

Embedded multilevel optimization for nonlinear time-stepping mesh-based reluctance network

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Introduction

The present work proposes a methodology for electrical machines design. It is based on the use non-linear reluctance network (RelNet) and multilevel surrogate based optimization via Space Mapping technique:

The non-linear reluctance network is solved by computing the meshes magnetic flux and its topology is automatically updated for each rotor position.

Space Mapping (SM) is used to couple linear and saturated models in an optimization procedure by means of two techniques: Radial Output Space Mapping and Embedded Space Mapping.

Axial flux electrical permanent magnet machine modeling

Machine double rotor/ simple stator (AFPM)

2D equivalent model linearization

2D linearized AFPM

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II. Reluctance network



V. Multilevel Optimization (ROSM/ ESM)

Objectif : Couple Saturated and non saturated model in an optimization procedure in order to minimize global optimization simulation time

V. 1. ROSM



III. Non-linear mesh-based resolution

Linear mesh-based model

$$(\mathbf{F}_{mm}) - [\mathbf{S}] [\mathbf{R}] [\mathbf{S}]^{\mathrm{T}} (\Psi^{\mathrm{L}}) = 0 \quad \bigoplus \Phi = [\mathbf{S}]^{\mathrm{T}} \Psi |_{\Phi}^{\Psi:}$$

Non-linear system

 $f(\Psi) = (F_{mm}) - [S][C_g]H([S]^T \Psi^{NL} Section^{-1}) = 0$

N-R algorithm

 $\Psi_{k+1}^{\mathbf{NL}} = \Psi_k^{\mathbf{NL}} - \lambda . J(\Psi_k^{\mathbf{NL}})^{-1} . f(\Psi_k^{\mathbf{NL}})$

Torque ripple

 $\Gamma = R_{eq} \Re B_n . H_t . dS$

Ψ: Meshes flux Φ : Edges flux [S]: Structure matrix [R]: Reluctances matrix F_{mm}: Magnetomotive forces [C_g]: Geometrical constant matrix H: Magnetic field function: H(B) B_n : Normal flux density H_t : Tangentiel Magnetic field

l/w≯

 $\mathbf{\hat{f}}_{b2}$

Periodic boundary conditio

• **f**_{b1}

Residual vector:

$R_{v} = [f(x_{1}) - C(x_{1}) \quad f(x_{2}) - C(x_{2}) \quad \mathbf{K} \quad f(x_{n}) - C(x_{n})]$

Weight factors:

$$\Phi.w = R_v \qquad \Phi_{ih} = \exp(-c \|x_i - x_h\|_2^2)$$

$$V.2. ESM$$

$$\downarrow V.2. Uncertainty (1)$$

$$\downarrow V.2. ESM$$





Conclusion

> A reliable tool dedicated to the modeling of machine based on the conventional reluctances network and multilevel optimization is presented.

Two SM techniques are presented to couple the saturated and linear models in order to reduce the computation time and to converge to the most accurate solution. Under:

 $\begin{vmatrix} Fem_{BS} \le 200 \text{ (V)} & Fem_{HS} \le 260 \text{ (V)} \\ J \le 9 \text{ (A.mm}^{-2} \text{)} \end{vmatrix}$

 $\left[\Gamma_{BS} = 100 \,(\text{N.m}) \,\Gamma_{HS} = 33.3 \,(\text{N.m})\right]$



