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

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## 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

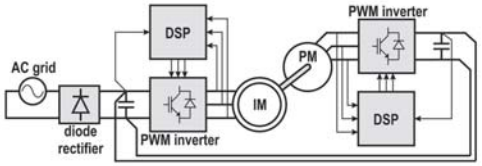
$$\dot{\boldsymbol{x}}^f = A_c\boldsymbol{x}^f + B_c\boldsymbol{u}^f + A_{sc}\omega_s\boldsymbol{x}^f + A_{rc}\omega_r\boldsymbol{x}^f$$
$$\dot{\boldsymbol{x}}^f = [\psi_{r\alpha} \quad \psi_{r\beta} \quad i_{sd} \quad i_{sq}]'$$
$$\boldsymbol{u}^f = [u_{s\alpha} \quad u_{s\beta}]'$$

### Needs an accurate model

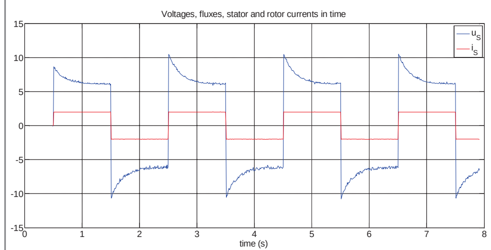
- Unavailable from manufacturer
- Theoretical Jiles-Atherton relations
- Experimental evaluation

## Experimental test for saturation

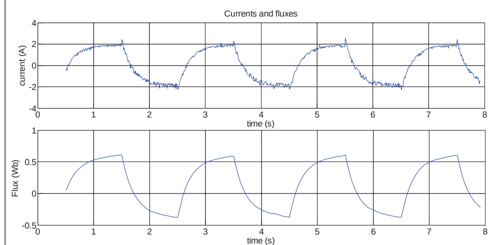
### Experimental set-up




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

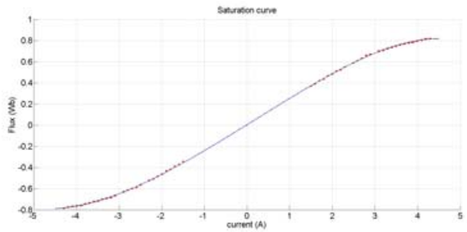



$$\psi_s = \int_0^t (u_s - R_s i_s)\,dt \qquad i_H = i_s - \frac{\frac{d\psi_s}{dt}}{R_r}$$



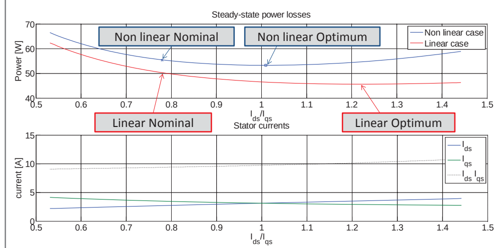

## Steady-state optimal currents

### Inductances with saturation effect




We assume $L_r$ and $L_m$ to be proportional to $L_s$

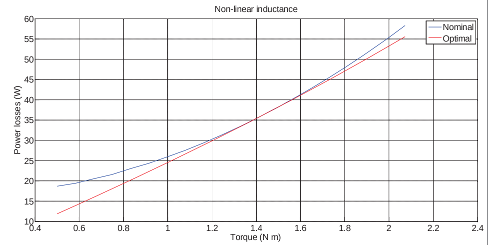
### Optimization of stator currents




- 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

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