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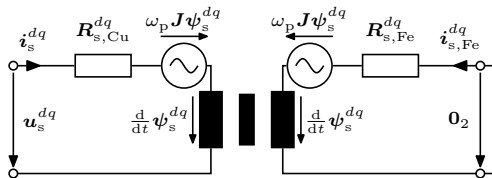
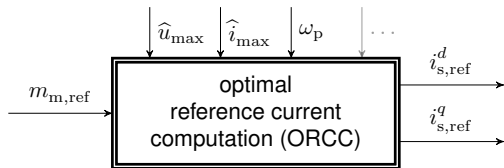
Generic loss minimization for nonlinear synchronous machines by analytical computation of optimal reference currents considering copper and iron losses

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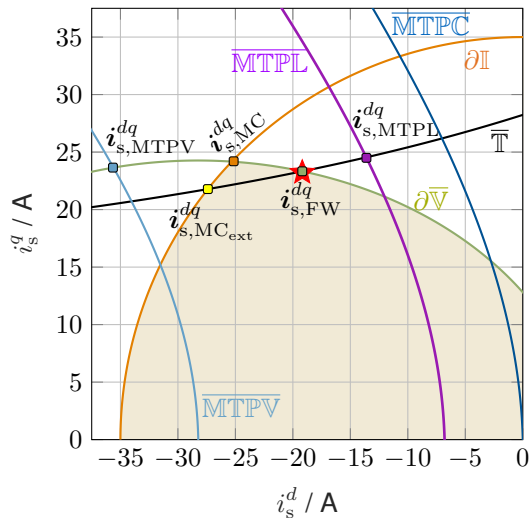
Problem Formulation



- Only feasible reference currents $i_{s,ref}^{dq} \in \mathbb{S} := \left\{ i_s^{dq} \in \mathbb{R}^2 \mid \|u_s^{dq}(i_s^{dq})\| \leq \hat{u}_{max} \wedge \|i_s^{dq}\| \leq \hat{i}_{max} \right\}$
 - Considering copper and iron losses $p_{m,L} \propto (i_s^{dq})^\top R_{s,Cu}^{dq} i_s^{dq} + (i_{s,Fe}^{dq})^\top R_{s,Fe}^{dq} i_{s,Fe}^{dq}$
 - Magnetic saturation and cross-coupling effects
- Nonlinearities: $\psi_s^{dq} = \psi_s^{dq}(i_s^{dq})$, $R_{s,Fe}^{dq} = R_{s,Fe}^{dq}(i_s^{dq}, \omega_p)$ **NIMO: Maybe adding fig. nonlin flux maps**
- Analytic computation of nonlinear optimization, e.g. MTPL $f = p_{m,L}$

$$i_{s,ref}^{dq} := \arg \max_{i_s^{dq} \in \mathbb{S}} -f(i_s^{dq}) \quad \text{s.t.} \quad \text{sign}(m_{m,ref}) = \text{sign}(m_m) \wedge |m_m| \leq |m_{m,ref}|$$

Methodology



Online Linearization & reformulation as quadric

$$\mathbb{Q}_A := \{ \mathbf{i}_s^{dq} \in \mathbb{R}^2 \mid (\mathbf{i}_s^{dq})^\top \mathbf{A} \mathbf{i}_s^{dq} + 2 \mathbf{a}^\top \mathbf{i}_s^{dq} + \alpha = 0 \}$$

$$\Rightarrow \partial \mathbb{I}, \partial \bar{\mathbb{V}}, \bar{\mathbb{T}}, \text{shaded } \bar{\mathbb{F}} := \bar{\mathbb{V}}(\hat{u}_{s,\max}) \cap \mathbb{I}(\hat{i}_{s,\max})$$

Optimization & reformulation as quadric

$$\mathbf{i}_{s,\text{ref}}^{dq} := \arg \max_{\mathbf{i}_s^{dq} \in \mathbb{S}} -f(\mathbf{i}_s^{dq}) \quad \text{s.t.}$$

$$\text{sign}(m_{m,\text{ref}}) = \text{sign}(m_m) \wedge |m_m| \leq |m_{m,\text{ref}}|$$

$$\Rightarrow \bar{\mathbb{MTPC}}, \bar{\mathbb{MTPL}}, \bar{\mathbb{MTPV}}$$

Intersection of two quadrics (analytic)

$$\mathbf{i}_{s,X}^{dq} := \mathbb{Q}_A \cap \mathbb{Q}_B, \quad X \in \{ \text{MTPL}, \text{MC}, \text{FW}, \dots \}$$

Prioritization of intersection $\Rightarrow$ ★ $\mathbf{i}_{s,\text{ref}}^{dq}$

Simulation Results

