InnoTesting

„Correlation of Simulation and Test Results"

Wildau (D), 23. Februar, 2017

Workshop C

Transient Electro-Thermal Analysis for Multi-core Power Cable at System Level

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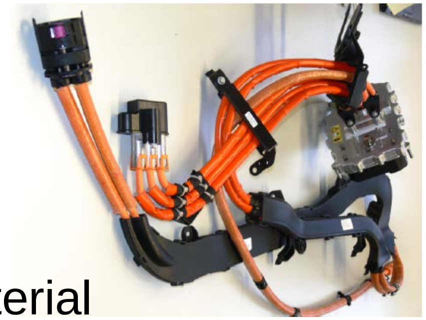
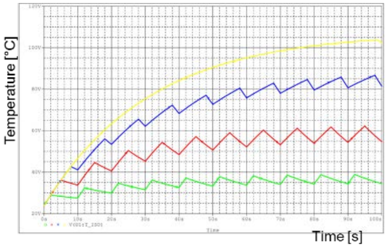
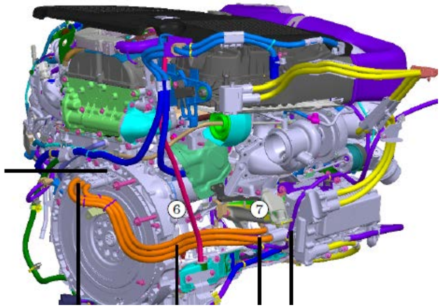
Motivation



- New challenges on high volt on-board network: cable should
  - conduct high currents
  - as light weight as possible
  - be reliable - heightened thermal load on cable isolation material

→ Regarding electrical, weight and reliablity optimization:
need to know the core and the cable surface temperature in repect to it's
- build-in location (conduction, convection, radiation)
- ambient temperature
- transient electrical load (e.g. PWM)





- Transient analytical temperature estimation only sporadically possible
- Transient numerical FE-Simulation on system level causes high calculation time costs

Approach: Semi-analytic-numerical simulation model

→ Parametric transient thermo-electrical PSPICE-model for a power cable

Parametric Transient Thermo-Electrical PSPICE-Model

Approach – Schematic and Input parameter

Electrical parameter:

Current
Wire: electr. conductivity

Thermal parameter:

Wire: thermal conductivity, heat capacity
Wire: temp. coefficient
Isolation: thermal conductivity, heat capacity

Geometrie parameter:

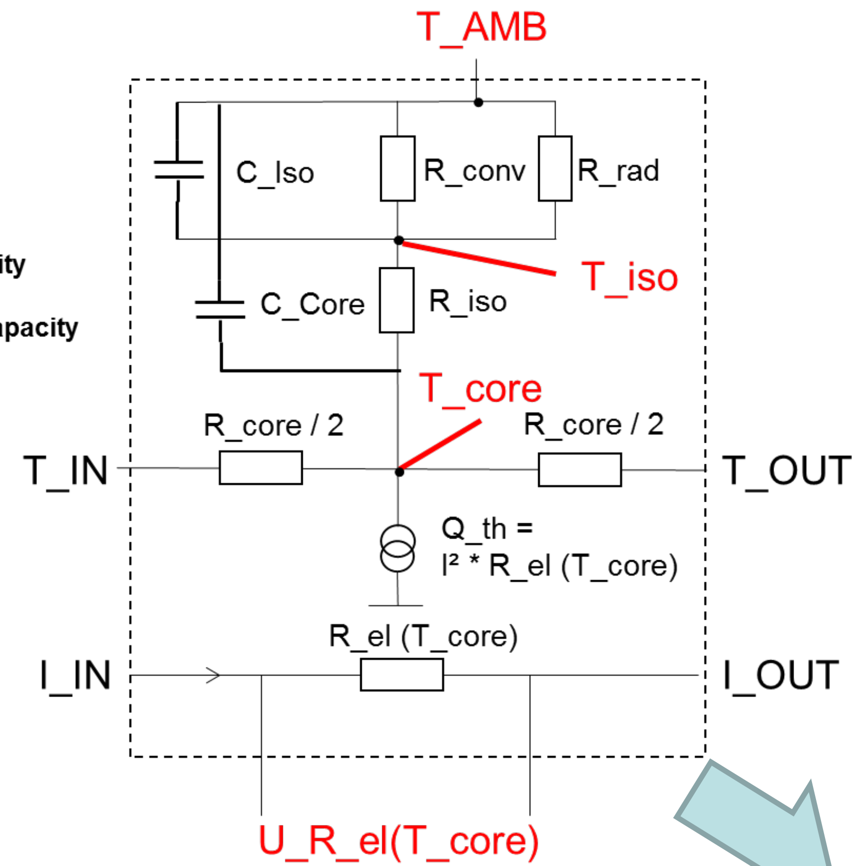
Wire: length

Wire: diameter
Isolation: thickness

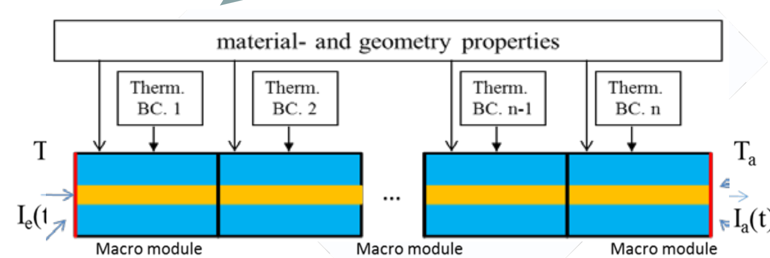
Boundary conditions:

In- and outlet temperature
Ambient temperature
Heat transfer coefficient

Transient electrical load (e.g. PWM)

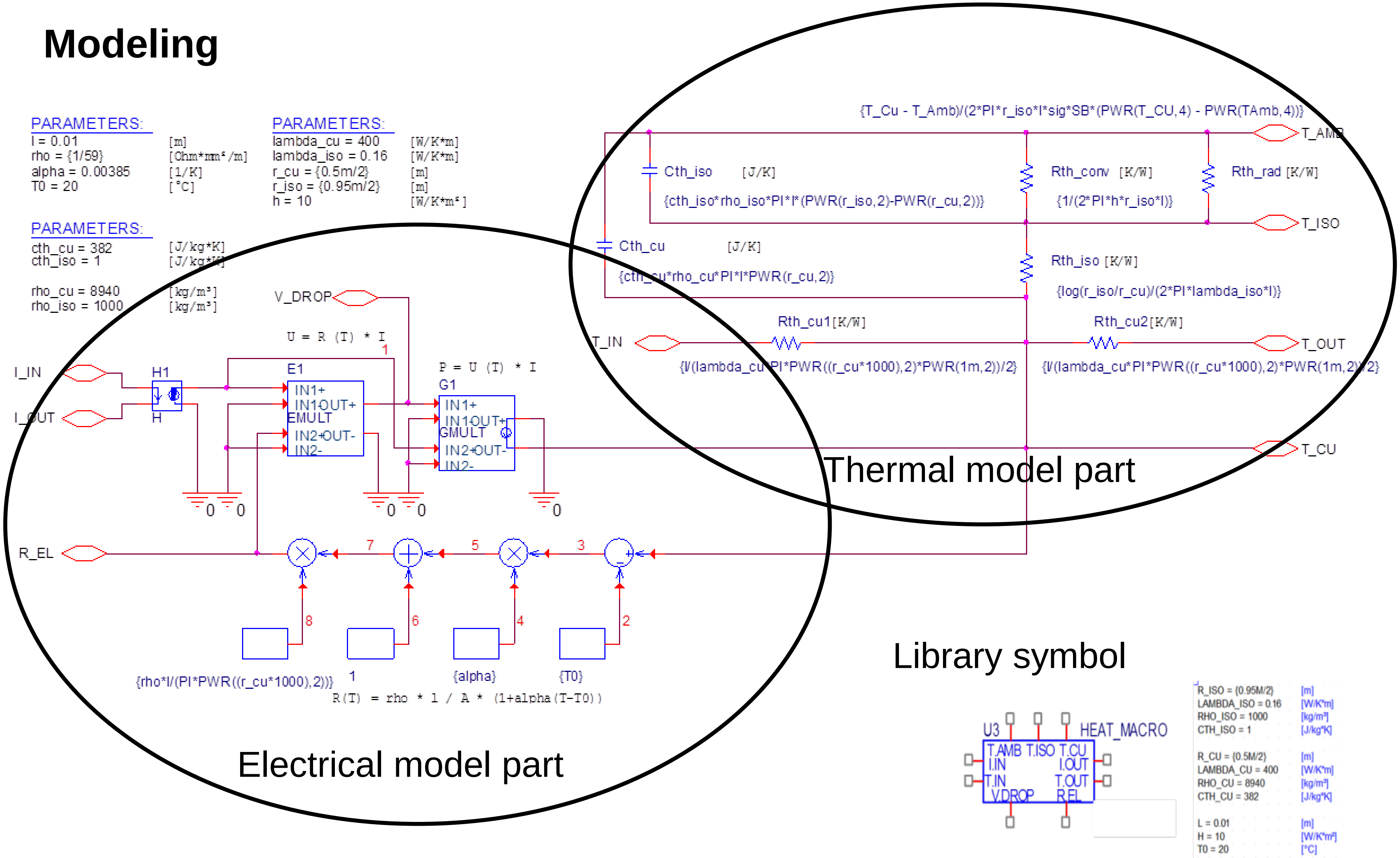


Macro model can be connected in series in respect to different thermal boundary conditions



Parametric transient thermo-electric coupled PSPICE- model for a one-core cable

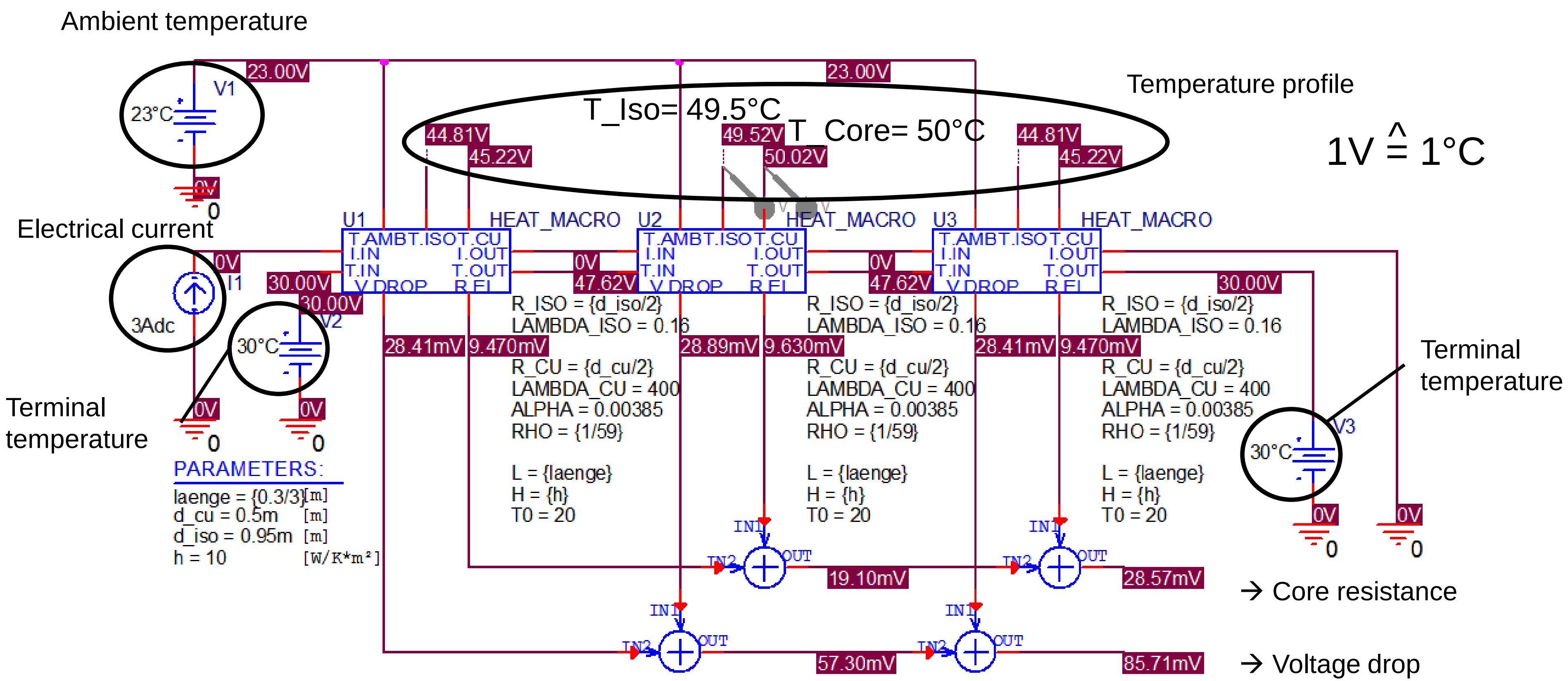
Modeling



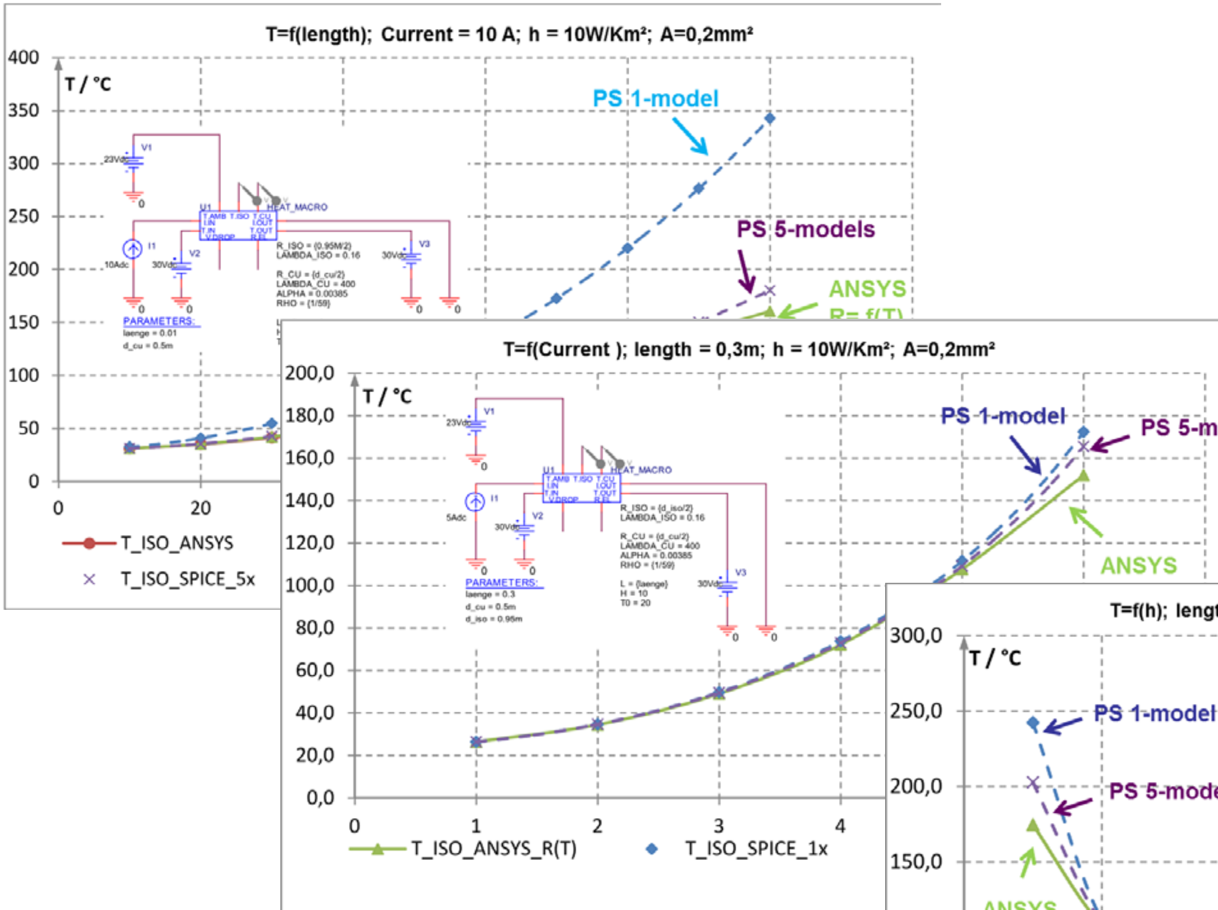
Parametric transient thermo-electric coupled PSPICE- model for a one-core cable

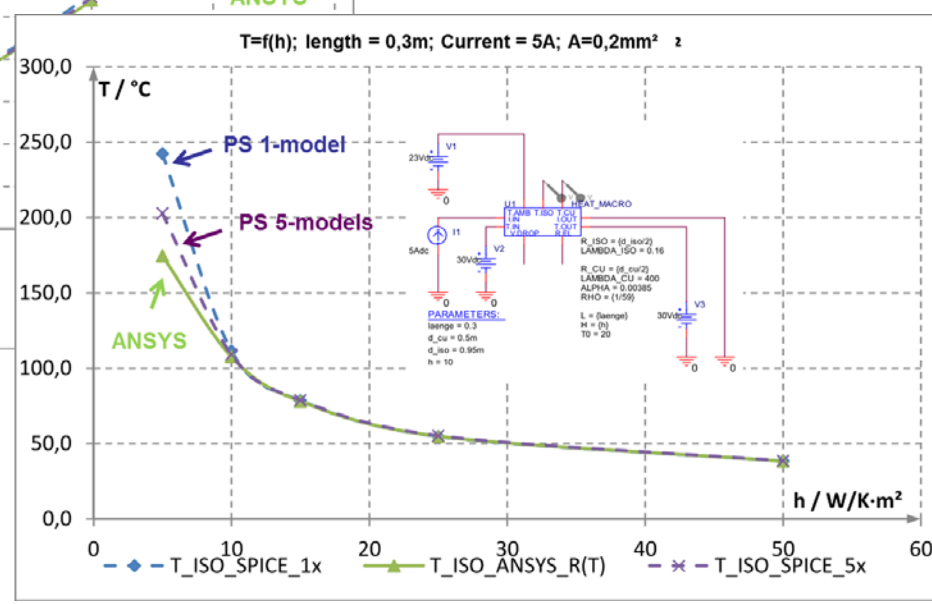
Example: Discretitiaton by three macro models

- Applying material and geometry data, electrical and thermal boundary conditions



Static validation of PSPICE- and FE-Models for one-core cabel



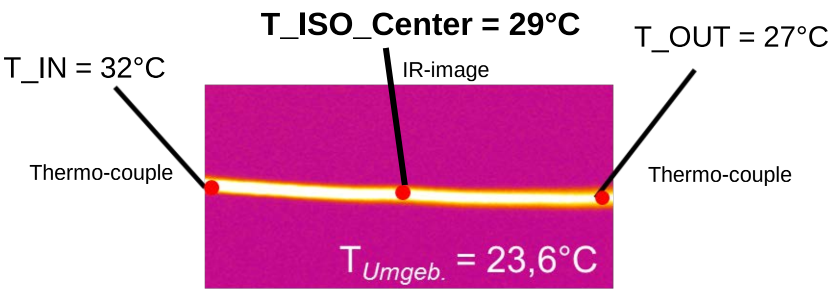


→ Good agreement for a discretitation > 5

Validation of PSPICE- and FE-model and Experiment

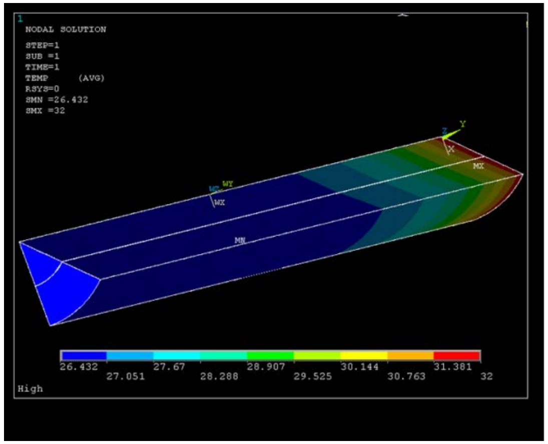
- **BC: I = 3A, h = 10 W/K m², l = 0,3 m, A = 0,2 mm²**
  T_AMB = 23,6°C, T_IN = 32°C, T_OUT = 27°C

Experiment:



IR-image

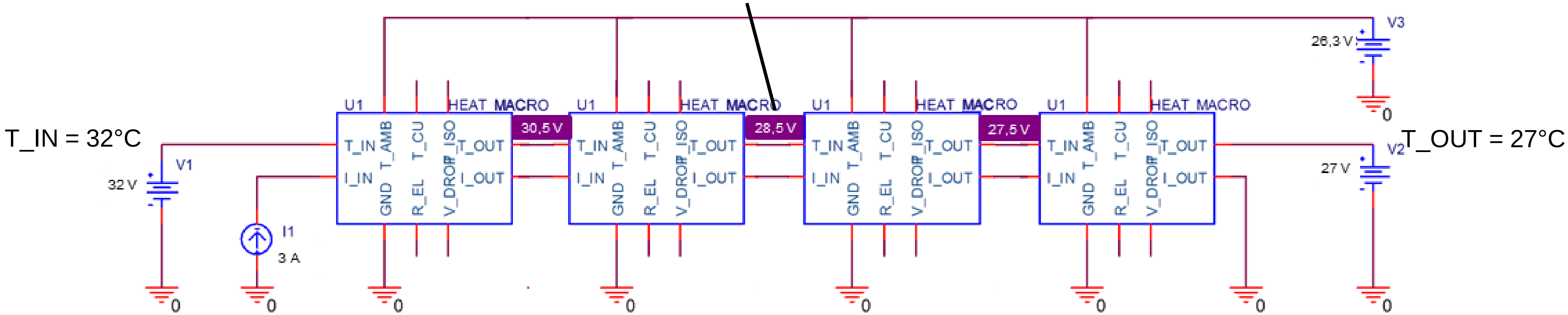
FE-model:



T_IN = 32°C
T_OUT = 27°C
T_ISO_CENTER = 26,56°C
T_Core = 26,61°C

PSPICE Macro-model:

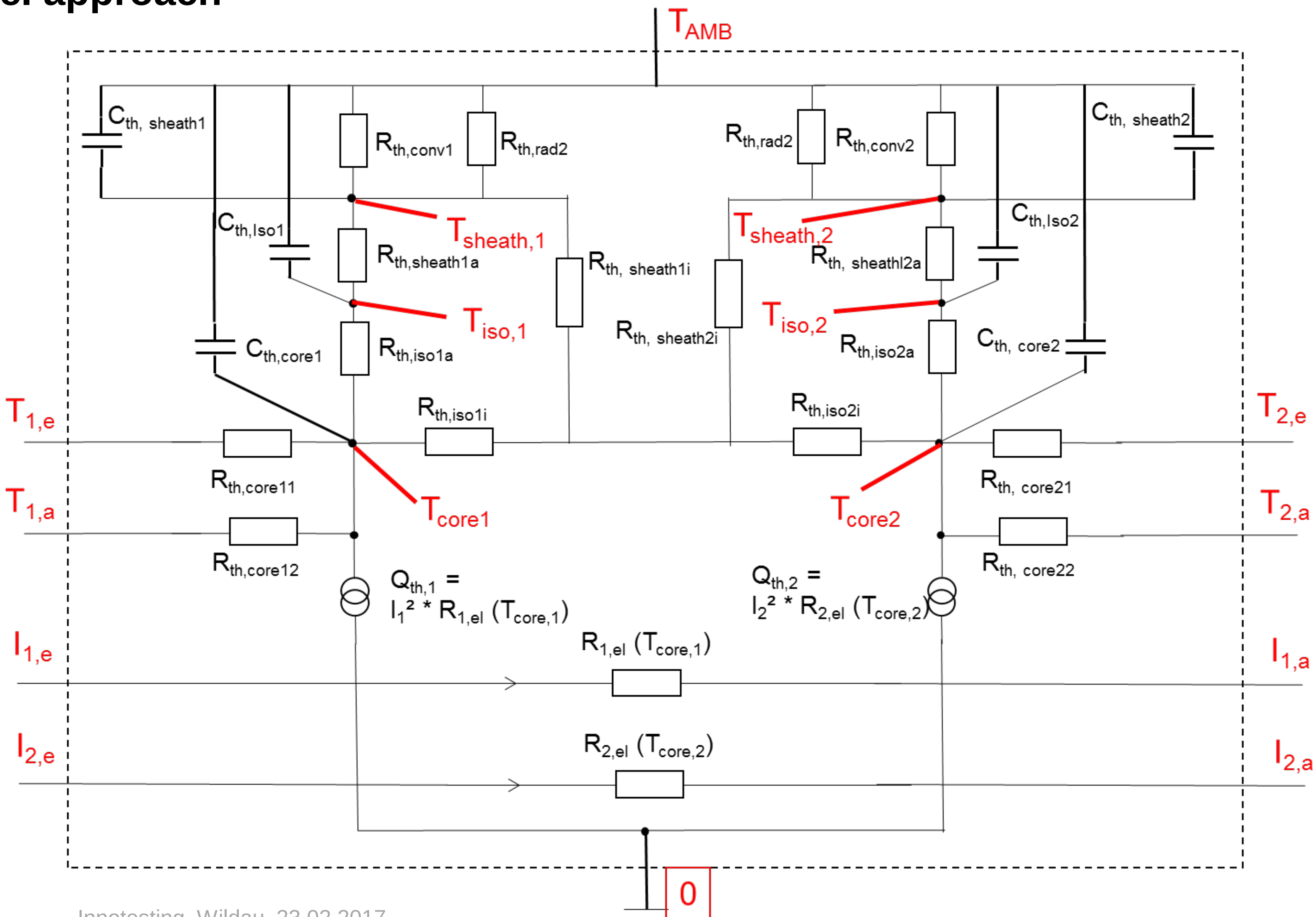
T_Core = 28,6°C



→ Error : Experiment vs. FE-Simulation ~ 8%
→ Error : Experiment vs. PSPICE-Simulation ~ 5%

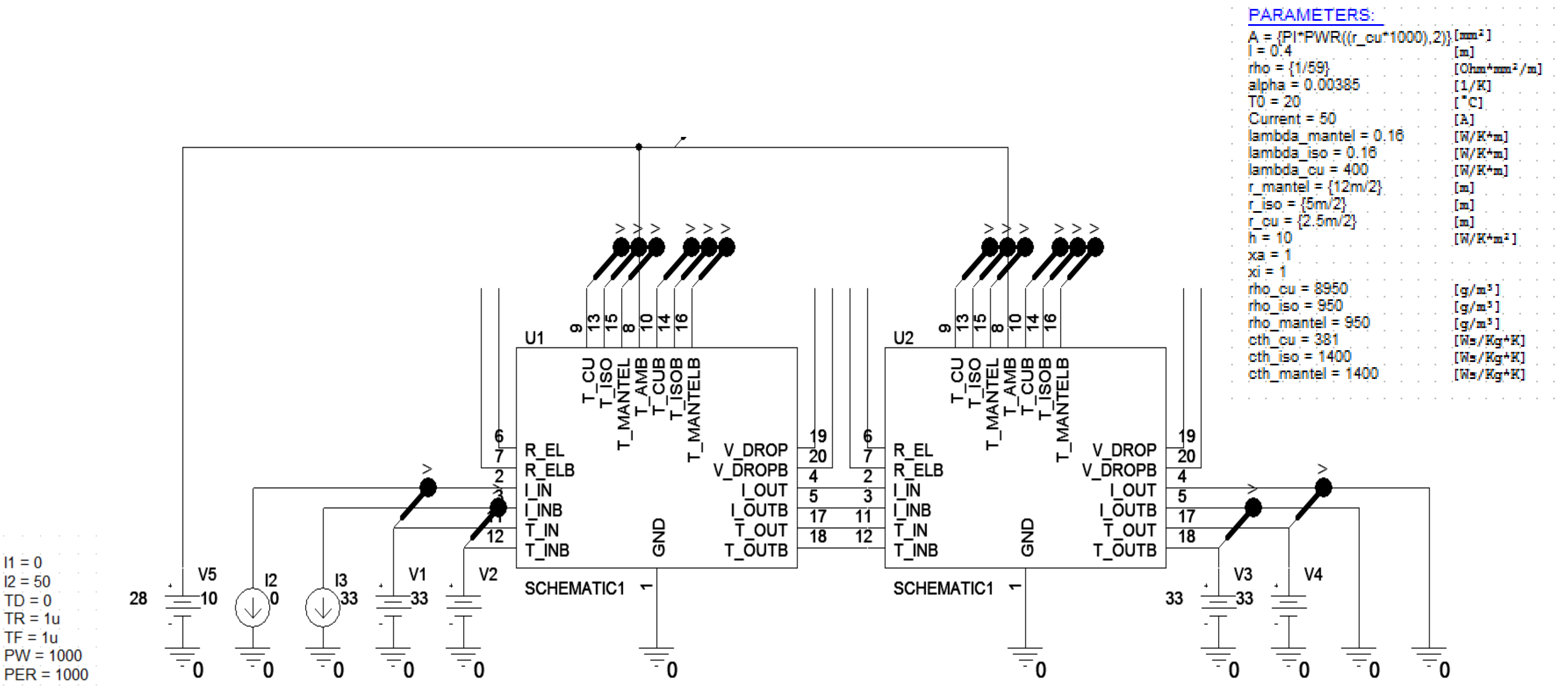
Parametric transient thermo-electric coupled PSPICE-model for a two-core cable

Model approach



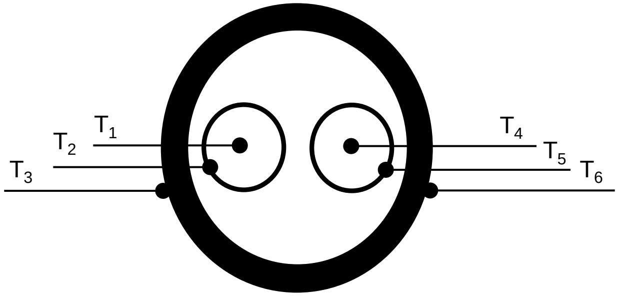
Parametric transient thermo-electric coupled PSPICE-model for a two-core cable

Example: Modeling and Simulation



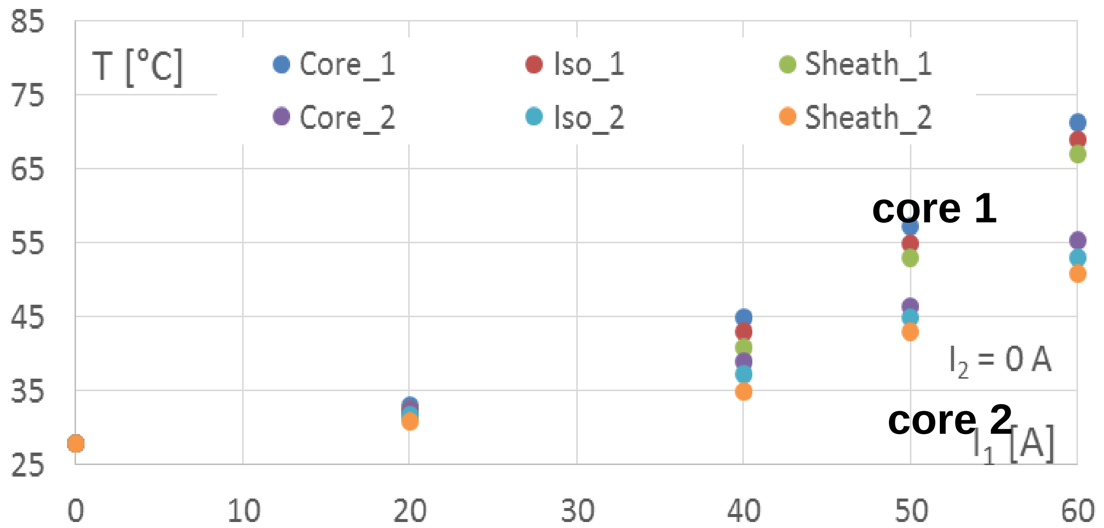
Experiment

Position of NTC temperature sensors



Length l = 1 m
Cable surface A = 12 mm²
Narural convection

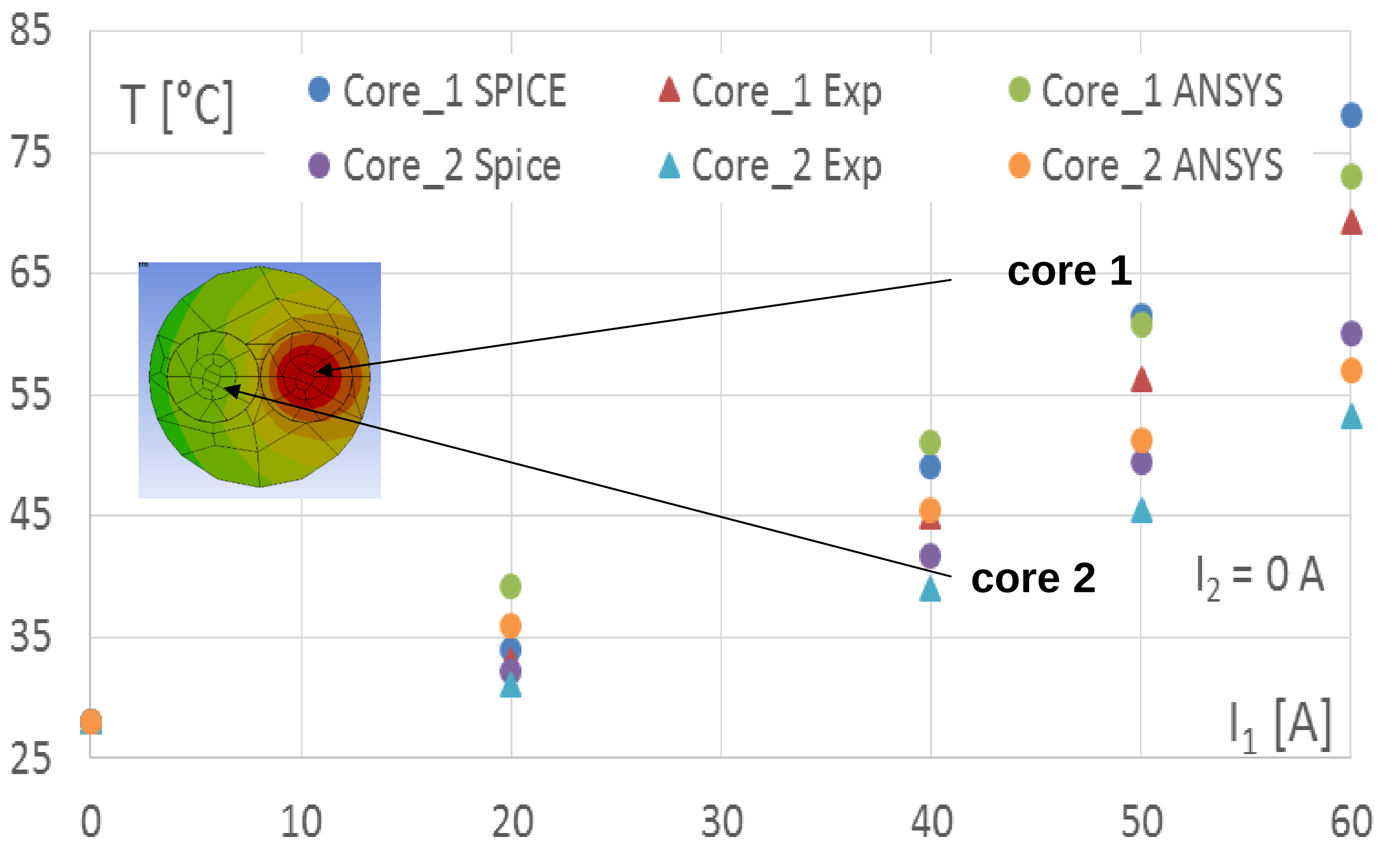
Result: temperature in respect to current through core1 (static)



→ Result pausible

Comparision PSpice- / FE-model and Experiment (Static)

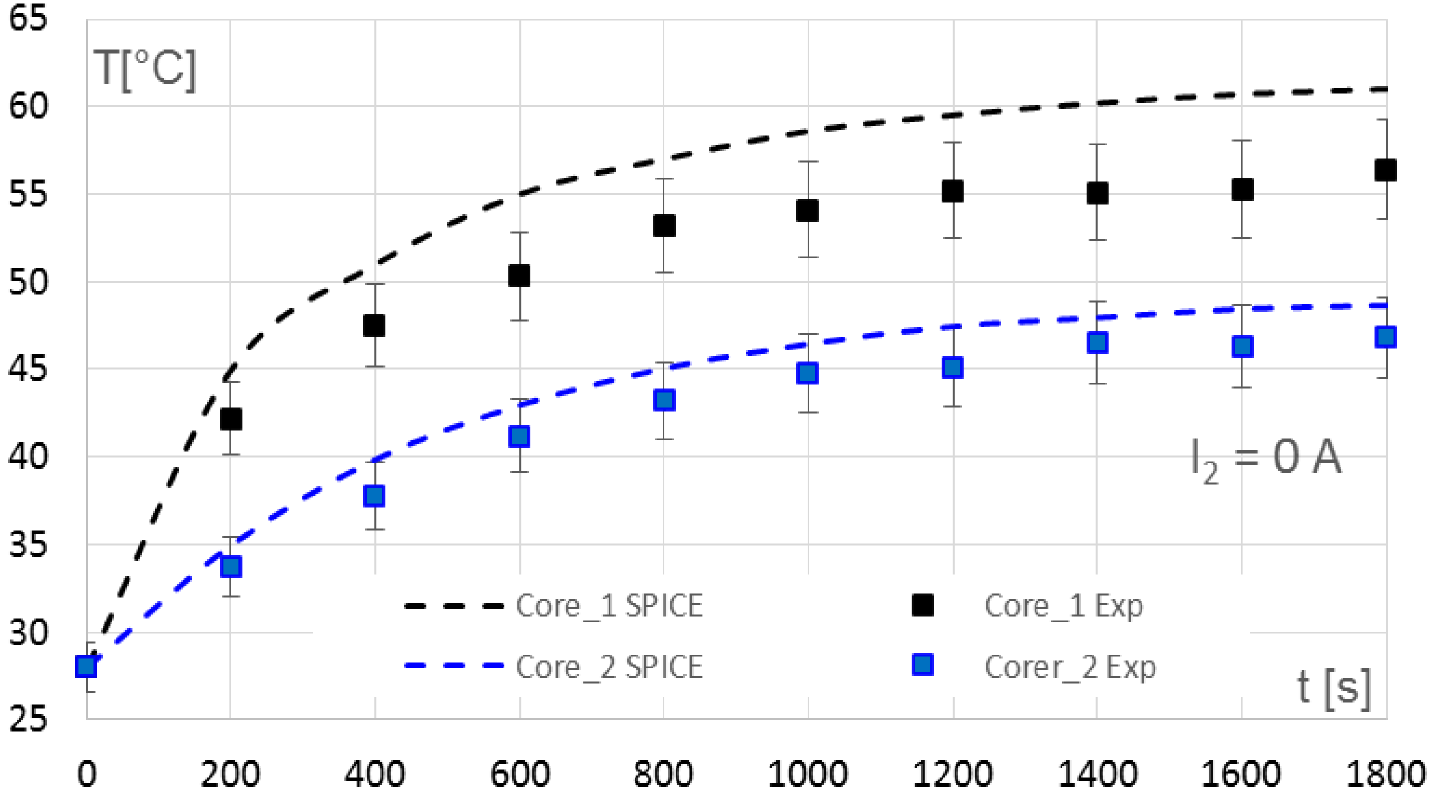
Cable core temperatures in respect to current through core 1



→ Static – acceptable agreement

Comparision PSpice-model and Experiment (Transient)

Cable core temperature in respect to current in core1 for I = 50 A



→ Transient - acceptable agreement

Comparision PSpice-model and Experiment (Transient)

Comparison between the experiment, the ANSYS Model and the PSpice model after t = 1800 s (T_{Amb} = 28 °C, h_{conv} = 10 W/mK).

	Experiment	PSpice
$T_{core1, center}$ [°C]	56.4	61
$T_{core2, center}$ [°C]	46.8	48.7
T_{IN} [°C]	33	33
T_{OUT} [°C]	33	33

→ Deviations are between 10% (active conductor) and 4% (passive conductor)

Conclusion / Outlook

- First model approach of a one-core cable was successfully evaluated
- Two-core cable model upgrade based on one-core cable approach
- For system level investigations PSpice-library element are available
- Experimental validation using NTC's, thermo-couples and IR-Thermography
- Both, one and two core model approaches were validated by FE-model and experiment and have shown acceptable agreement for static and transient behavior
  – depends on discretization

→ Experimental check-backs on real applications (looking for partners)
→ Model extension for multi-core (> 2 cores) cable

detailed information in *International Journal of Engineering Research and Development*
→ http://ijerd.com/paper/vol13-issue2/Version-1/G13214454.pdf (open access)

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Thank you for your attention !

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