3D Power Inductor : Calculation of Iron Core losses

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INTRODUCTION

- Designing magnetic components requires the well-known of electromagnetic losses they lead to.
- Evaluation of those losses is quite complex because they depend on frequency, amplitude, waveform, geometry and materials' nature.

OBJECTIVES

- Taking into account 3D geometric effects and material non-linearity to evaluate iron losses in magnetic devices used in power electronics.
- Applying volumetric models at an element scale instead of applying at a macroscopic scale

METHOD

- « Steinmetz » type volumetric models
- Datasheet curve fitting to get k,α, and β parameters
- Element scale iron losses calculation
- Independent from the formula used, could be easily adjustable to a new one

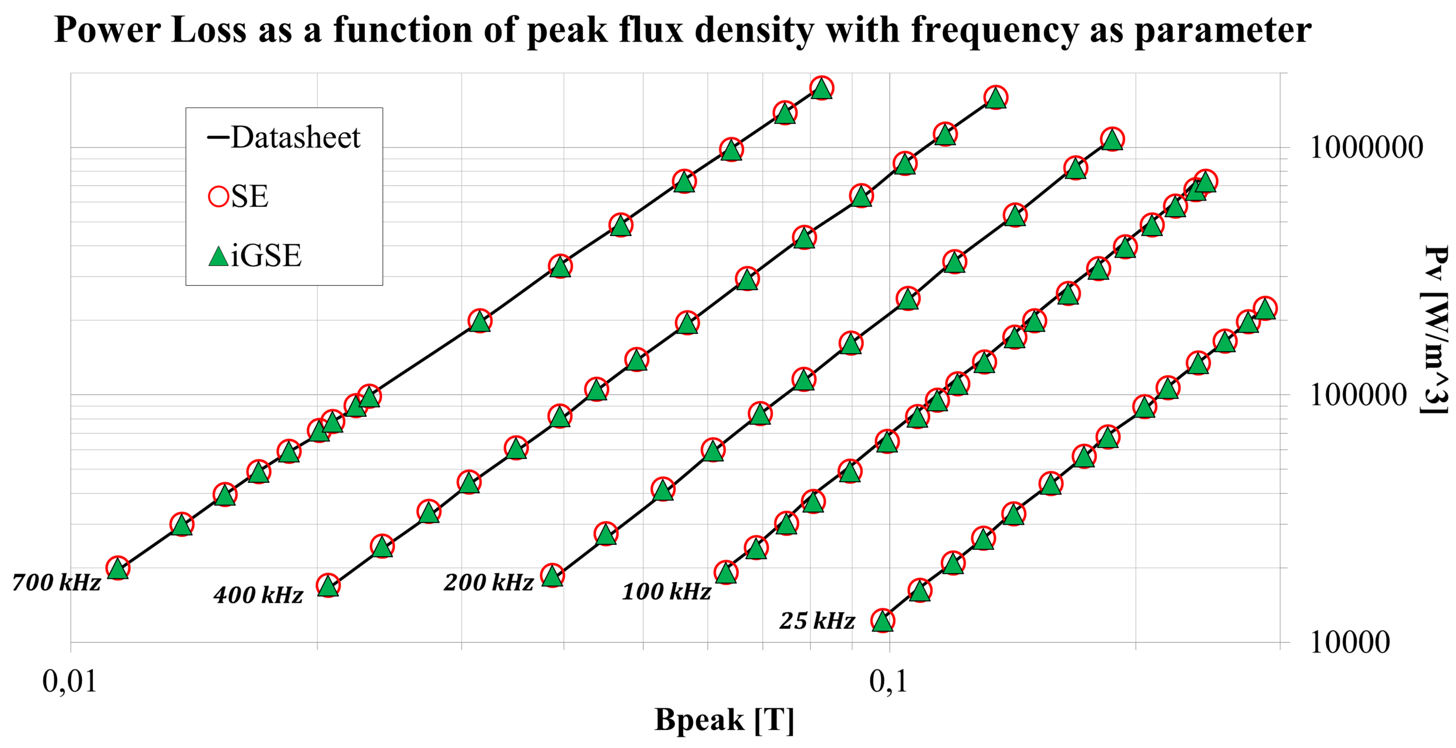

Figure 1. Preliminary validation of theoretical model for unsaturated sinusoidal supplying- 3F3 ferrite at 100° C

Steinmetz Equation (SE) :

$$\overline{P_v(t)} = kf^{\alpha}\hat{B}^{\beta}$$

Improved Steinmetz Equation (iGSE) :

$$\overline{P_v(t)} = \frac{1}{T}\int_0^T k_i\left|\frac{dB}{dt}\right|^{\alpha}(\Delta B)^{\beta-\alpha}dt$$

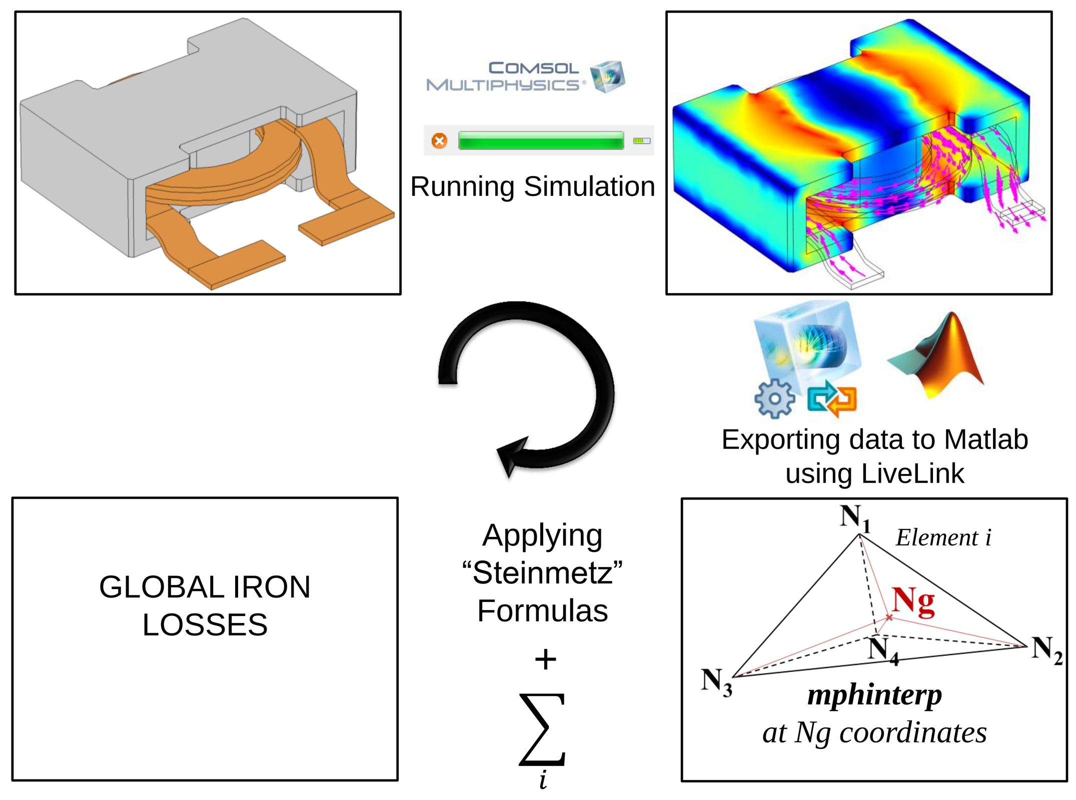

Figure 2. Process of the implemented method using COMSOL Multiphysics with MATLAB Livelink.

APPLICATION & RESULTS

- Coupling Electrical Circuit with FEM
- Taking into account 3D Effects and Magnetic non-linearity
- Local Magnetic flux density and Iron losses distribution
- Global Iron Losses – Comparison with classical calculations

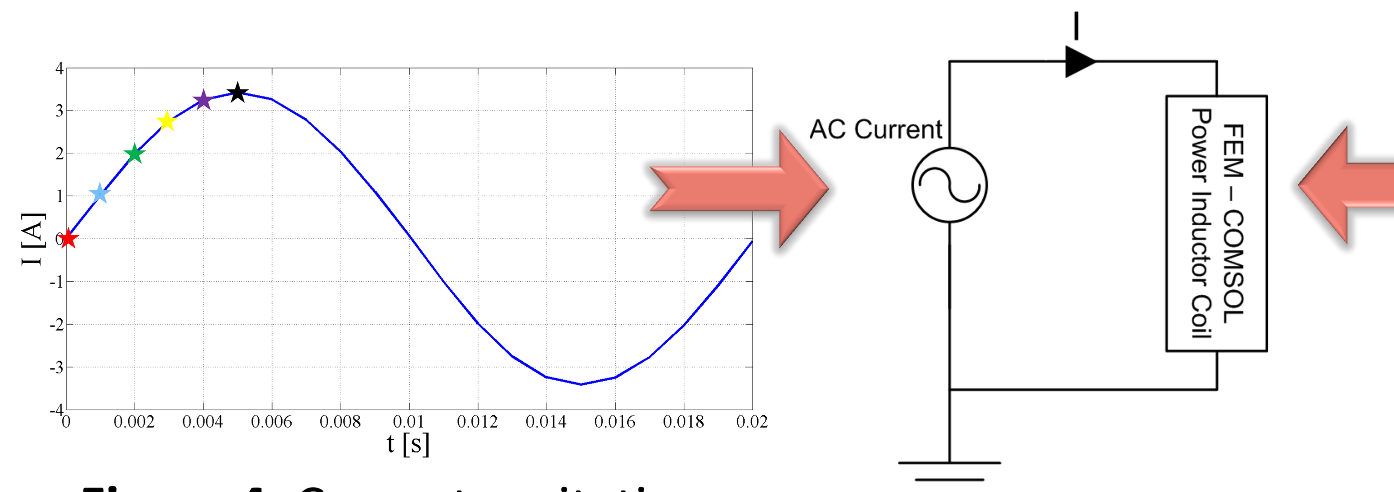

Figure 4. Current excitation waveform and coupling schematic

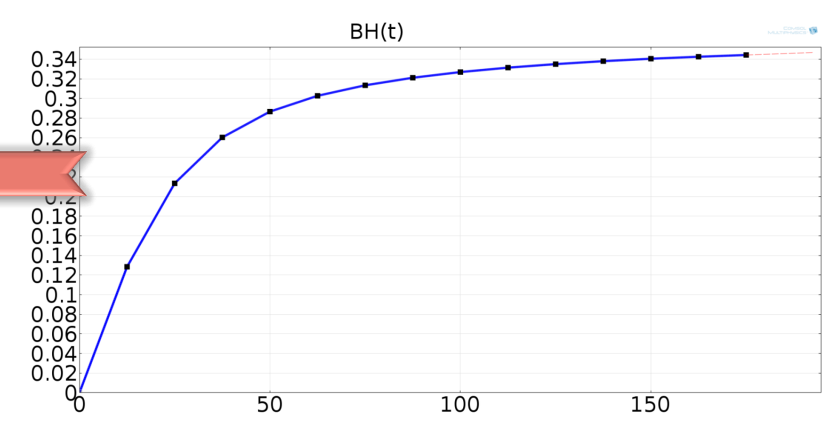

Figure 3. Ferroxcube 3F3 ferrite BH curve

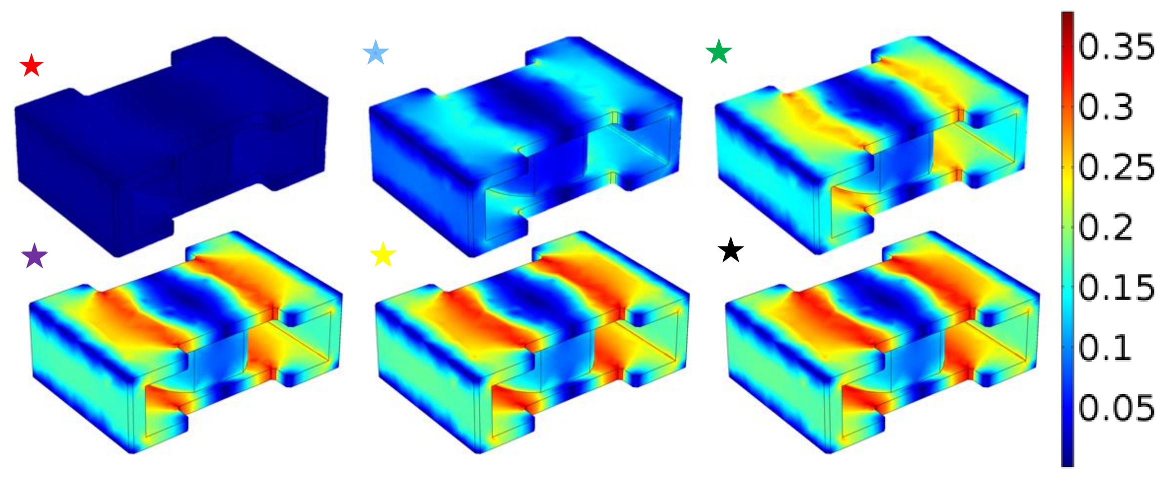

Figure 5. Magnetic flux density spreading inside the iron core at different time

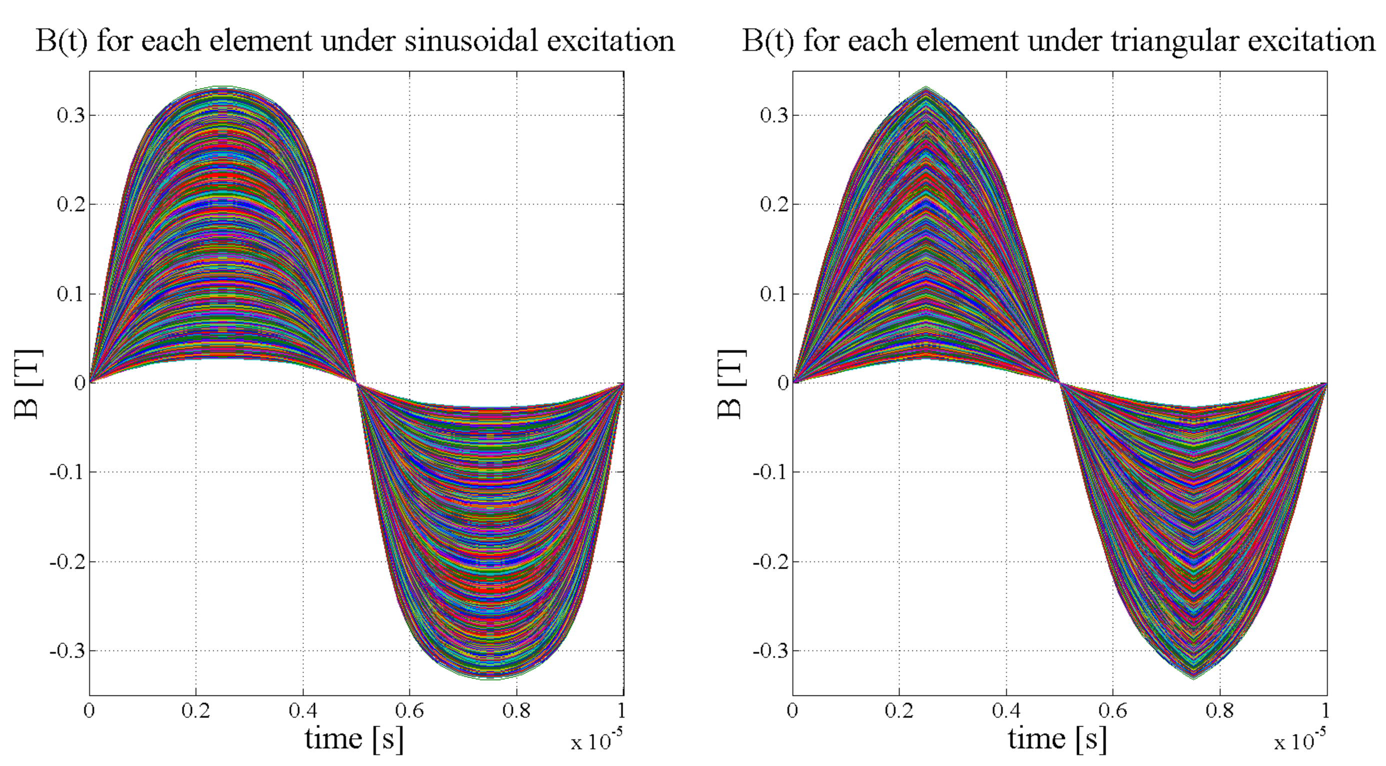

Figure 6. Left – 100 kHz sinusoidal current supplying
Right - 100 kHz triangular current supplying

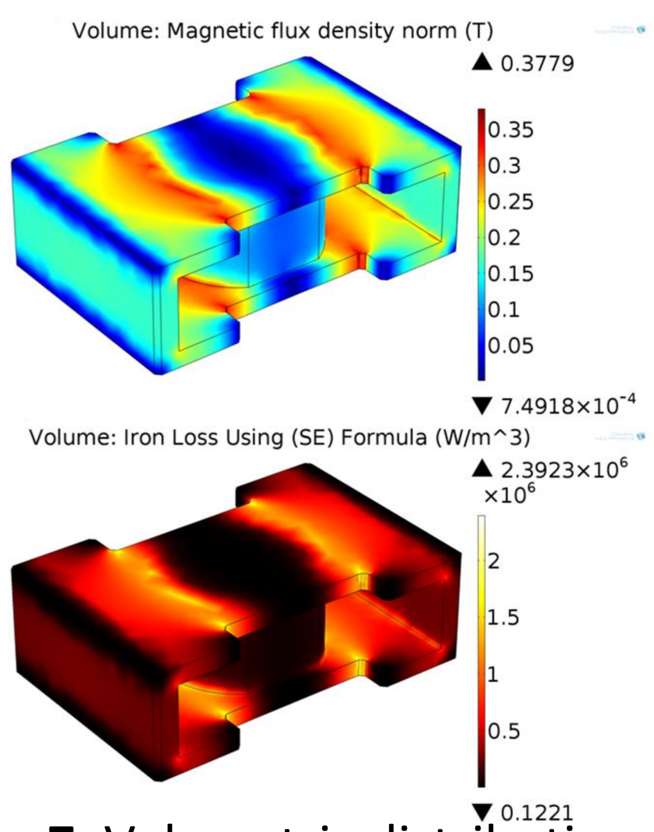

Figure 7. Volumetric distribution : magnetic flux density and losses

Current Waveforms	Sinusoidal	Triangular
(SE) : $kf^{\alpha}\widehat{B_{th\_ave}}^{\beta}V_{tot}$	394W	394W
(iGSE) : $\left(\frac{k_i(\Delta B_{th\_ave})^{\beta-\alpha}}{T}\int_0^T\left|\frac{dB_{th\_ave}}{dt}\right|^{\alpha}dt\right)V_{tot}$	394W	360W
(SE1 + SE2) : $\sum_{n=1}^{N_{area}} kf^{\alpha}\widehat{B(n)_{th\_ave}}^{\beta}V_{tot}$	120W	120W
(iGSE1 + iGSE2) : $\sum_{n=1}^{N_{area}}\left(\frac{k_i(\Delta B(n)_{th\_ave})^{\beta-\alpha}}{T}\int_0^T\left|\frac{dB(n)_{th\_ave}}{dt}\right|^{\alpha}dt\right)V_{tot}$	120W	108W
(3DSE) : $\sum kf^{\alpha}\widehat{B_{elem}}^{\beta}V_{elem}$	113W	113W
(3DiGSE) : $\sum\left(\frac{k_i(\Delta B_{elem})^{\beta-\alpha}}{T}\int_0^T\left|\frac{dB_{elem}}{dt}\right|^{\alpha}dt\right)V_{elem}$	111W	95W

Table 1. Results of global losses from classical approaches (red) and our new approach (green)

CONCLUSION

- New method presented here allows taking into account with a good accuracy, 3D geometric effects in iron losses calculation.
- Those effects could have a manifest contribution.
- Having a good knowledge of electromagnetic losses is primordial to thermally design a magnetic componen

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