JIG makes difference

in performance validation

JC Sun
Bs&T Frankfurt am Main GmbH

psma magnetics workshop
March 2023 in Orlando

Bs&T Frankfurt am Main
Hannah Arendt Str. 36
60438 Frankfurt am Main

JC and his...

- physicist & engineer
- make and design ferrite 3Cx and 3Fx

FERROXCUBE
A YAGEO COMPANY

- sales amorphous metals 2605/2714/2705

Metglas®

- marketing nanocrystalline 500F components

VAC
VACUUMSCHMELZE

- Bs & T Frankfurt am Main GmbH

Bs&T Analyzer

2022 Bs & T Chicago Corp.

Content

- Introduction of Bs&T
- Electrification & magnetization
- Magnetic quality ~ non linearity
  material µ
  core A_L
  coil L
- Measuring condition
  standard & authority of interpretation
- JIG makes the difference

Bs & T Analyzer I

Sinus Magnetization AC

high excitation

IEC 62044-3

loss, μ_a driven by B mode

B_{peak}, loop driven by H mode

low excitation

IEC 62044-2

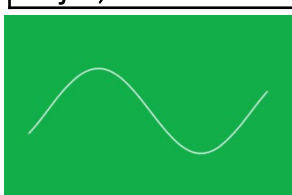
DC superposition

BsT-Pro

loss map (f, B, T, ***H_{DC}***)

μ_{rev} (f, B, T, ***H_{DC}***)

major, and biased minor loop



Pulse Magnetization

fast transit of magnetic state

dB/dt

IEC 60367-1 Annex G (393 IEEE)

BsT-Pulse

differential and **amplitude L**,

energetic L, power loss i.e. Q factor

Pulse Magnetization

fast transit of magnetic state

dB/dt

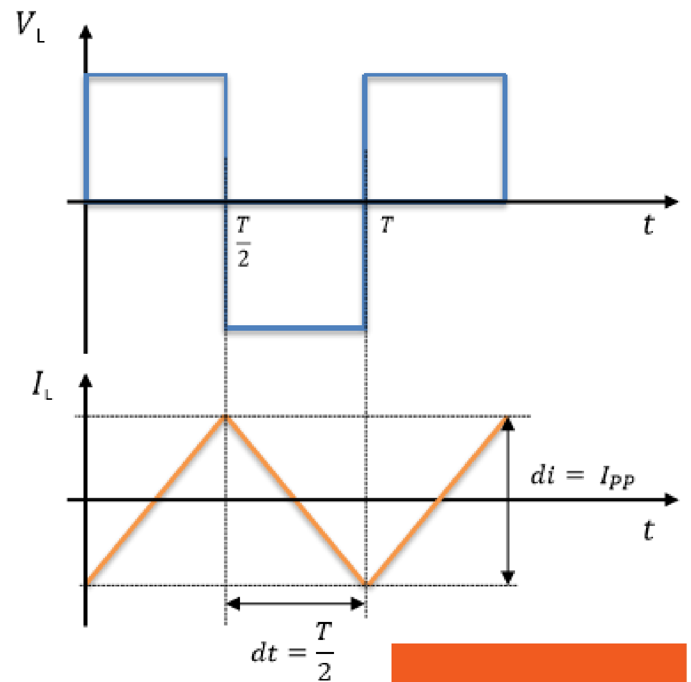
Damped oscillation

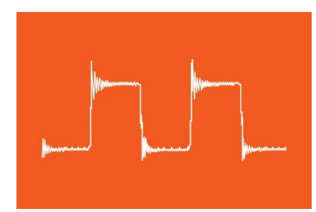
BsT-Pulse

differential and amplitude L

energetic L, power loss

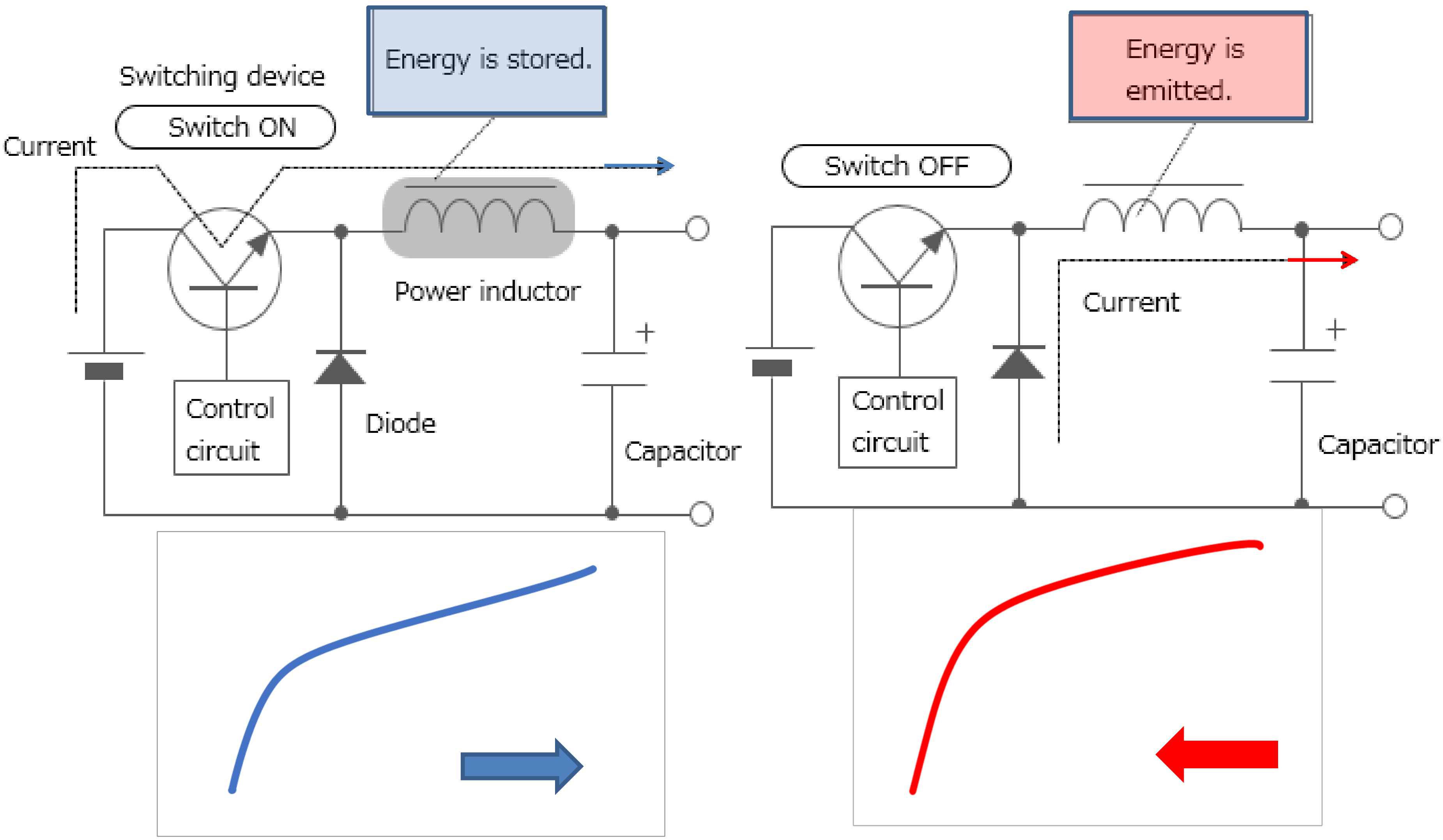
Square Wave





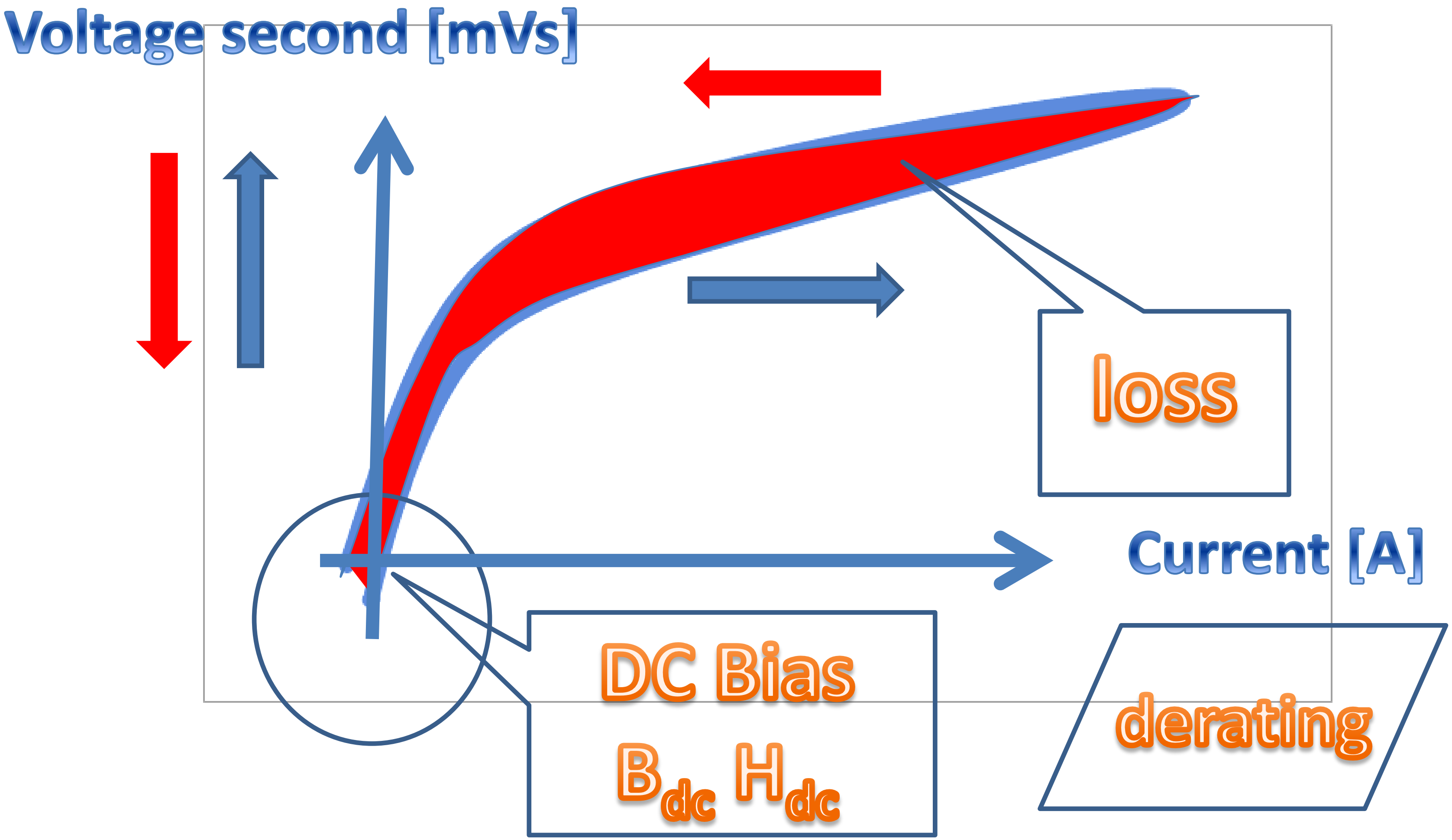
bipolar pulse magnetization

ON and OFF



Energy is stored.
Switching device
Switch ON
Current
Power inductor
Control circuit
Diode
Capacitor
+
Energy is emitted.
Switch OFF
Current
Control circuit
Capacitor
+

magnetization vs. demagneitzation



Coil is Nonlinear and shows Saturation

Commutation curve is between magnetization and demagnetization path; with other words, loss less coil, demagnetization = magnetization curve

$$L_s(i) = \frac{N \cdot \Phi}{i} = \frac{\Psi}{i}$$

Differential L

$$L_d(i) = \frac{\mathrm{d}(N \cdot \Phi)}{\mathrm{d}i} = \frac{\mathrm{d}\Psi}{\mathrm{d}i}$$

$$v(t) = L_d(i) \cdot \frac{\mathrm{d}i}{\mathrm{d}t} = \frac{\mathrm{d}\Psi}{\mathrm{d}i} \cdot \frac{\mathrm{d}i}{\mathrm{d}t} = \frac{\mathrm{d}\Psi}{\mathrm{d}t} =$$

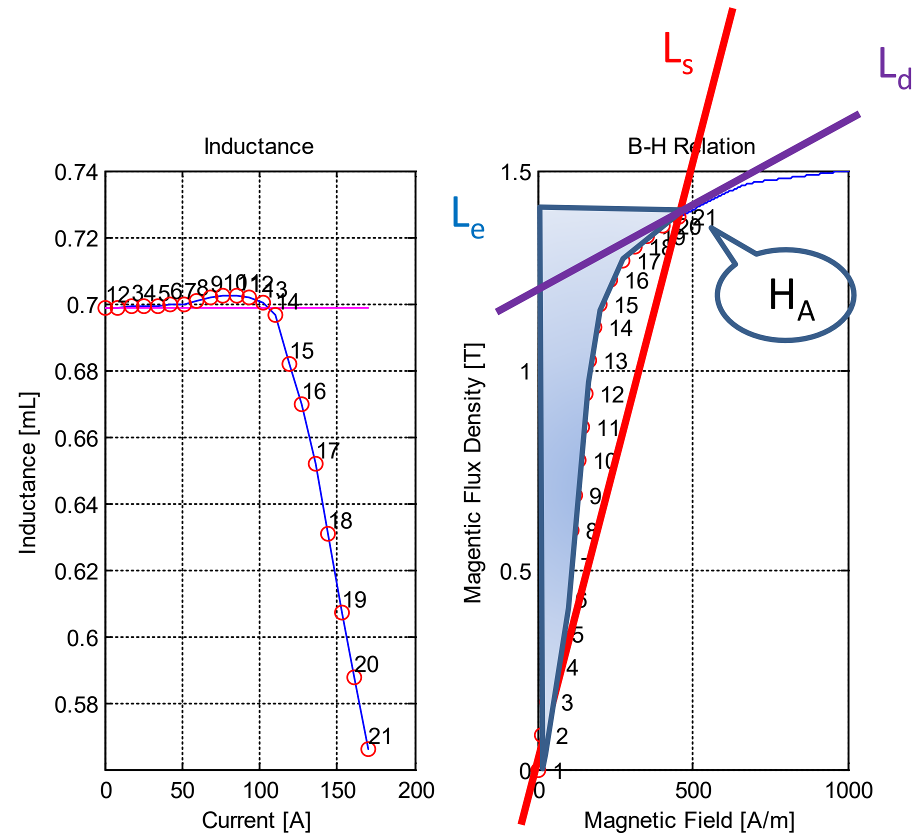
$$\frac{\mathrm{d}\left[i \cdot L_s(i)\right]}{\mathrm{d}t} = L_s(i) \cdot \frac{\mathrm{d}i}{\mathrm{d}t} + i \cdot \frac{\mathrm{d}L_s(i)}{\mathrm{d}t}$$

Amplitude L $\rightarrow$

$$L_s(i) = \frac{1}{i} \int_0^i L_s(i')\, di'$$

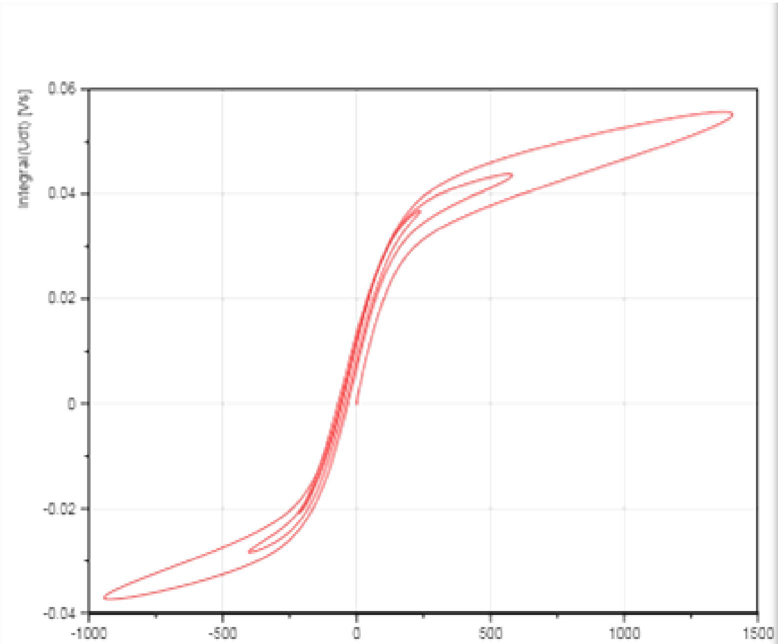
$$L_e(i) = \frac{2}{i^2} \int_0^i i \cdot L_s(i')\, di'$$

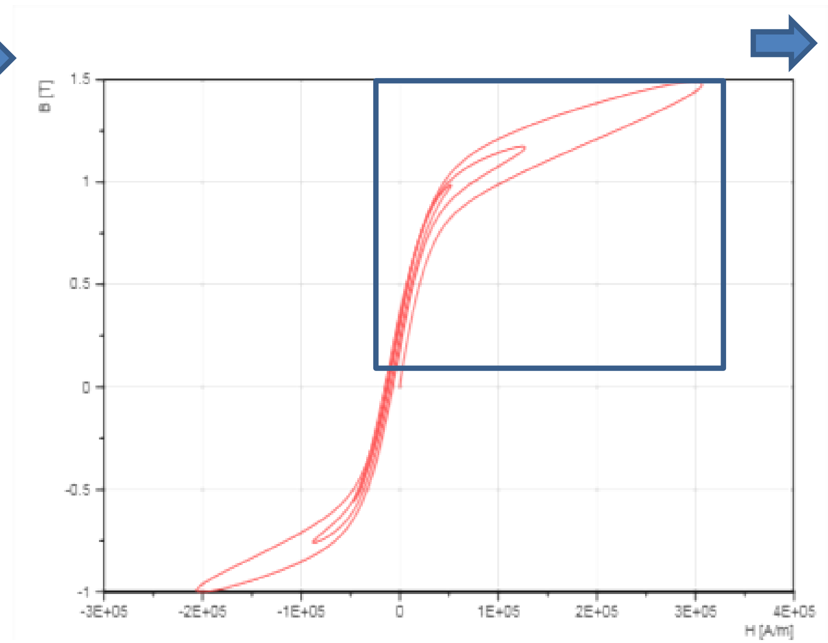
Energetic L



Alex van den Bossche

Validation of coil L, core A_L and material µ





- Material
- Geometrie
- Spulendaten

$\Phi = \Psi / w_s$

$\Theta = i \cdot w_p$

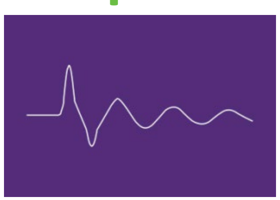
- Material
- Geometrie

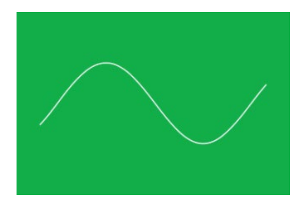
$B = \Phi / A$

$H = \Theta / L$

- Material

component **core** **material**





Validation of small signal for material, condition in standard

- **IEC 62044-2**: "Magnetic properties at low excitation level"

9 Inductance Measurement – Test Signal

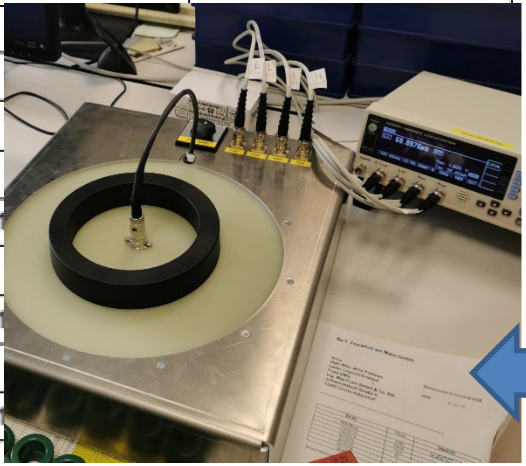
- LCR meters or impedance analysers are used to make inductance measurements.
- The upper limit for AC voltage for this type of equipment is typically between 1 Vrms and 20 Vrms.
- Measurements are made using the **series** mode unless the parallel mode is specified.
- The recommended peak flux density is 0.25 mT (for small toroids 1 mT)
- The recommended test frequencies are either 10 kHz or 100 kHz

$$L = A\,L\,N^2 \qquad AL = \frac{\mu 0 \mu}{le/Ae}$$

JIG for small signal

Table 1- Relationship of test turns to magnetic structure, test frequency and inductance factor A_L

	Turns	Frequency kHz	A_L nH/N^2
Toroid	1	10	> 10 000
		100	> 1 000
	10	10	> 100
		100	> 10
	100	10	NA
		100	NA
Cores using bobbin	1		
	10		
	100		
Cores using Planar Winding	1		
	10		
	100		

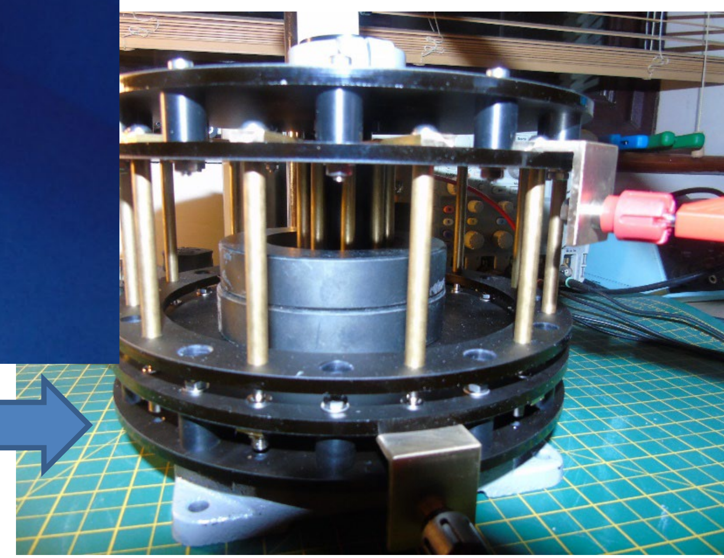


Workshop

202**2**

JIG for large signal

3 phase common mode choke

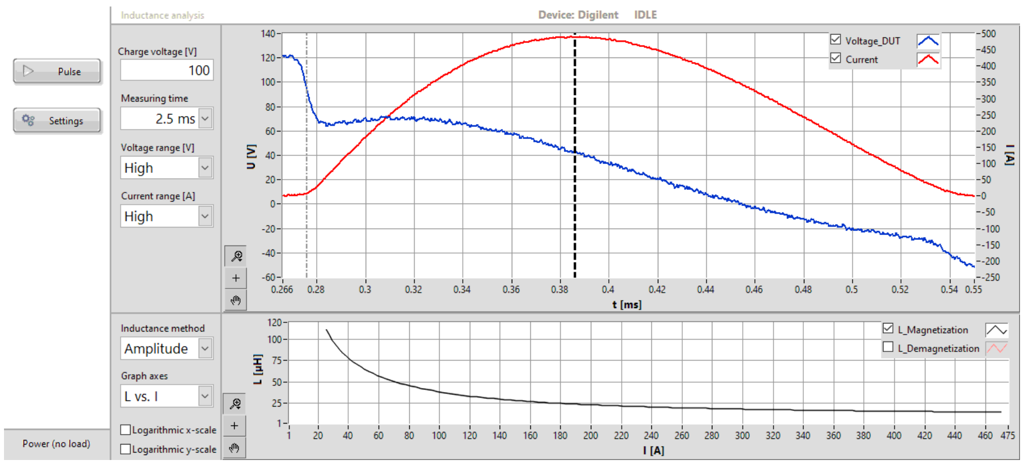


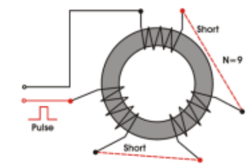
Workshop

2023

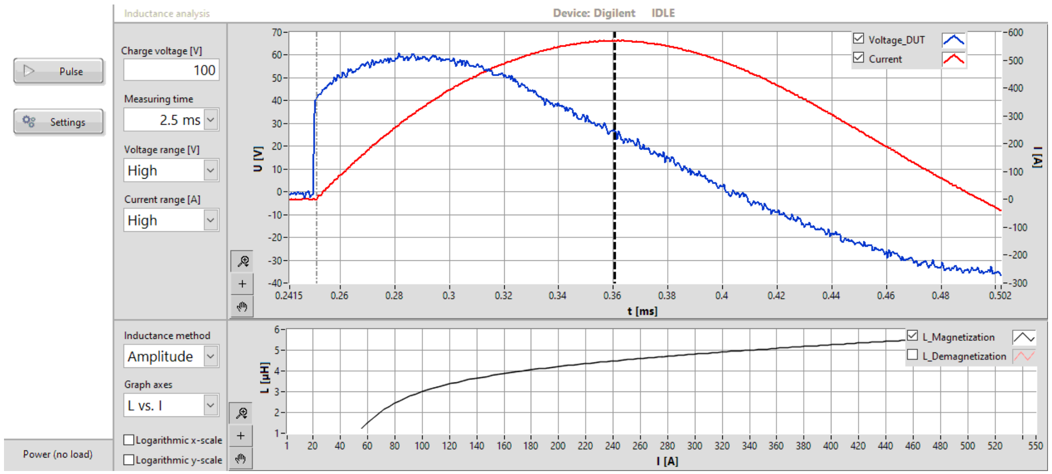
All the denotes of L’s performance

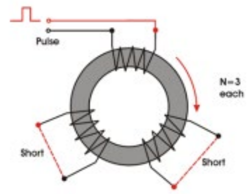
L_{core}





L_{leak}





conclusion

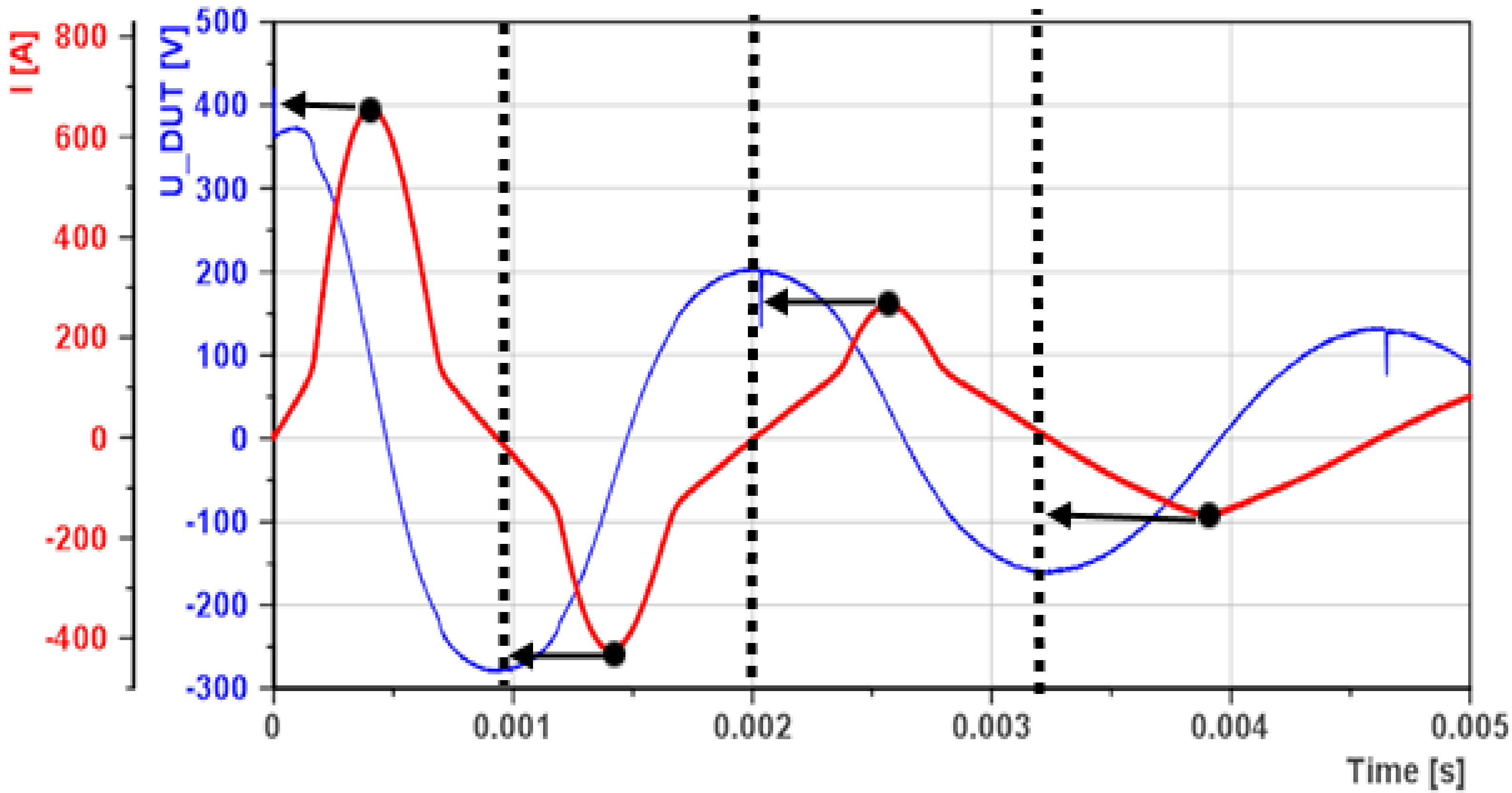
- Validation of inductance is challenging
- Measuring conditions for material/core might be cited/recommended in standards
- effective and efficient measurement always in details like JIGs
- JIG makes the difference in validation of component performance

*further reading: JC Sun IEEE power Maganzine060/2021
Recent Development in Measuring Technology of soft magnetic components for High Power Applications

Annex with an example for Different mode choke

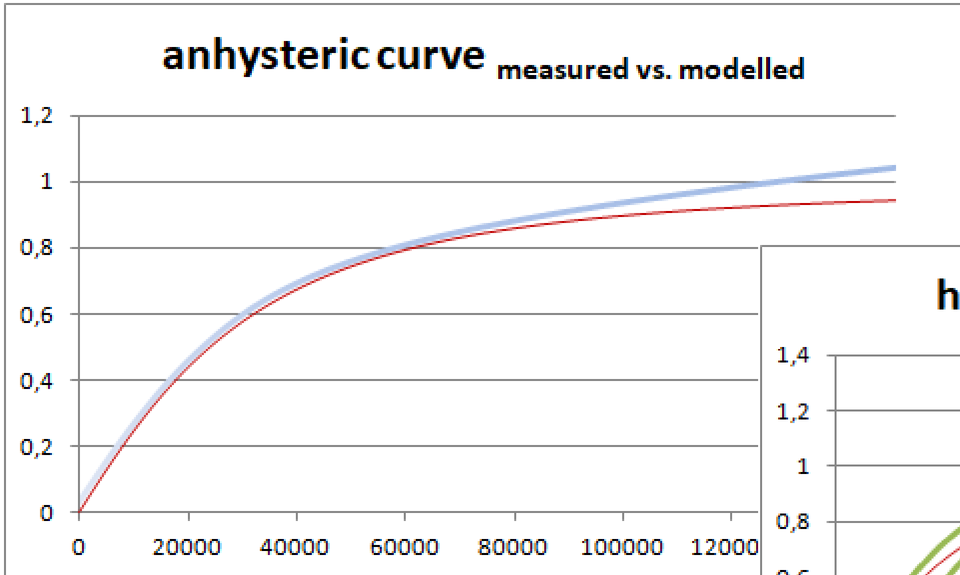
- Dmc (presented in workshop 2017):
  cored with material &shape *HS1016* (CSC) 2x wound with edge wire with N=53
- Voltage load: 400V
- Capacitor: 430 µF
- Device: BsT-Pulse 1k3k Typ SN0001b
- Application: ultra speed charging 400kW, one phase

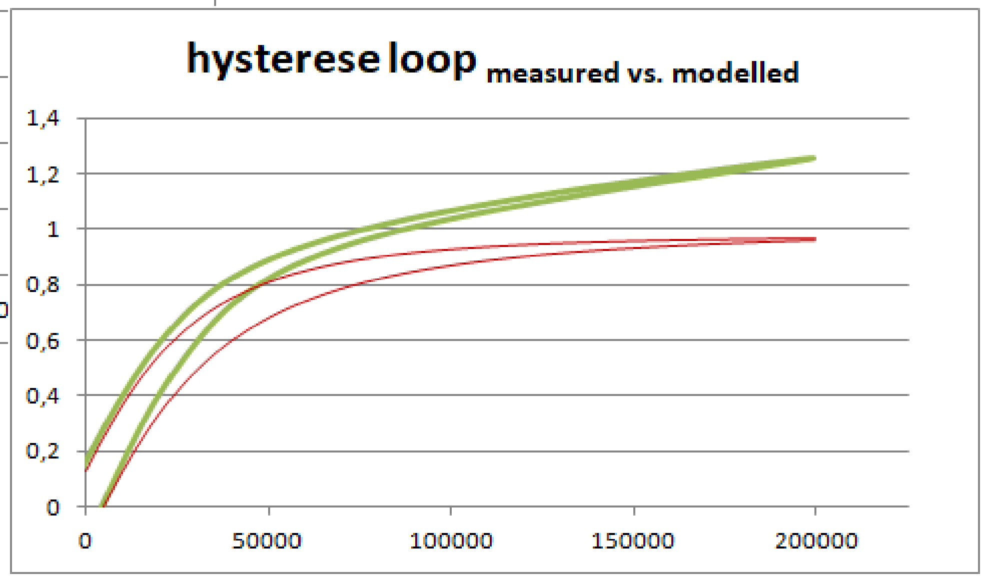
Voltage and current decay



PSMA workshop magnetics Damp-Oscillation BsT-pulse

Curve & Loop via parameter fitting [Rivas]





further reading: JC Sun BodoPower 09/2020
Damp-Oscillation Solution for Validation of the Metal Alloyed Powder Core