Field Oriented Sensorless Control of Traction Machines

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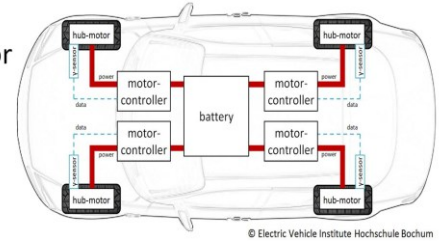
Introduction

There are various methods to integrate an electric drive in a vehicle such as

- Central motor
- Axis motor
- Hub motor



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In a research project of the the University of Bochum, we use hub motors because this

- allow us to save space, for example to use for the loading area
- allow active torque vectoring
- increases the efficiency
- reduces the number of parts
- ….

Disadvantages of hub motors

- High undamped masses
- Higher costs
- Difficulties in wiring
- ….

Why sensorless control?

For high quality control of PMSM a position angle is needed, so normally in case of hub motors 4 position sensors are needed. But:

- Sensors are expensive
- Signal transmission can be difficulty due to the parallel power lines (differential signal transmission is needed)
- Cables require limited space

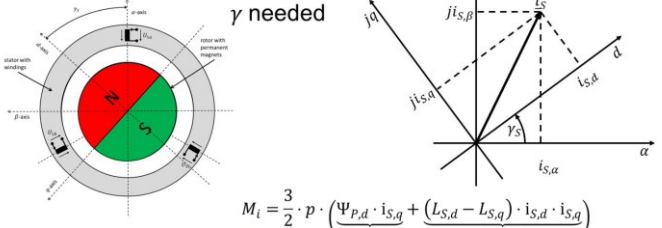
Advantages of sensorless control

- If sensorless control can be used, the cost for the sensors and the signal transmission do not apply any longer
- Also less parts mean a less error rate
- ….

Field Oriented Control

For easy and high quality control, sizes of the stator field has to be converted into rotor sizes.

$X_a, X_b, X_c \rightarrow \underbrace{X_\alpha, X_\beta}_{\gamma \text{ needed}} \rightarrow X_d, X_q$



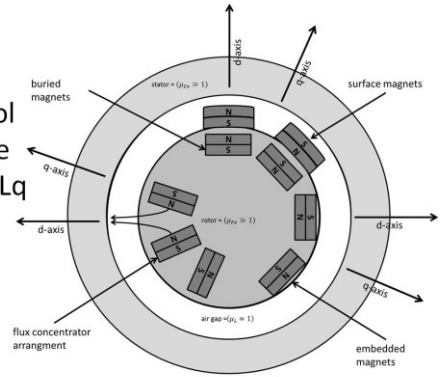
$$M_i = \frac{3}{2} \cdot p \cdot \left(\underbrace{\Psi_{P,d} \cdot i_{S,q}}_{Term\,1} + \underbrace{\left(L_{S,d} - L_{S,q}\right) \cdot i_{S,d} \cdot i_{S,q}}_{Term\,2} \right)$$

Principles of Sensorless Control

- Sensorless do not realy mean sensorless, but instead of additional sensors like a incremental- or a hall-sensor are only the already existing current sensors are used
- 2 basic methods are existing
  - Evaluation of asymmetries in the machine design by impressing and analysing of high-frequency currents
  - Integration of magnetic flux

Assymetries in electrical machines

Best machine design for use of sensorless control is a big difference between Ld and Lq



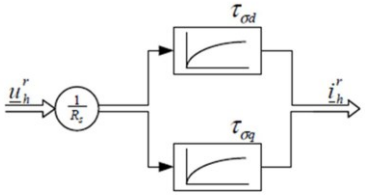
High frequency signal injection

A method which is relative easy to implement and can be used with standard hardware is discripted here

- The method is based on impressing a rotating voltage space vector with a constant amplitude
- Different feedback in the current response due to different inductances can be measured
- The angular postion can be gained from the current response

Simpliefied high frequency model

- For high frequencies at least a decade about the break frequencies R_S can be neglected



- Band pass filter is needed to filter out the fundamental current and the harmonics

Steps to get the rotor angle

- To extract a term which is only a function of Ld, Lq the signal must be high pass filtered in a coordinate system which is synchronous with the test signal.
- There will always be a non calculable phase shift based on secondary effects in the machine and the inverter which make it necessary to re-determine for every combination of machine and converter

Integration of magnetic flux

- Is based on the easy to measure phase currents and the known phase voltage commands
- L and R must be known
- $\Psi_{p\alpha} = \int (u_{s\alpha} - R * i_{s\alpha})dt - L * i_{s\alpha}$
- $\Psi_{p\beta} = \int (u_{s\beta} - R * i_{s\beta})dt - L * i_{s\beta}$
- $\gamma = \tan^{-1}\left(\frac{\Psi_{p\beta}}{\Psi_{p\alpha}}\right)$

Combination of both rotor angle estimation methods

Because a traction drive is not as dynamic as an industrial drive switching between the methods can be done by an easy to design two point regulator

Conclusion

- 2 generally known methods in the theory can be combined practical
- High-frequency fluctuations can be filtered out for automotive application due to high inertia
- Necessary expenses for adaption on a single system of machine and inverter do not matter due to high volumes in the automotive sector

Thank You

Questions

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