AC fictive power source: challenges and approaches

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- Need
- Design principle
- Challenges and approaches
- AC fictive power source: current state
- Future steps

Need: To develop a reference system for laboratory calibration of the EMF for AC supplies in railway systems

Targeted specifications:

Generate sinusoidal voltage:

15 kV – 16.7 Hz

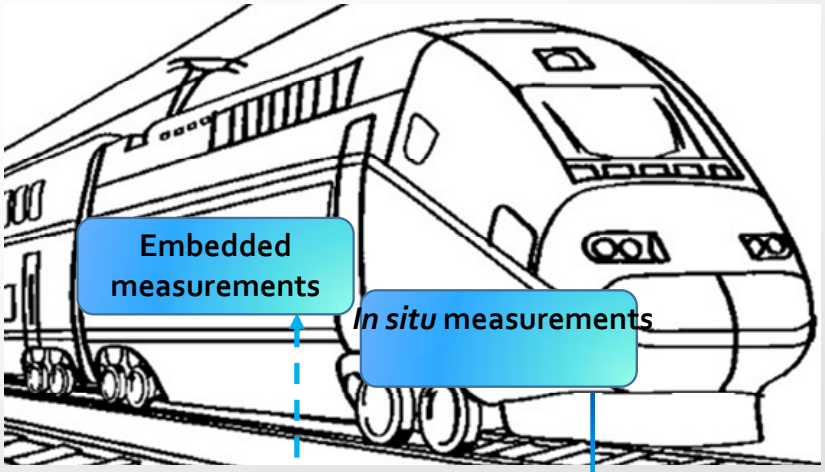
25 kV – 50 Hz

Generate distorted current:

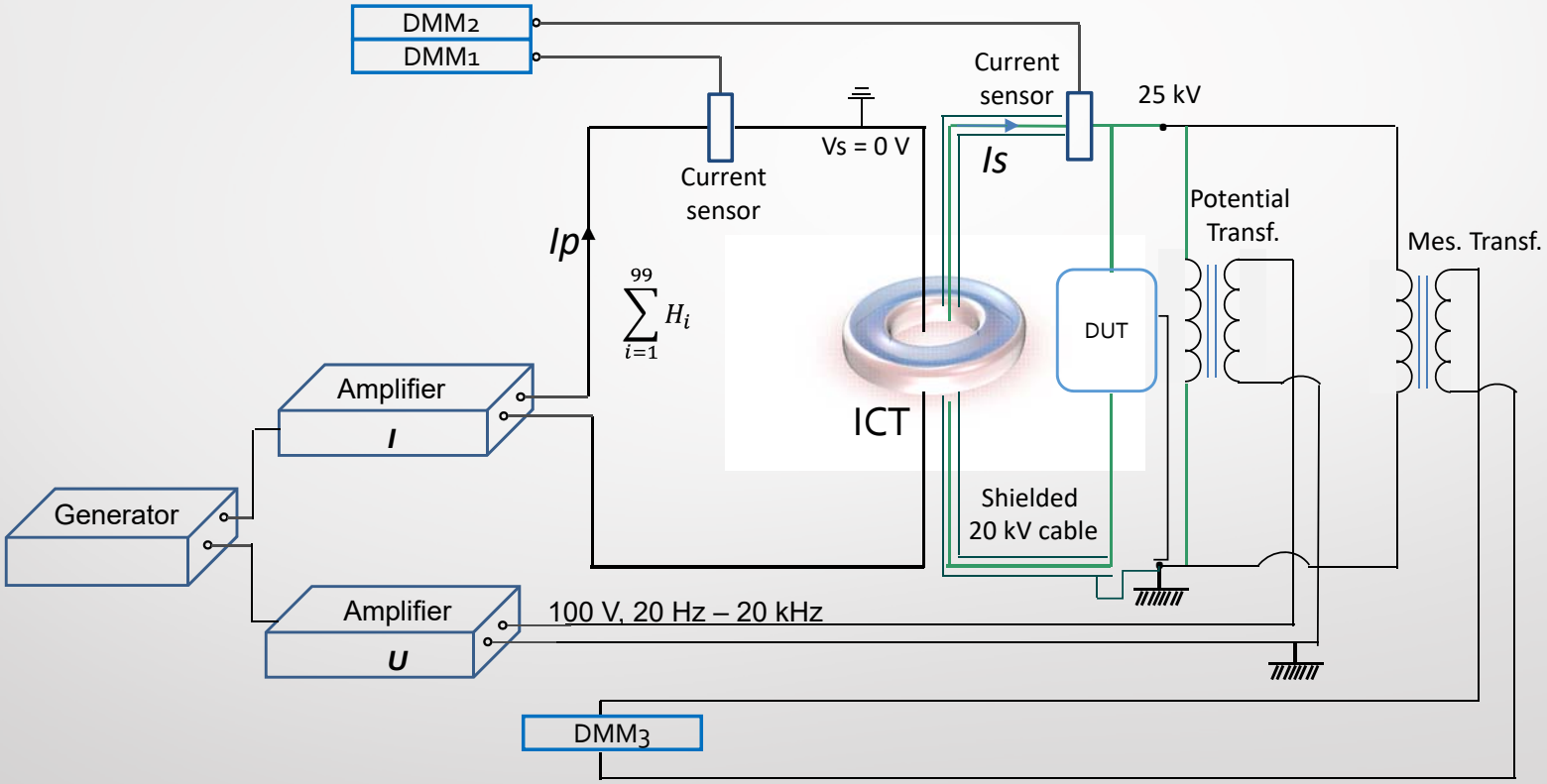
500 A – 50 Hz +

harmonics up to 5 kHz

Target uncertainty: 0.5 % of the measured energy under distorted waveforms



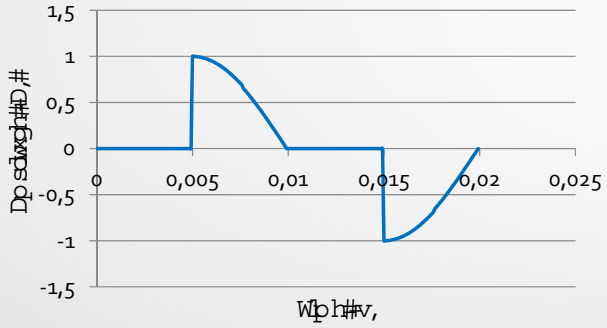
AC fictive power source: design principle



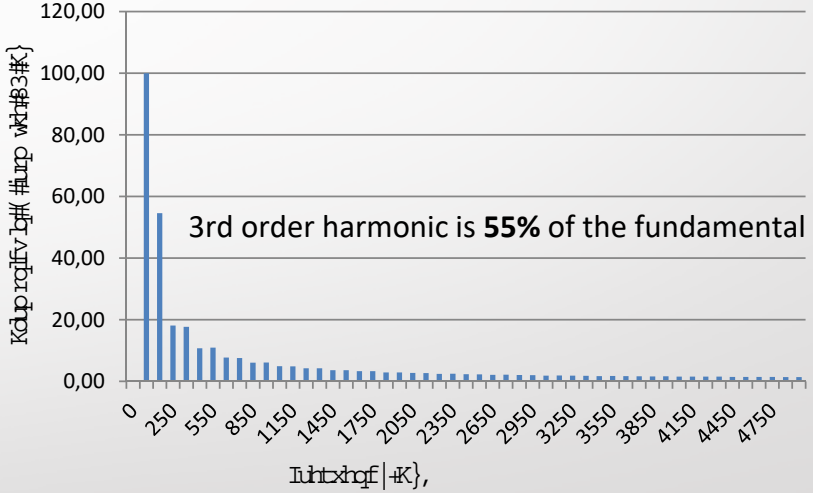
AC fictive power source: challenges & approaches

Challenge: Generate current with high level and high order harmonics (up to 99)

- Classical transformers are designed for 40 - 60 Hz
- Phase-fired test waveform defined in EN 50463-2 standard



Targeted RMS value: **500 A**



Solution: Find the operating point of the ICT (Injection Current Transformer), a wideband current transformer, by adjusting several parameters

Operating point of ICT: parameters to adjust

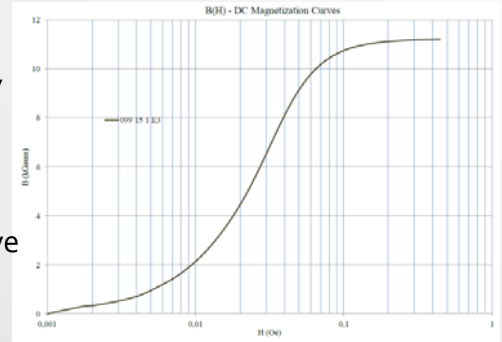
P1: Magnetic properties of ICT

Issue: not really known since magnetic properties change with thermal and mechanical treatment, with the frequency, too.

Approaches: test 2 types of magnetic materials

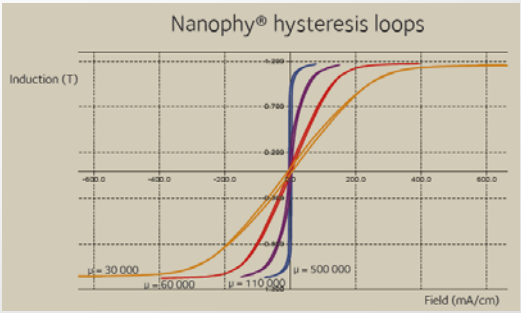
Low permeability (15000)

Non-linear magnetisation curve



High permeability (>70000)

Linear magnetisation curve



Non-linear:

'+' Material more easily found on the market

'+' Impose voltage control rather than current control

'-' Nature and value of the secondary impedance should be considered

'-' Closed loop to be implemented based on the secondary current measurement

Linear:

'+' Direct ratio between the injected and the output current

Low corrections with respect to each harmonic are to be expected

'+' Open-loop way of working

Operating point of ICT: parameters to adjust

P2: Ratio of ICT and impedance transfer

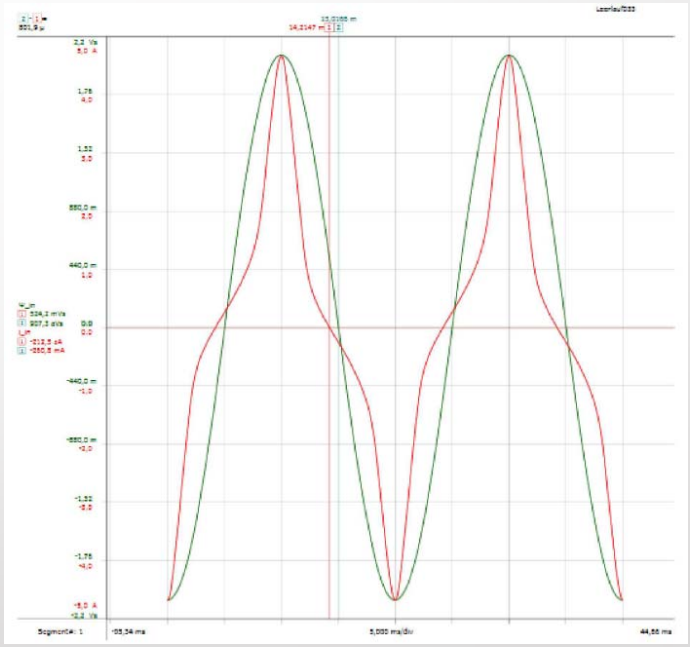
Issue: Find the balance between the supply signal (type and level) and the secondary loop impedance to avoid saturation of the ICT

Approaches: Optimise the ICT ratio, the secondary loop impedance and choose the appropriate control mode

$$k_n = \frac{N_1}{N_2} = \frac{I_2}{I_1} \qquad Z_2 = \frac{v_1}{i_2 \cdot k_n}$$

$$v_1 i_1 = v_2 i_2 \qquad Z_1 = Z_2 \cdot \left(\frac{N_1}{N_2}\right)^2$$

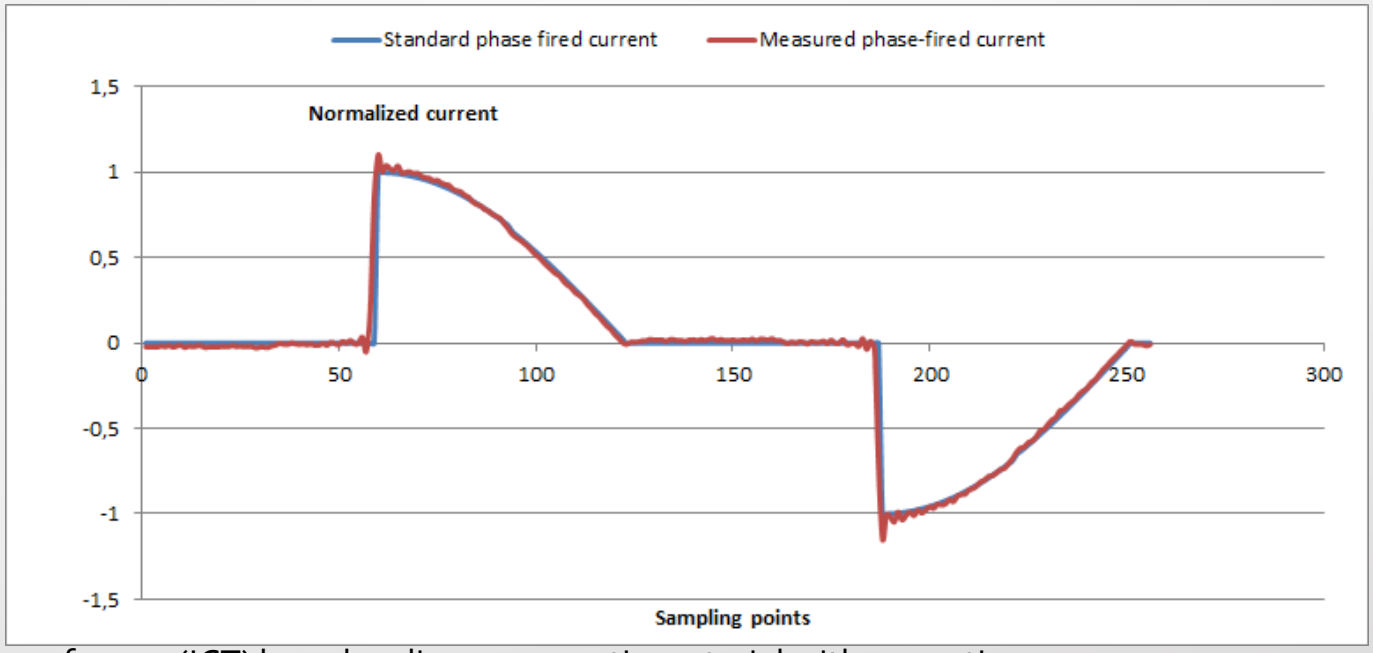
- Impedance of the secondary loop is transferred to the primary with the square of the ICT ratio (loop to be connected with the EMF to be calibrated on the train => **not too short; unknown EMF impedance**)
- The neccessary suply voltage might remain conform to Boucherot formula and stay under the amplifier characteristics that are limited in voltage (up to 50 V)



https://www.hbm.com/index.php?id=7589&L=3&utm_marketing-project-id=U-0011.

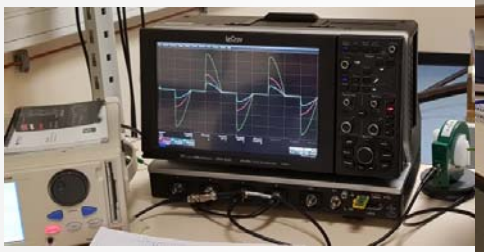
AC fictive power source: current state

It supplies distorted current up to 100 A rms and harmonics up to 5 kHz at a voltage potential of 12 kV and 50 Hz



- Injection Current Transformer (ICT) based on linear magnetic material with corrections
- ICT ratio of 10
- 1.5 mΩ secondary impedance
- Current controlled mode

AC fictive power source: current state



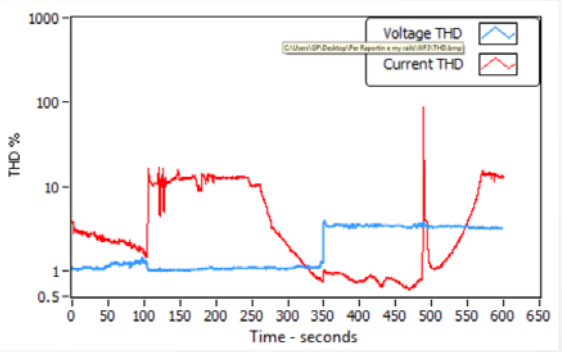
Features

- Compactness (transportable on site)
- Able to reproduce the field distortion
- Adapted for larger magnetic materials
- Versatile:
  both voltage or current control modes are available

AC fictive power source: future steps

Definition of test waveforms for laboratory calibration

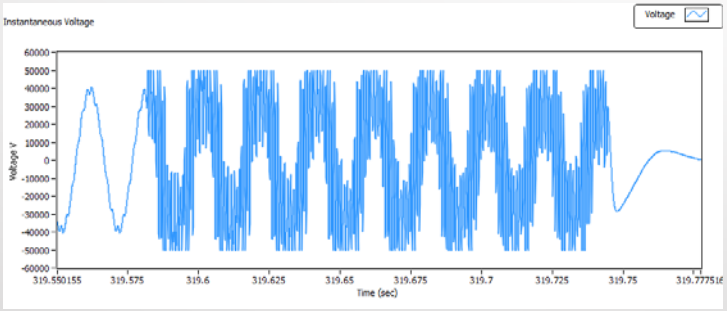
Link the THD and the existing harmonics in the acquired signal with the instantaneous current and voltage waveforms.

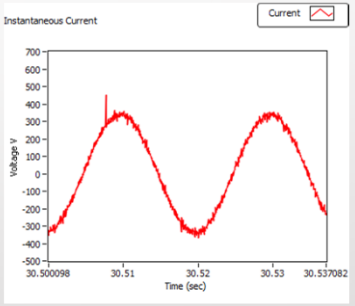


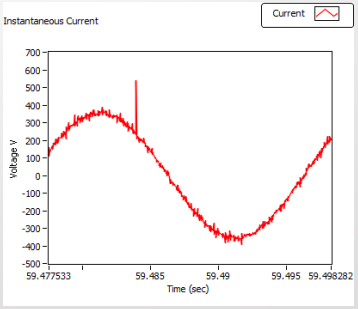
Collaboration work:
Railenium,
University of Strathclyde,
NPL, FFII, LNE

Graphs from
Y. Seferi and B. G. Stewart
document

Several sequences to be analysed







Extract information and define the test waveforms to be generated by the fictive power sources.

AC fictive power source: future steps

Calibration of a commercial EMF under distorted conditions