ITN ENERGY-SMARTOPS WORKSHOP "Optimization to provide energy savings by better integration of operations across the process-mechanical-electrical interfaces", LADENBURG, GERMANY, 22-24 Oct 2013.

Energy-SmartOps Integrated Control and Operation of Process, Rotating Machinery and Electrical Equipment

Assessment of steady-state losses in electrical drives

Giampaolo Torrisi, Dr. Sebastien Mariethoz, Prof. Roy Smith

Automatic Control Laboratory – ETH Zurich

Introduction

Field Oriented Control	Dynamic performance
Constant nominal flux	Non-optimal for losses
Model with linear inductances	Sufficient for basic control

A non-linear model for the inductances is necessary to optimize losses

Induction Motor modeling

Model with linear inductances

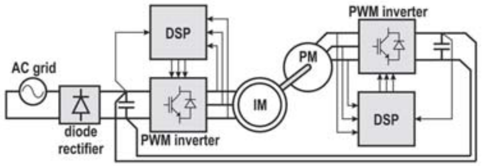
$$\dot{\boldsymbol{x}}^f = A_c \boldsymbol{x}^f + B_c \boldsymbol{u}^f + A_{sc}\omega_s \boldsymbol{x}^f + A_{rc}\omega_r \boldsymbol{x}^f$$
$$\dot{\boldsymbol{x}}^f = [\psi_{r\alpha} \quad \psi_{r\beta} \quad i_{sd} \quad i_{sq}]'$$
$$\boldsymbol{u}^f = [u_{s\alpha} \quad u_{s\beta}]'$$

Needs an accurate model

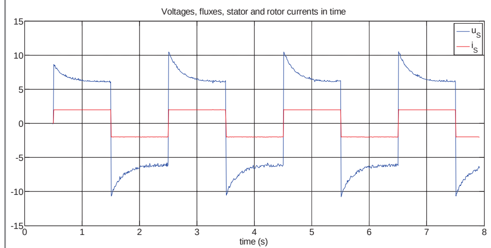
- Unavailable from manufacturer
- Theoretical Jiles-Atherton relations
- Experimental evaluation

Experimental test for saturation

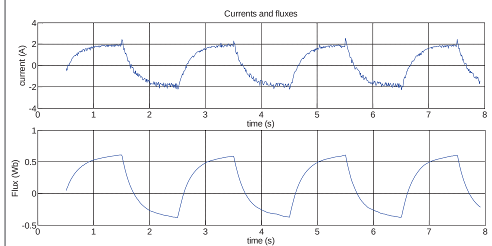
Experimental set-up



i_{sd}	Alternating I_{ref} or $-I_{ref}$
i_{sq}	0 (no torque)

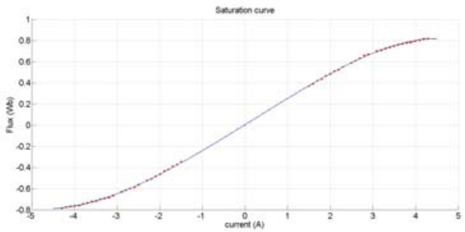


$$\psi_s = \int_0^t (u_s - R_s i_s)\, dt \qquad i_H = i_s - \frac{\frac{d\psi_s}{dt}}{R_r}$$



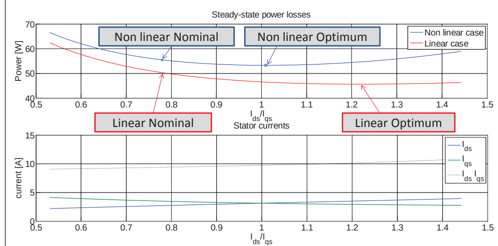
Steady-state optimal currents

Inductances with saturation effect



We assume L_r and L_m to be proportional to L_s

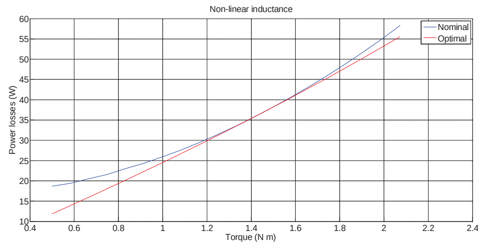
Optimization of stator currents



- up to 21% losses mismatch with linearity
- 4% improvement assuming non-linearity
- 3.5% more losses if linear optimum was implemented instead of non-linear one

Improvements in efficiency

Losses as a function of the torque



Improvement in drive efficiency:

- Rated power: 0.3 – 1.2%
- Low power, 4 - 16%

Future work

- Real-time control of stator currents to achieve dynamically theoretical savings
- Capability to optimally control varying loads known in advance
- Take in account hysteresis and iron losses

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme PITN-GA-2010-26940

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

energy smartOps

Motor on test: Baldor EM3546, 750 W - 1 hp, 115 V, 60 Hz, 2 pole pairs. Nominal Torque = 2.073 Nm