Transient analysis: everything=f(time)

1. Equations with time-derivative term?
2. Time discretization
3. Choosing the correct time step.
4. Transient excitation
5. Transient postprocessing:
   field pictures, local values, integral values
6. Effect of automatic time stepping

Governing Equation

Transient heat transfer $\mathrm{div}(\lambda \mathrm{grad} T) = -q_{source} \boxed{- c\rho \frac{\partial T}{\partial t}}$

Transient electric field $\mathrm{div}(\sigma \cdot \mathrm{grad} U) = \boxed{-\frac{\partial(\varepsilon \cdot gradU)}{\partial t}}$

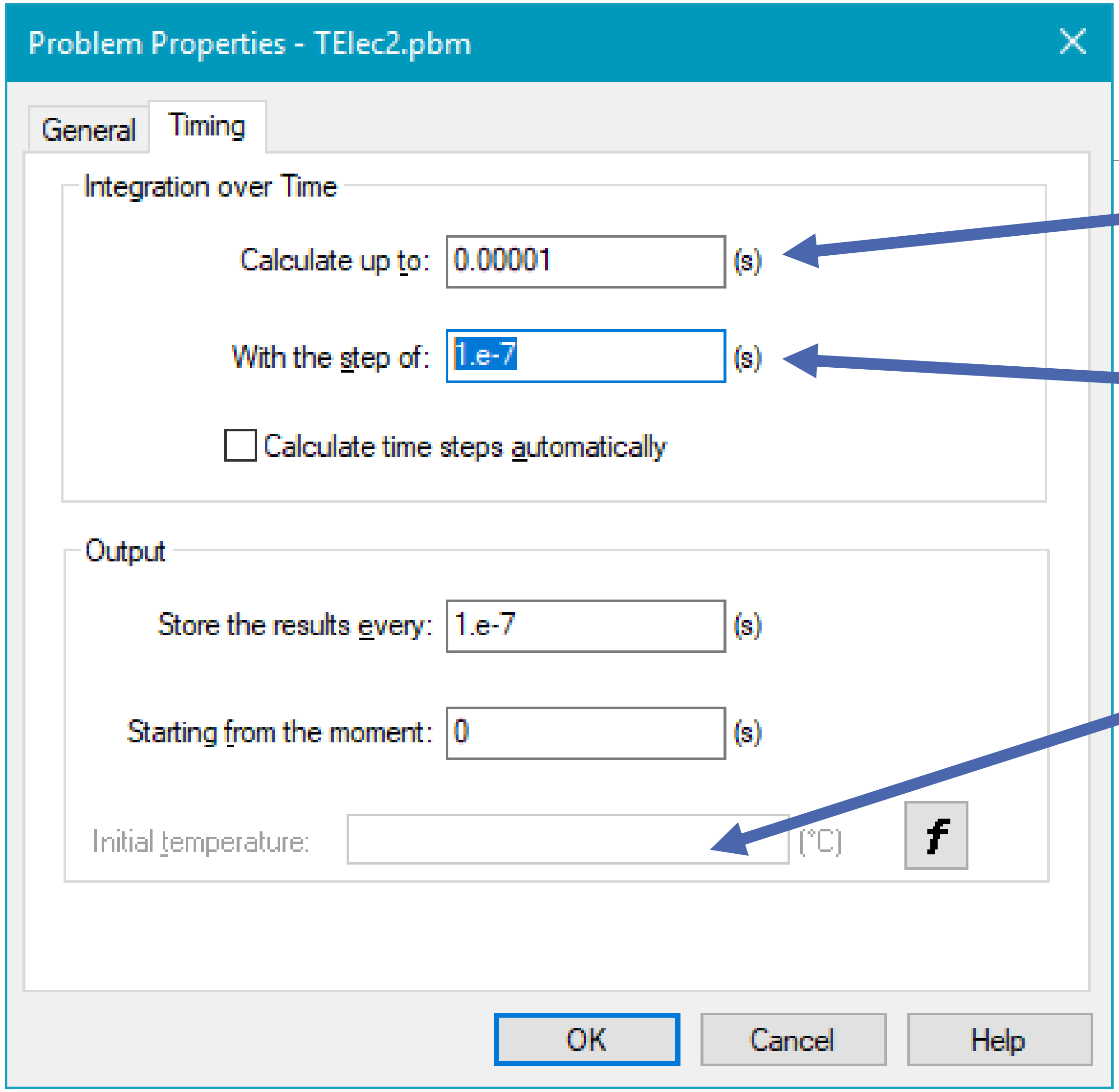
Transient electric field $\mathrm{rot}(\frac{1}{\mu} \cdot \mathrm{div}\mathbf{A}) = -\mathbf{J_0} + \mathrm{rot}\mathbf{M} \boxed{- \sigma \frac{\partial \mathbf{A}}{\partial t}}$

Transient term

Time Stepping

Time Integration:	From	To
Time range:	0	T_{MAX}
Time Step:	ΔT: fixed or automatic	
Storing results		
With time step:	$n \cdot \Delta T$	
Starting from:	0 or T_{MIN}	T_{MAX}

Editing time parameters



Time range (the upper bound)

Time step

Uniform initial value T_0 (only available for heat transfer analysis)

Automatic time step estimation

Choosing initial time-step

Starting from governing equation

$$\mathrm{div}(\lambda \mathrm{grad} T) = -q_{source} - c\rho \frac{\partial T}{\partial t}$$

Replace spatial and time derivatives with discrete analogues

$$\frac{\lambda \cdot \Delta T}{(\Delta l)^2} = c\rho \frac{\Delta T}{\Delta t} \Rightarrow \frac{(\Delta l)^2}{\Delta t} = \frac{\lambda}{c\rho}$$

Finally get the criterium of time-space coordination:

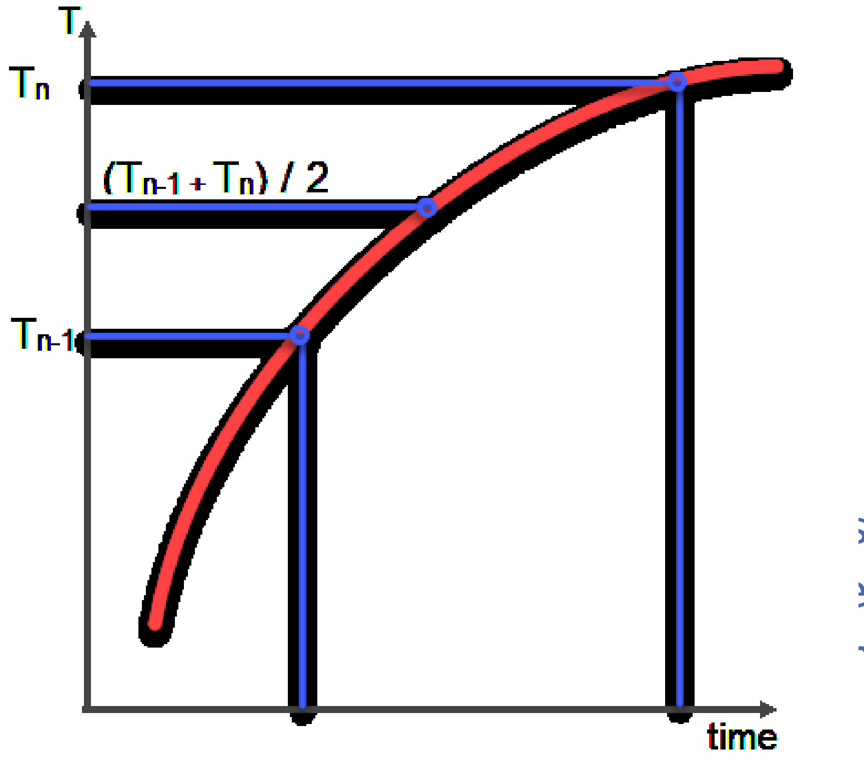
$$\Delta t = \min\left(\frac{(\Delta l)^2}{4\alpha}\right), where \quad \alpha = \frac{\lambda}{c\rho}$$

Time-step correction

The next time step is:

$$\Delta t_{n+1} = k \cdot \Delta t_n, wherek \in \left\{\frac{1}{4}, \frac{1}{2}, 1,2,4\right\}$$

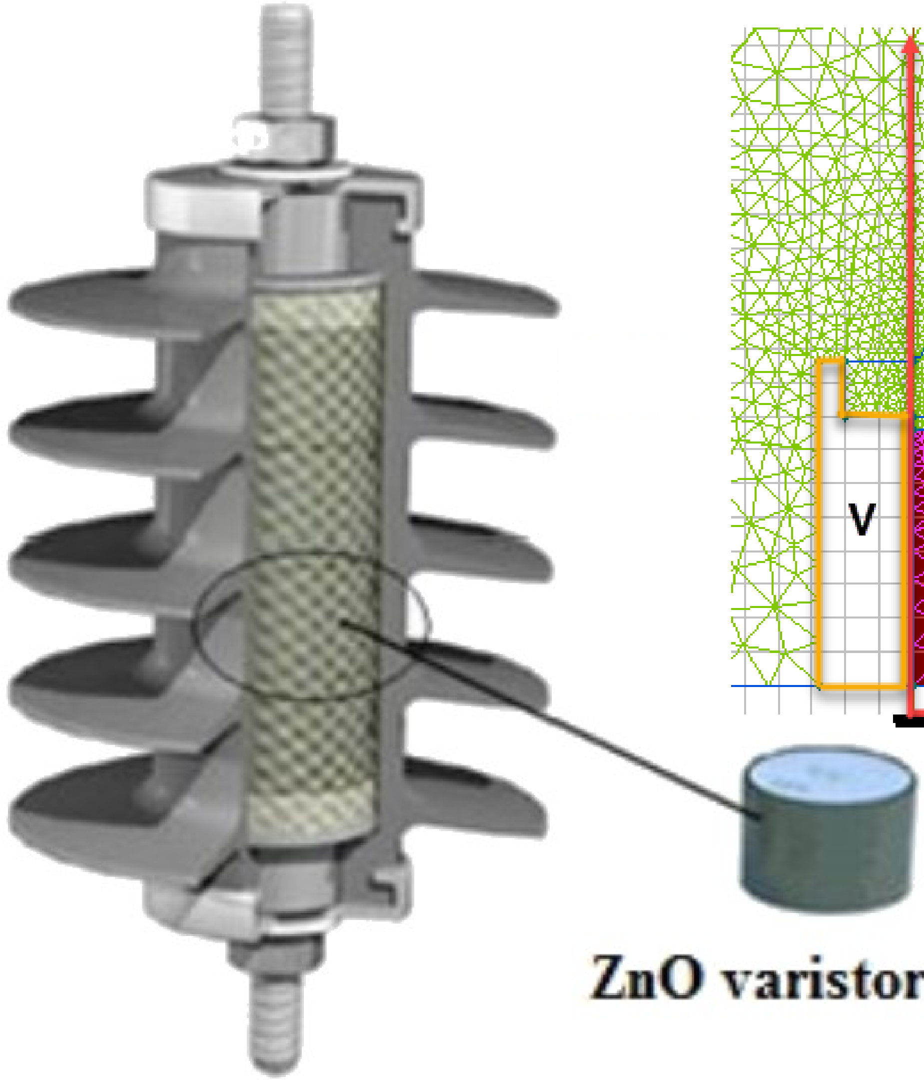
Dimensionless time derivative estimation:



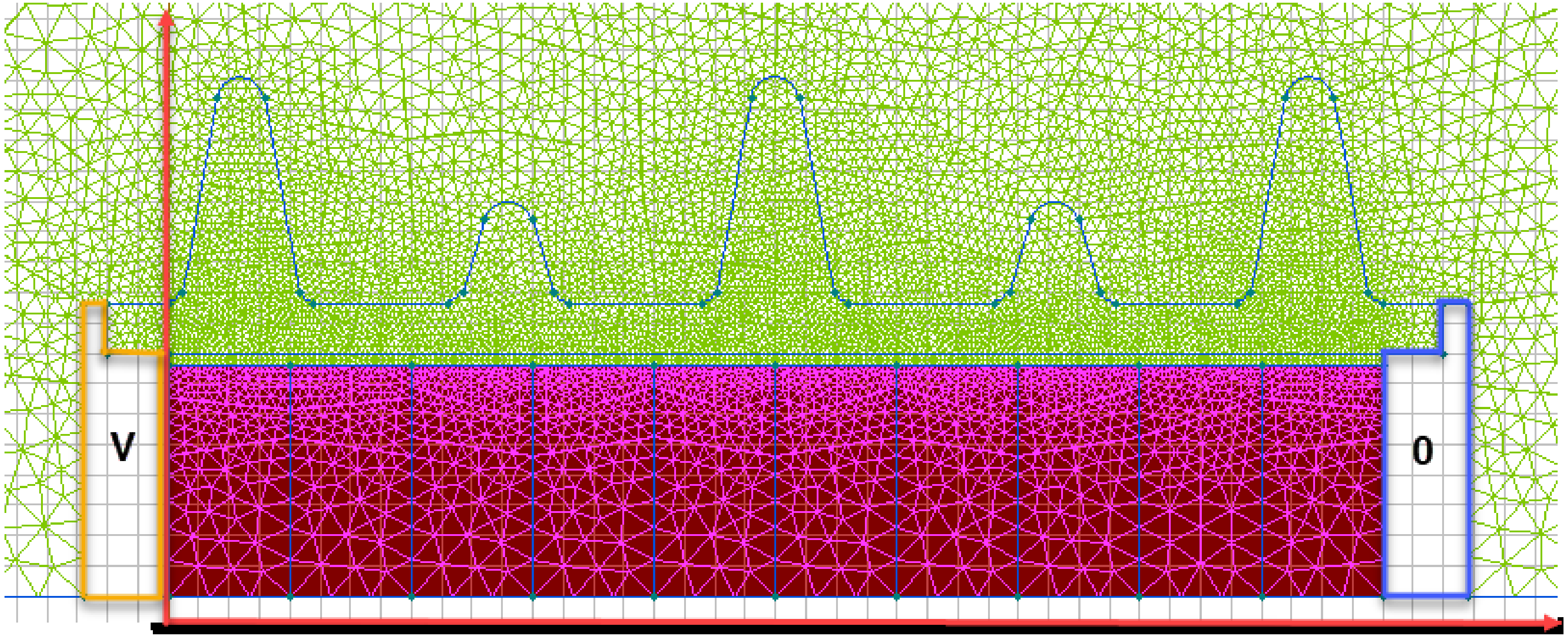
$$2\frac{u_n - u_{n-1}}{u_n + u_{n-1}}$$

next k is
sen according to
e derivative
nation Δu

Example 1: Surge Arrester based on ZnO varistor

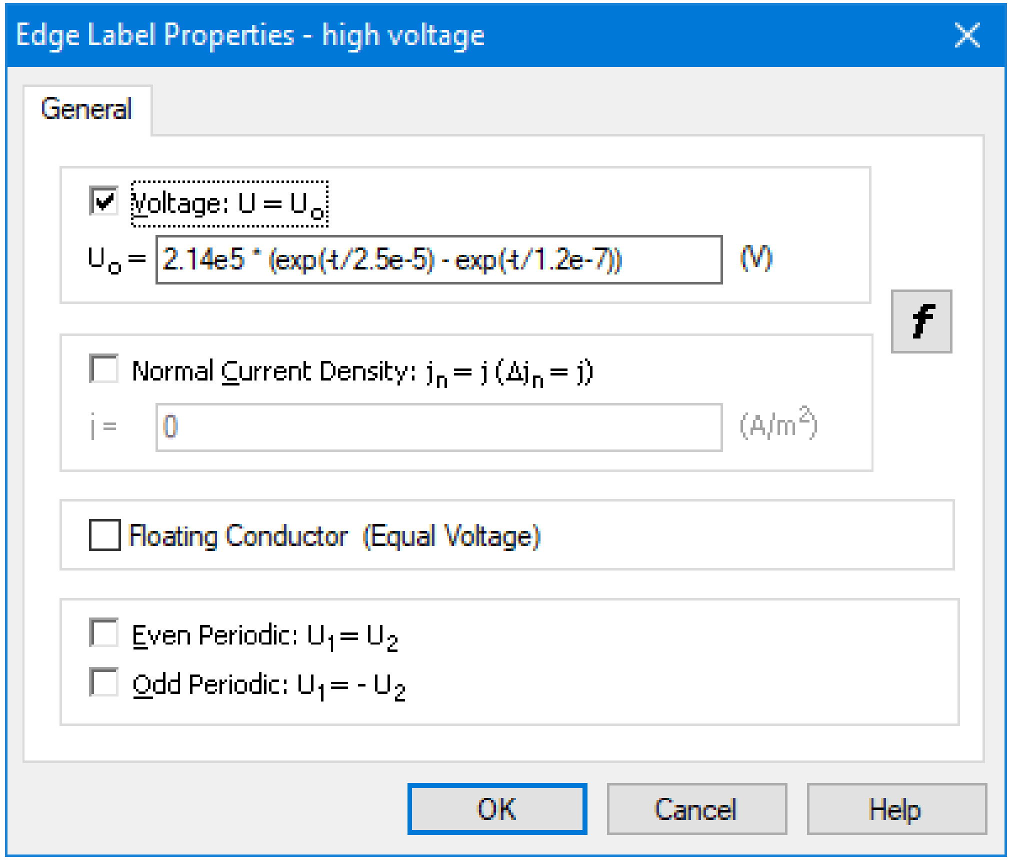


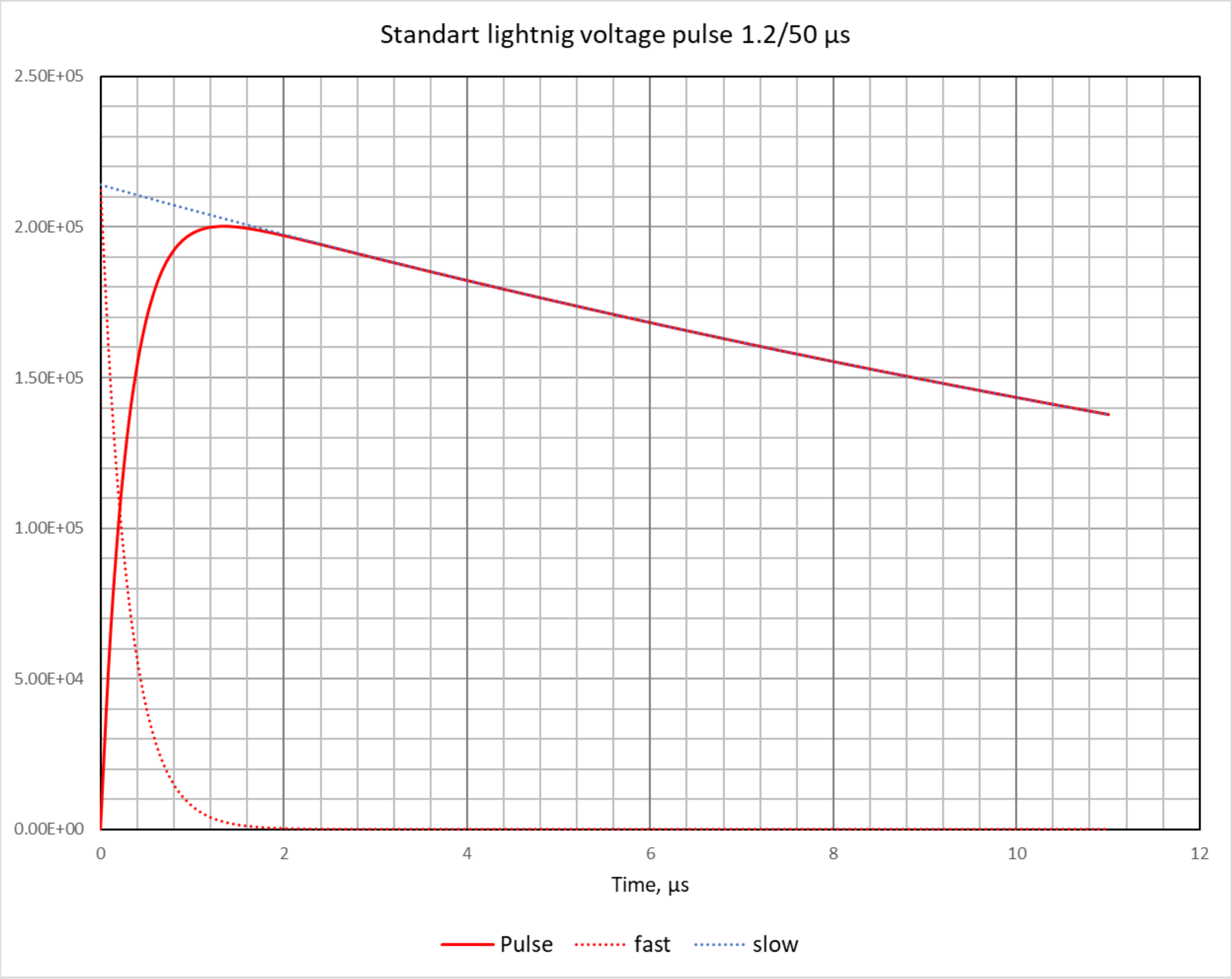
ZnO varistor block



Voltage pulse applied to the arrester

Standard voltage pulse: 1.2/50 μs





Postprocessing in transient analysis

1. Field pictures and other analysis tools work as usual

   within chosen time slice: $t = t_n$

2. Time plot and time tables available for both local and integral values

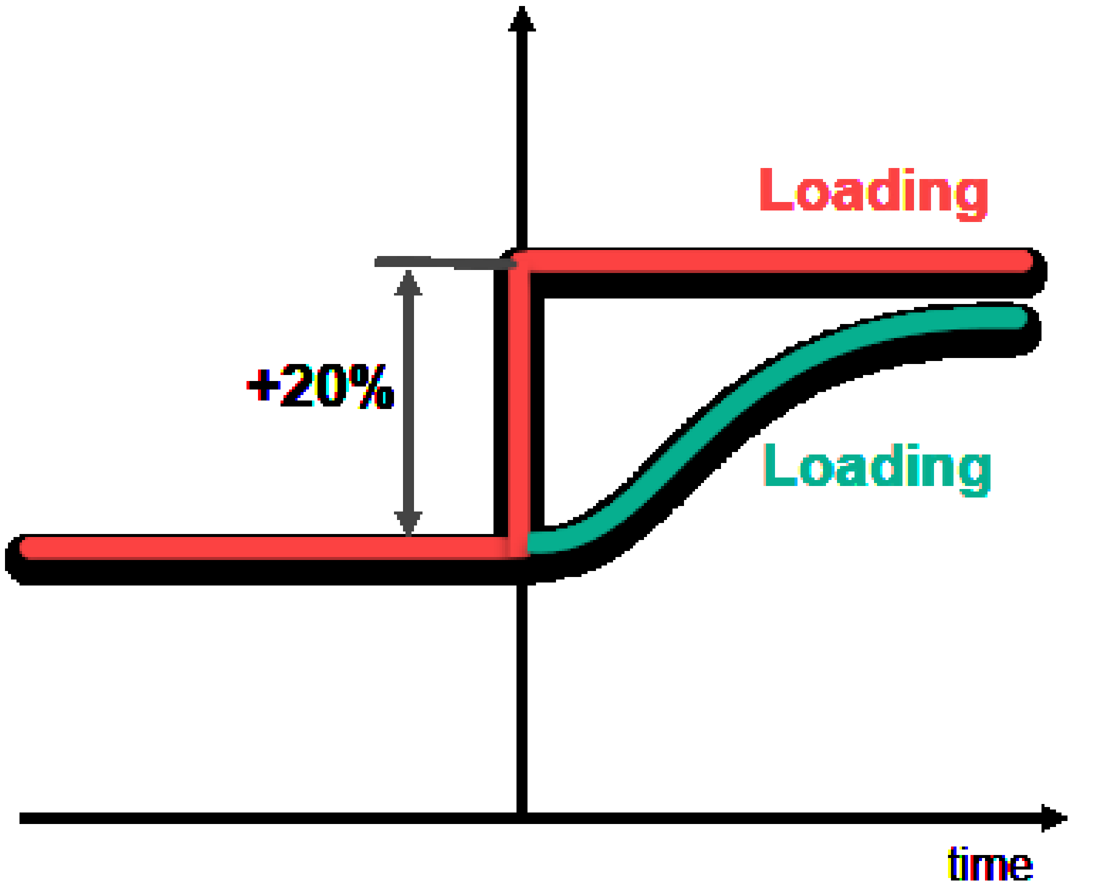
3. No integration over time so far, sorry!

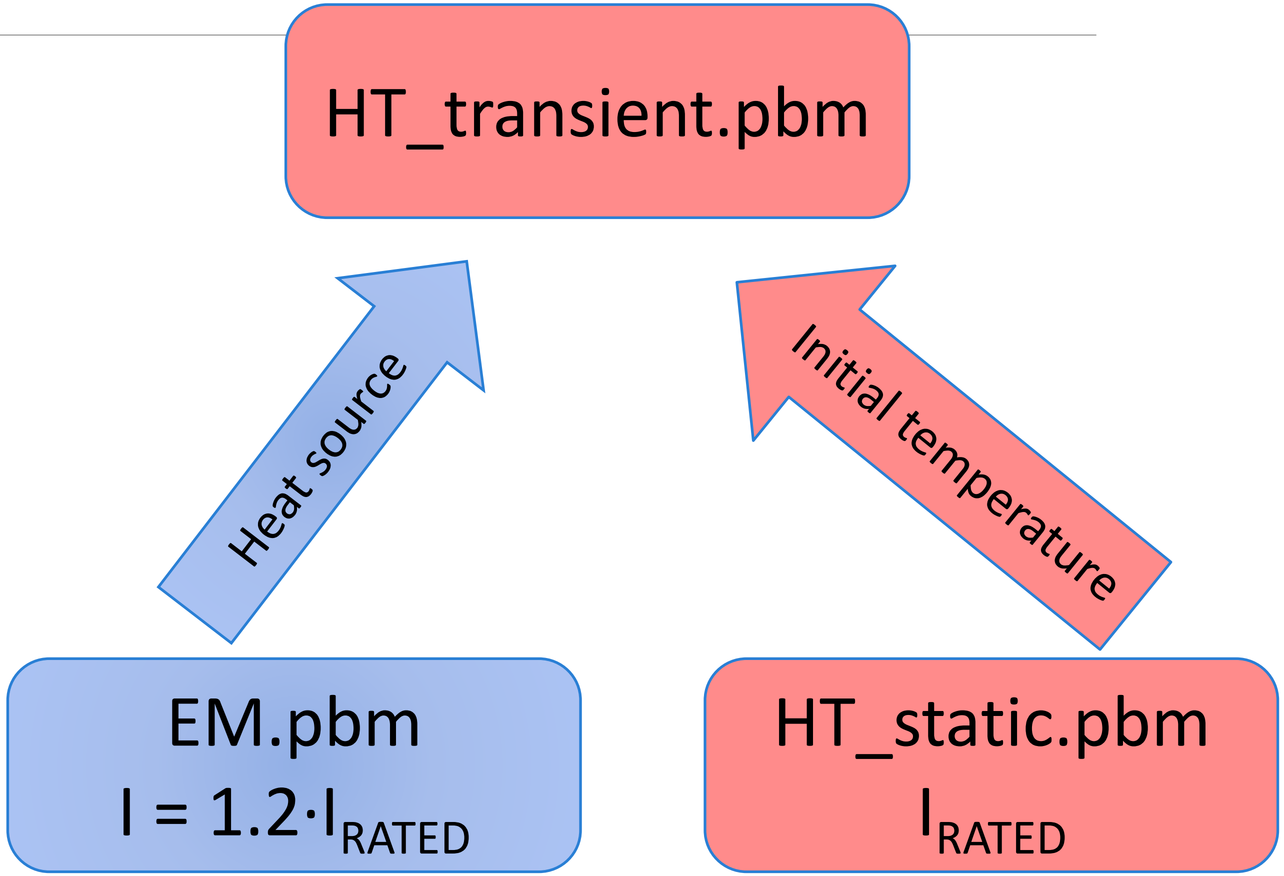
   Workaround: use third party tools (Excel,…)

4. Manual and automatic animation available

Example 2: Cable line overload

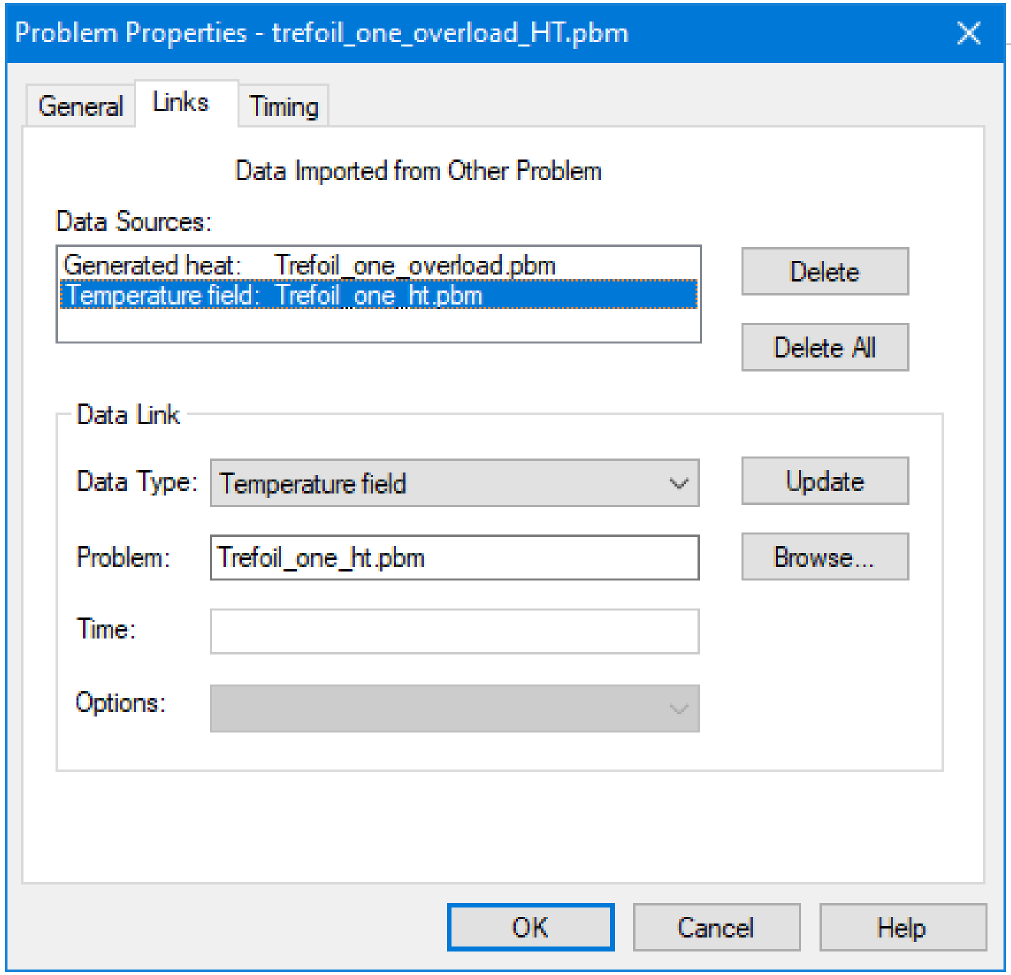
Let’s assume that we are forced to increase line current by 20% after an accident. What is the temperature response?



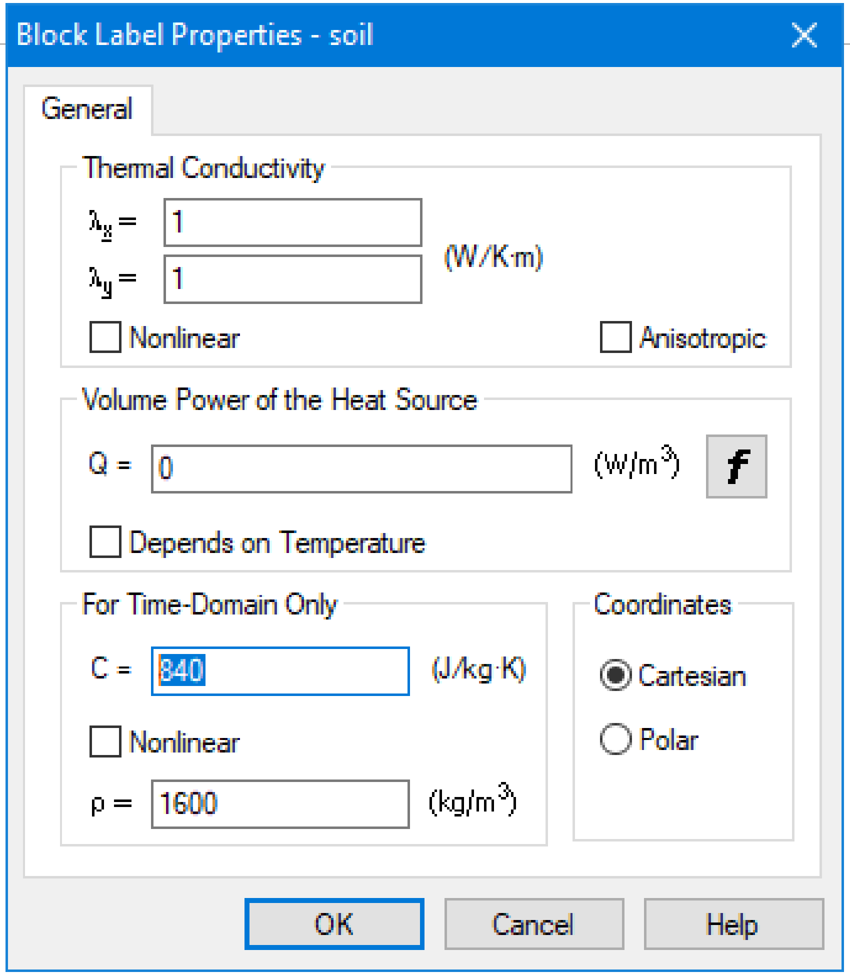


Problem coupling and transient data

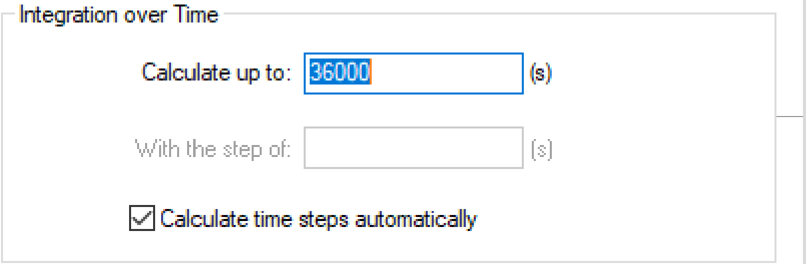
Two linked problem

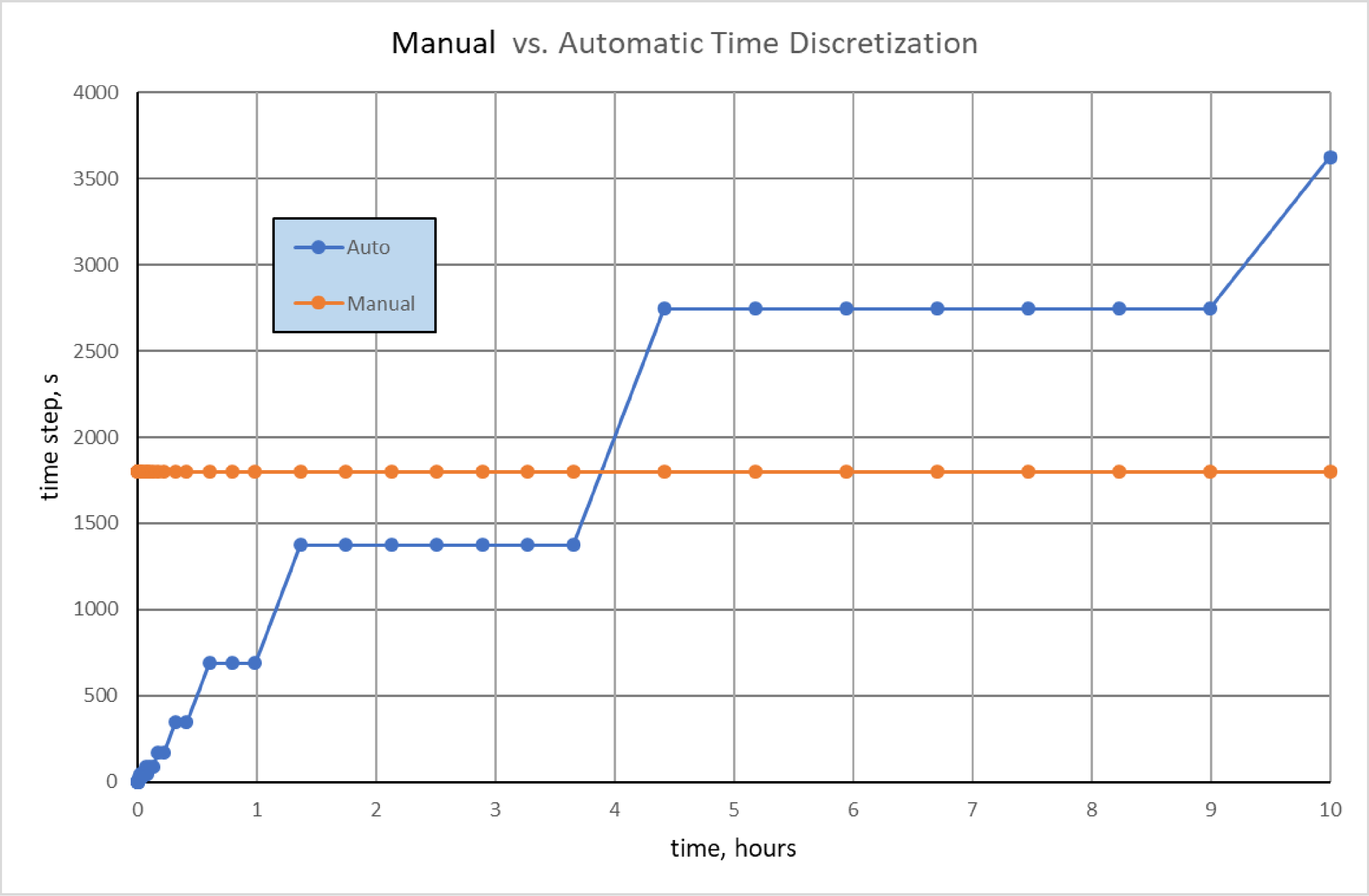


Specific heat; Mass density



Effect of automatic time stepping





Automatic time step effective with long transient process