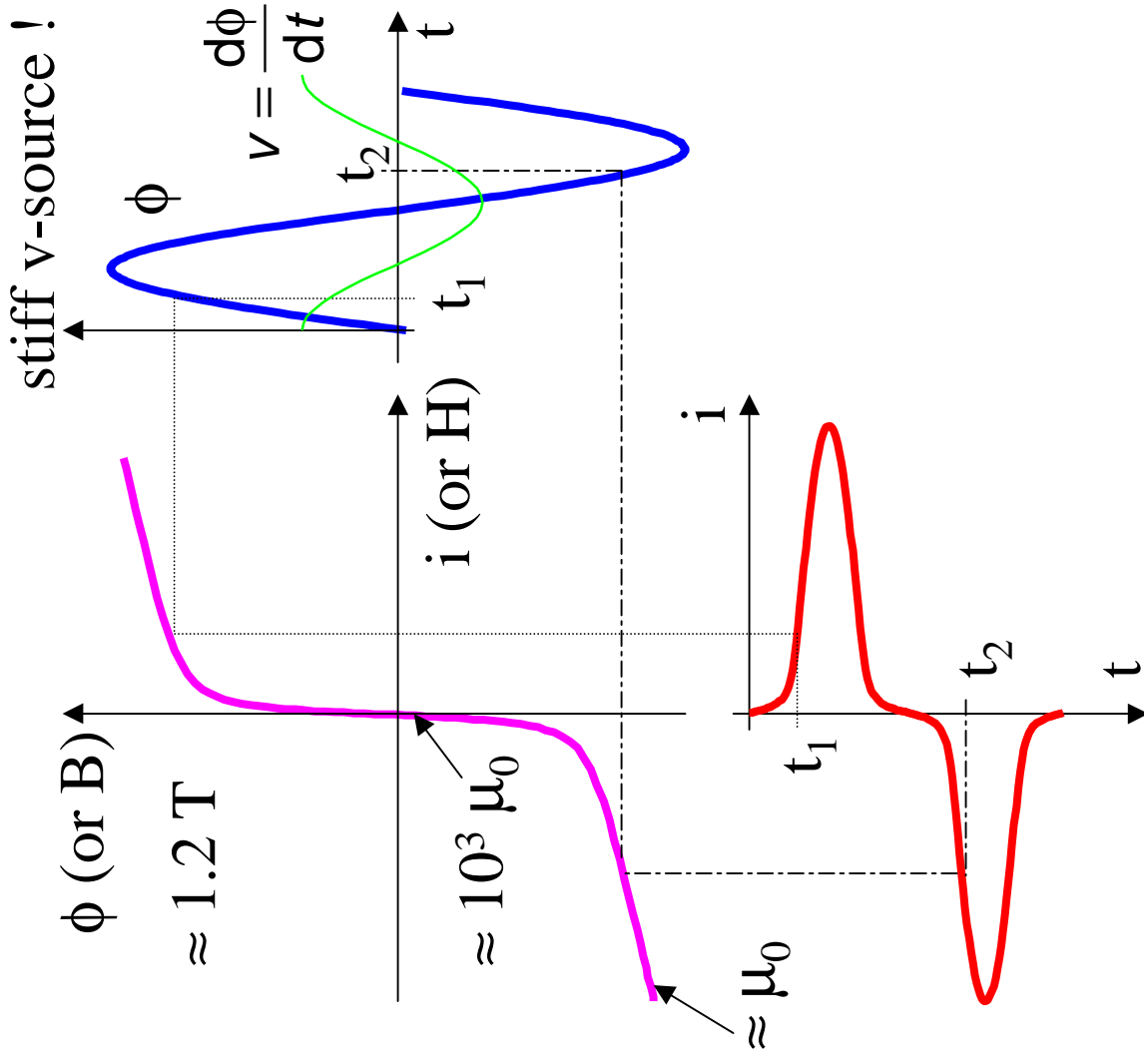
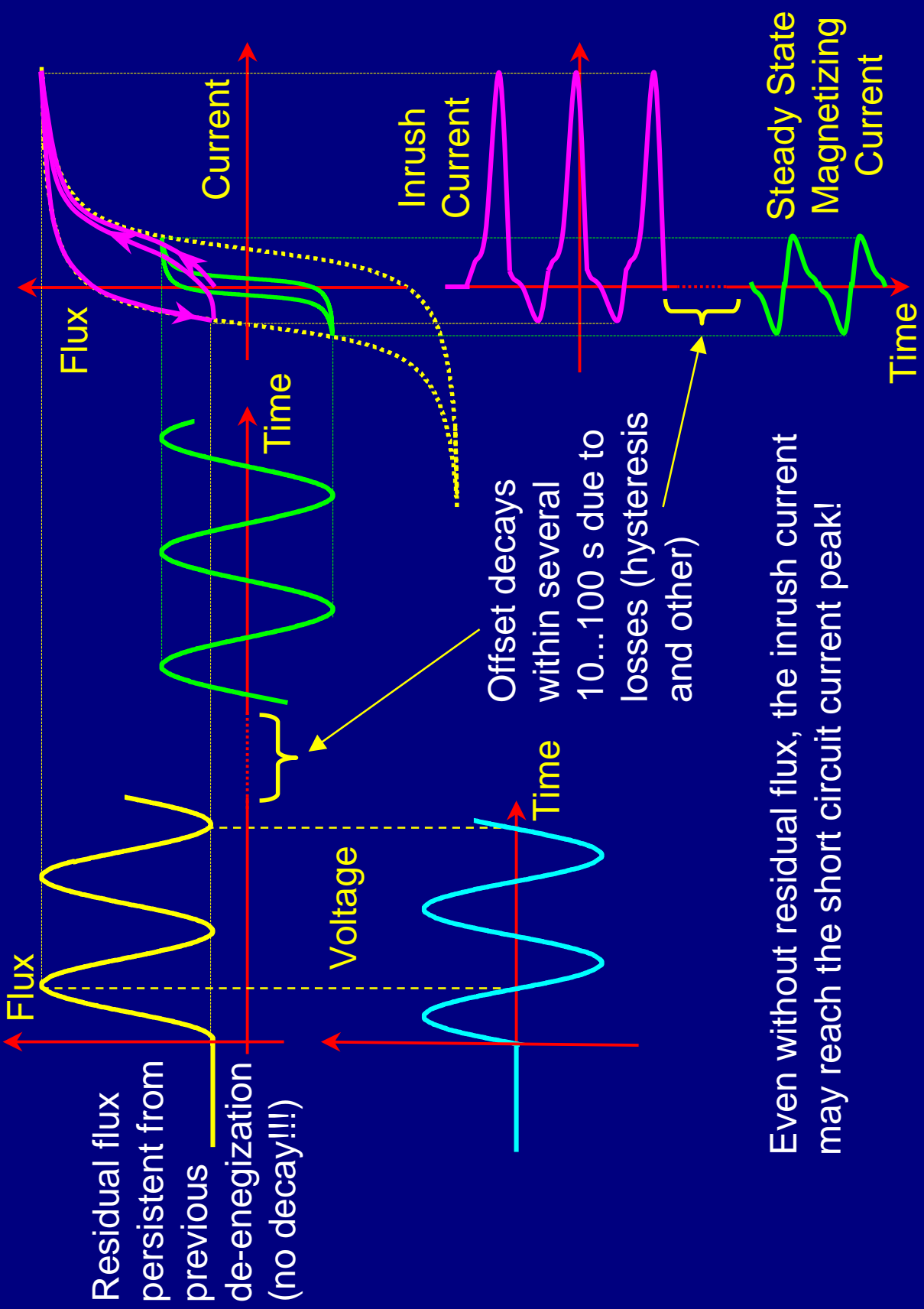


Transformer Magnetizing Current

- **Non-linear** magnetizing curve of iron core
 - ♦ high 3rd current harmonic in steady state
 - ♦ resonance problems with series capacitance \Rightarrow ferro-resonance
 - ♦ inrush current peak up to short circuit current



Transformer Inrush



Transformer Inrush

- **Problems**
 - ◆ 3rd harmonic in Neutral and Ground (either voltage or current, dependent on zero-sequence impedance)
 - ◆ inrush current lasts several 10...100 seconds (!)
=> high forces on windings
 - ◆ voltage sags due to high inrush current peaks; false relay triggering
- **Countermeasures**
 - ◆ Transformer core material
(high saturation flux, low magnetizing current)
 - ◆ pre-insertion resistors
 - ◆ Controlled switching: close breakers at appropriate times
- Problems: - need breakers with individual poles closing separately
 - precision of closing (mechanical delays, strategy)
 - pre-strikes

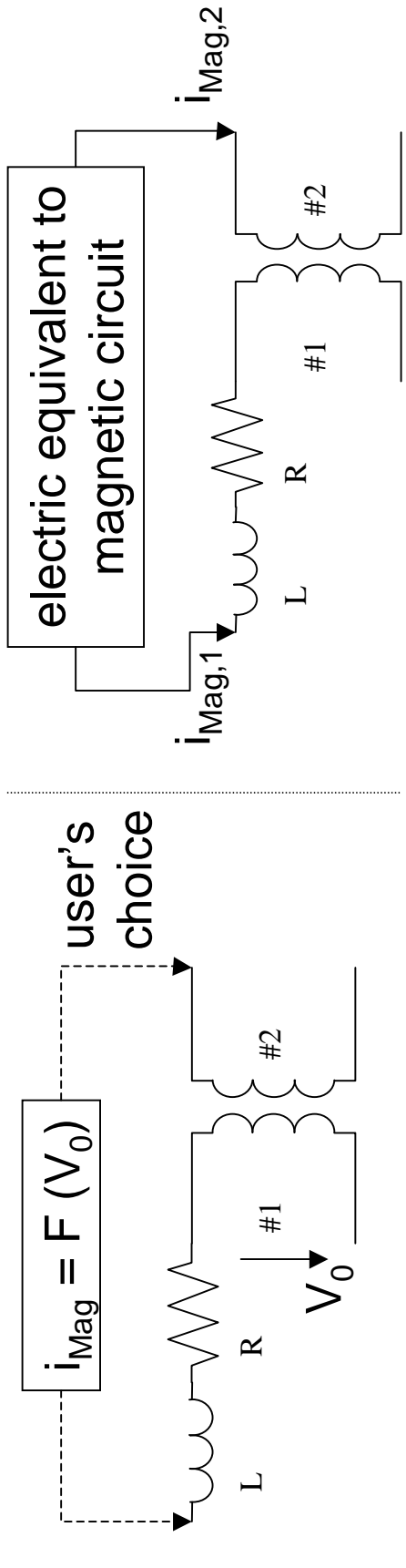
Transformer models in EMTDC

- **Standard**

- ◆ Magnetization curve ($B(H)$ – no Hysteresis – both models) is represented as **smooth mathematical function** (e.g. arctan, see HW04).
- ◆ Magnetizing current is injected either on winding #1 or #2.

- **UMEC "Unified Magnetic Equivalent Circuit"**

- ◆ Contains an electrical circuit equivalent to the magnetic circuit.
- ◆ Magnetization curve represented as piece-wise linear polygon.
- ◆ Magnetizing current is calculated for each winding separately.



Example: Energizing 3ph Transformer

- **Inrush and Magnetizing Currents (Std model)**
 - ◆ Inrush currents for different closing times (Y-Y, single coil energized)
 - ◆ Secondary voltage sags during inrush (artificial transients @ $dt = 50\mu s$)
 - ◆ Unavoidable high inrush with standard CB closing (3 poles simultaneously)
 - ◆ Optimal closing strategy (zero residual flux conditions)
 - ◆ Neutral current (3rd harmonic!)
- **UMEC model**
 - ◆ Default B(H) curve must be changed to derive 3rd harmonic of i_{Mag} .
 - ◆ Solution is more sensitive to time step due to linearized B(H) curve.