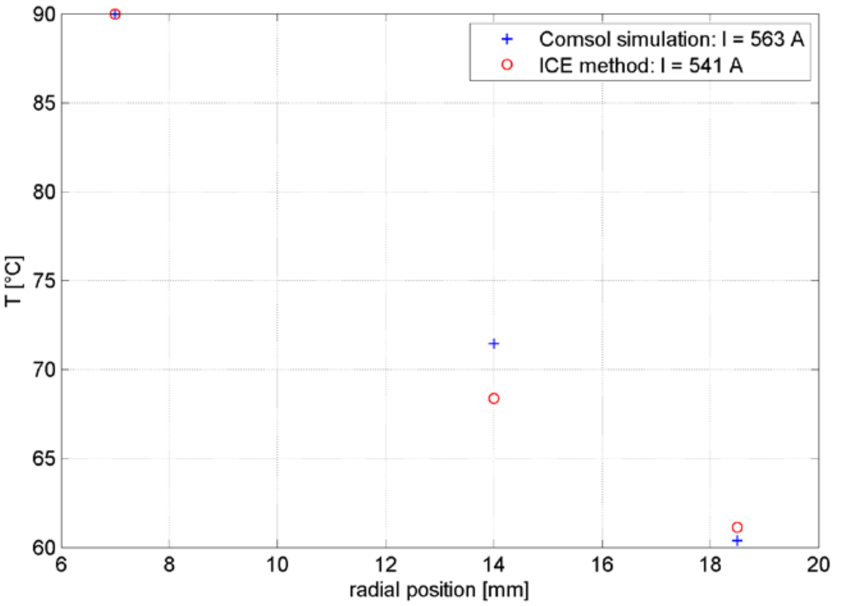
(2) Comparison of IEC standard calculation method with COMSOL Mutliphysics

- Three boundled single-conductor cables, comparison of temperature distribution and iterated ampacity



- With a still simple but more complex geometry results start to differ

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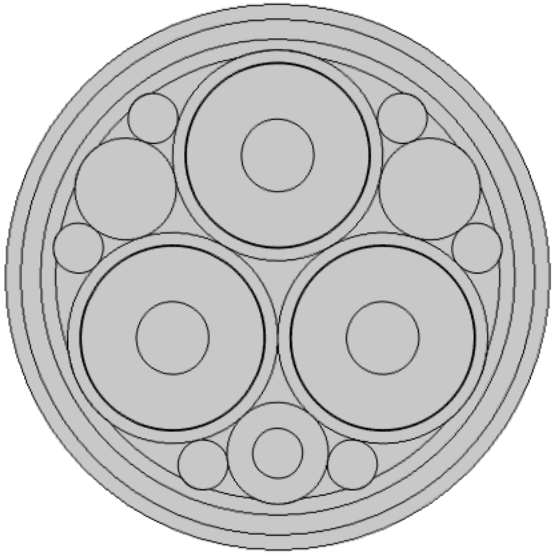
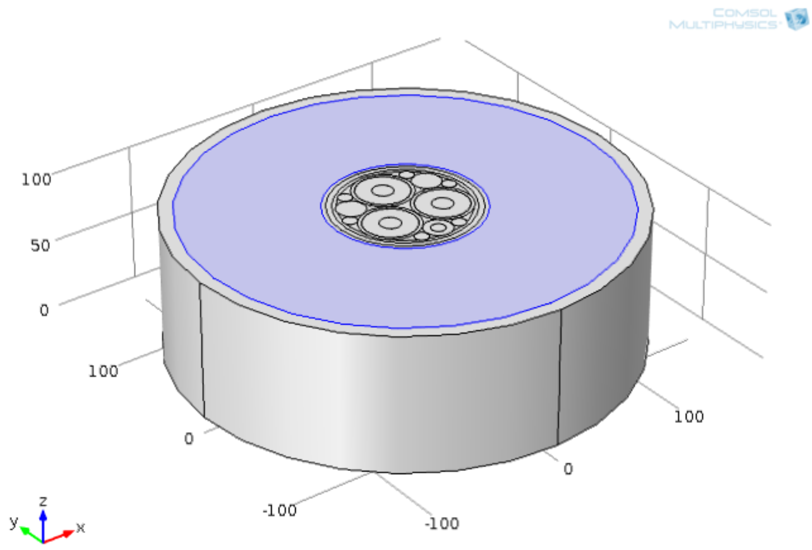
(3) Evaluation of a complex three-conductor geometry

- Next COMSOL Multiphysics was used to evaluate a more complex configuration containing free convection in a cylindrical casing
- Those configurations are often used in off shore wind farms to route the cable in a wind turbine to the generator



(3) Evaluation of a complex three-conductor geometry

- The geometry contains multiple conductors, screen and armour as well as several isolating matterials
- The cable itself runs vertivally through an air-filled metal cylinder
- The partly extruded geometry:



(3) Evaluation of a complex three-conductor geometry

- Implementation
- Cable:
  - 3D Heat Transfer in solids
  - Heat sources in conductot, armour and screen
- Outer cylinder
  - 2D-axisymmetric Conjugate Heat Transfer
  - Free convection resulting from the temperature field
  - Outer surface is cooled via Radiation and Convective Cooling boundary
- Cable surface and air filled cylinder are linked with an Extrusion Operator

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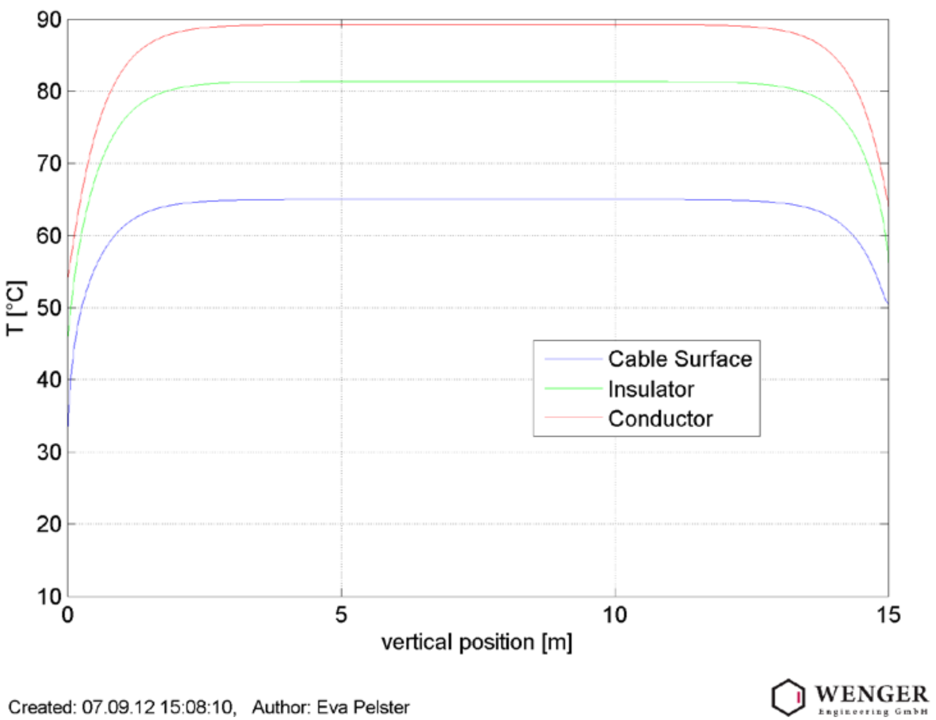
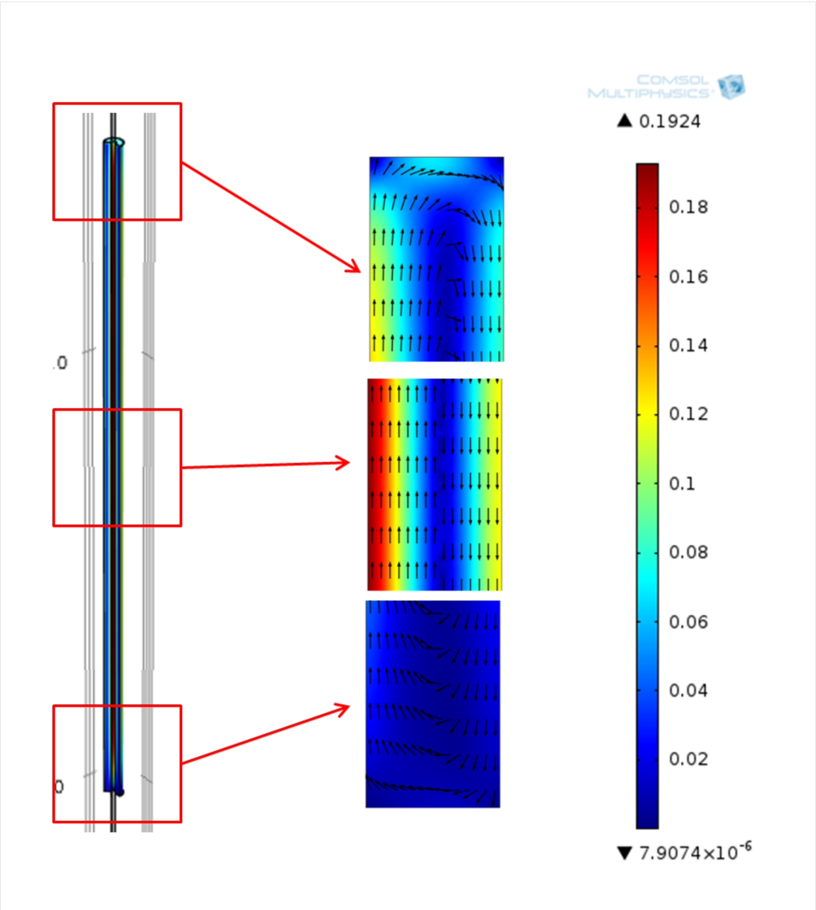
(3) Evaluation of a complex three-conductor geometry

- Results
  - The model was evaluated for different load cases, determining the typical temperatures for different conditions





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(4) Conclusion

- For ampacity calculations for simple configurations the IEC standard calculation agrees with the simulation results
- With higher complexity of the cable configuration the two methods start to differ, the standard calculation method contains larger safety margins where the simulation has a better ability in resolving the geometrical relations
- It was shown that a larger configuration containing free convection inside a cylinder could be implemented to further investigate cable designs

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