Simulation of Auxiliary Drives in Motor Vehicles

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SYNOPSIS

Modern motor vehicles consist of many electrical auxiliary drives. The range of the application area of these drives reaches from comfort functions like electrical window lifts, seat and mirror adjustment up to the use as ancillary units in the engine compartment.
In this lecture an established electromagnetic motor for seat adjustment is presented and fully simulated with Ansoft Maxwell V12. The operating motor behavior is derived with the aid of the transient field simulation and compared with the measured results. The necessary information for the model creation and the parameterization are generated by the analysis of motor geometry and material properties.
In the second part of this lecture an alternative auxiliary drive concept with brushless dc motor is presented. The development of this motor is also done by the tool Ansoft Maxwell V12. At this time all signs point to that mechanical commutated motors were sooner or later substituted by electrical commutated motors. Therefore the paper demonstrates the substitution off a PMDC motor with an EC motor.

1. INTRODUCTION

The Figure 1 shows an already established PMDC motor for seat adjustment. This motor is a typical example for an auxiliary drive in a car. The motor yoke length is l_{yoke} = 60 mm. In addition the maximum power is given with P_{mech} = 40 W for U = 14V system voltage. The motor has a stator with 2 poles and 8 rotor slots.

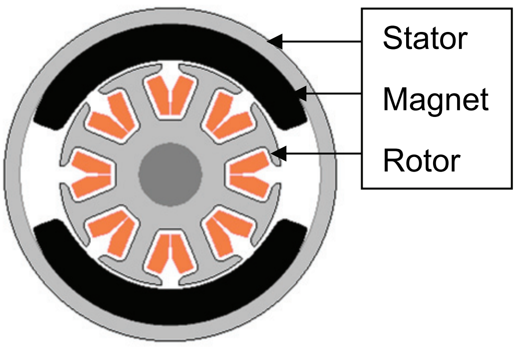

Figure 1: Schematic drawing of the PMDC motor

In the Figure 2 you can see the measured motor characteristic. On the x-axis you can find the motor torque. The left ordinate describes the motor speed (green line) and the right shows the motor current (red line). The maximum mechanical power is reached by 0,23 Nm. This linear motor behavior is typical for PMDC motors.

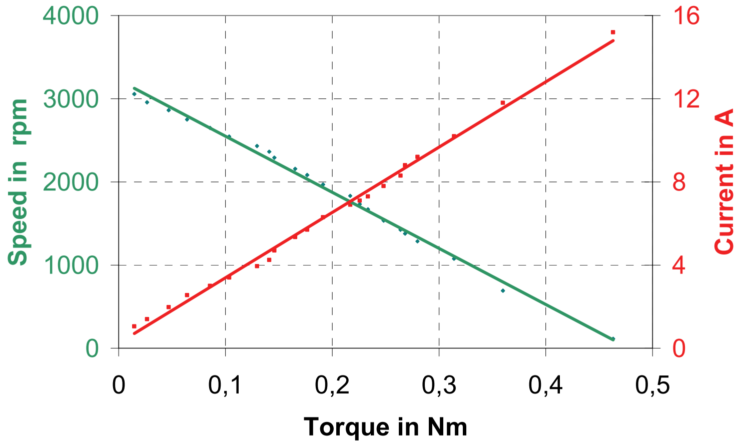

Figure 2: PMDC Motor characteristic measured

2. TRANSIENT SIMULATION OF THE PMDC MOTOR

The measured PMDC Motor is also simulated with Ansoft Maxwell V12 2D. A lot of boundary conditions consider a special point of view for the model creation. Those boundary conditions are for example non linear material parameters for the yoke and magnetic materials.
Another special requirement for the transient simulation is a match of the circuit model. This circuit model is shown in Figure 3 and is created with the Ansoft Maxwell Circuit Editor.

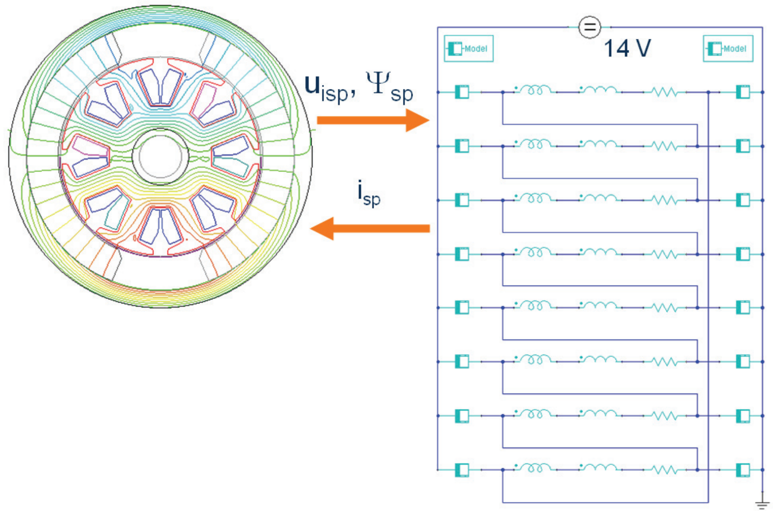

Figure 3: Transient motor model (2D field calculation linked with circuit diagram)

For the simulation of the brush commutator system the program included “commutator bar model” is used. The field calculation is computing the motor flux and the voltage and sending the information to the circuit model. Furthermore the circuit simulation calculates the winding current as a function of the rotor position.
The Figure 4 shows the measured and calculated motor torque. Both curves are under the aspect of the measurement accuracy nearly equal. As a result of the numerical simulation the motor behavior can completely described by the transient FEM modell.

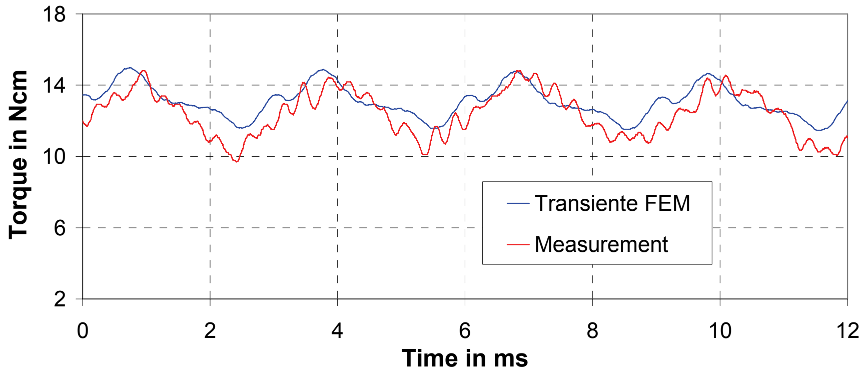

Figure 4: Measured and computed torque

3. DEVELOPMENT OF AN EC MOTOR

The group of EC motors is also called brushless dc motors (BLDC). To develop an EC motor there are several steps essential. The following flow chart shows possible motor configurations.

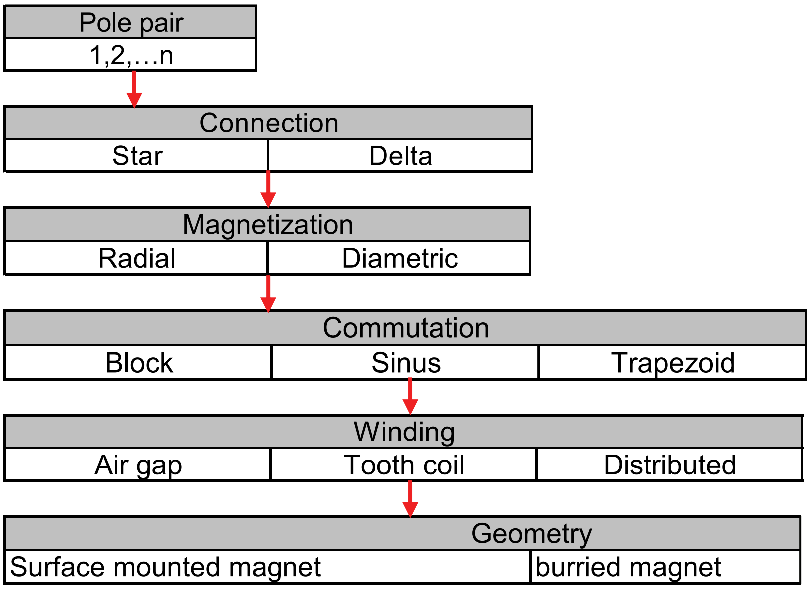

Figure 5: EC motor flow chart

The first step is to decide how many pole pairs the motor need. A lot of solutions are possible. The motor winding, which is in case of three phase motors in star- or delta-connection has to be chosen too. The magnetization of the magnets can be diametric or radial. It is dependent from the application, the magnet geometry and costs. Every EC motor needs an inverter for running. The inverter generates the corresponding voltage for block-, sinus- and trapezoid- commutation. For simple applications the focus is set on block-commutation, because it is usually the version with lower costs. After these steps the layout of the motor winding has to be developed. The winding depends on the production technology and has effects to the motor characteristics. The magnets can be surface mounted or buried. If there are unusual environmental conditions or high centrifugal forces a buried magnet solution is often used.

4. THE CREATED EC MOTOR

The developed EC motor has an inner rotor with two magnetic poles. The winding is in delta connection and positioned in the air gap. This slotless winding produces no cogging torque. The magnet material is NdFeB with a diametrical magnetization as a result of the block commutation. Apart from that radial magnetization also makes no sense, because it is difficult to magnetize a cylindrical magnet in this way. Finally the resulting rectangular air gap field creates a rectangular induced voltage and this requires a rectangular commutation for less harmonic content.

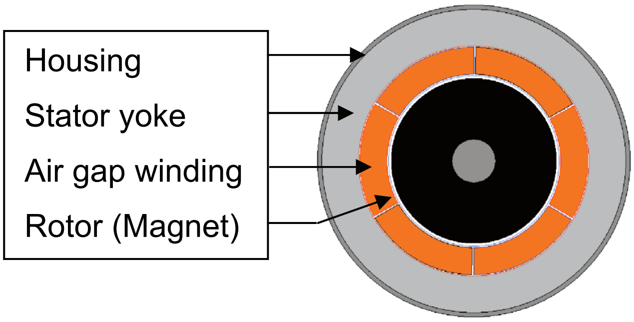

Figure 6: Schematic drawing of the chosen EC motor design

For the analytical development of the EC motor the equals (1) to (3) are used. These equals can be used, when the motor and inverter is considered as one system.

$$U_i = c \cdot \phi \cdot \Omega \qquad (1)$$

The induced voltage U_i is the product of the motor constant c, motor flux ϕ and mechanical speed Ω.

$$M_i = c \cdot \phi \cdot I_{dc} \qquad (2)$$

The motor torque is a function of the motor constant, the magnetic flux and the current I_{dc}. This current is nearly equal to the current that can be measured before the inverter on the DC side.

$$c = f(w) \qquad (3)$$

The motor constant c is a function of the winding. With the given working point and these three equations the necessary flux and the winding is fixed. The analytical appointed motor flux is 0.36 mWb and the number of winding turns of one phase is 60. The following motor data and the size of the magnet circuit are based on these parameters. As a result of these definitions and the material parameters the stator yoke and magnet length is 50 mm. The outer diameter is 36 mm and the magnet diameter is 19 mm.

5. NUMERCIAL CALCULATION AND OPTIMISATION OF THE EC MOTOR

The EC motor is also calculated with Ansoft Maxwell V12. The boundary conditions of the material parameters are assigned and nearly similar to the PMDC motor. An external circuit describes the motor winding and the voltage sources for the transient simulation.

In Figure 7 the rectangular voltage for one motor phase as seen from terminal is displayed. The second and third phases are analog, but the voltage is 120 degrees shifted.

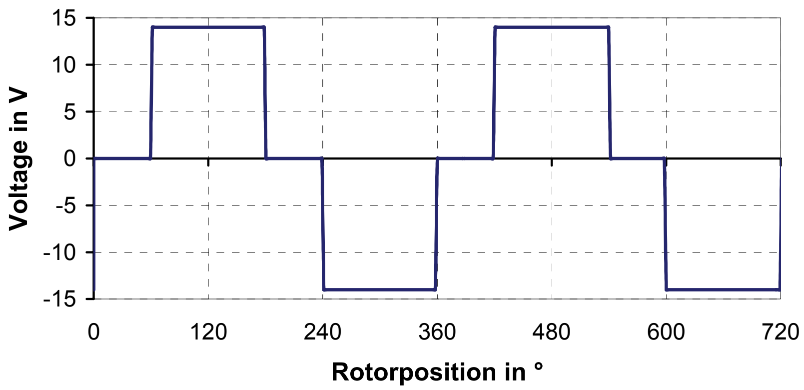

Figure 7: Voltage for one phase

The Figure 8 displays the motor induction and some exclusive flux lines. The maximum induction equals 1.7 Tesla and is positioned in the stator yoke. Analog to the two dimensional field calculations three dimensional ones are also done. The 3D field calculation is used to inspect effects on the end windings.

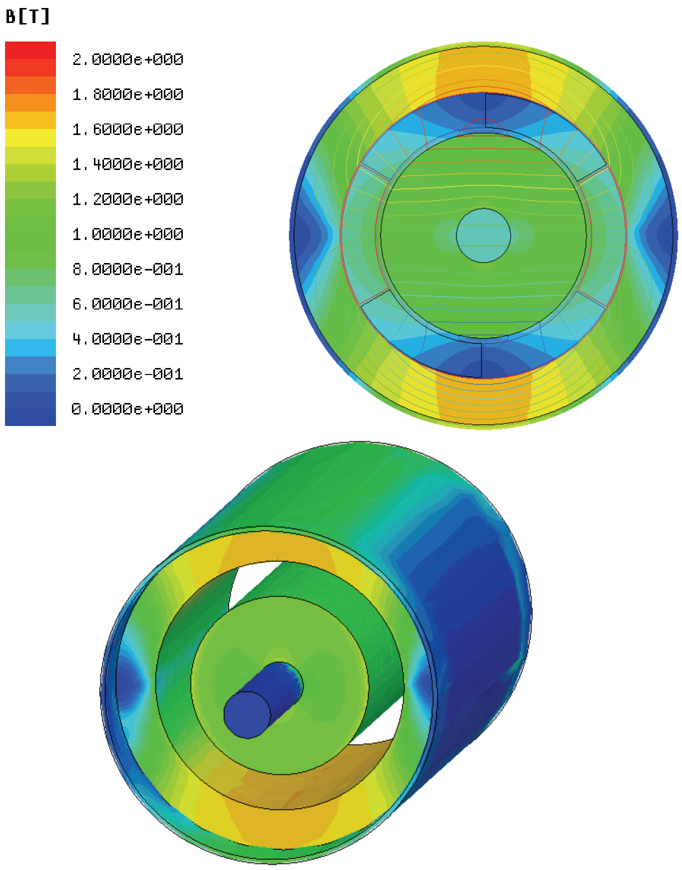

Figure 8: Calculated induction and flux lines with Ansoft Maxwell 2D and 3D

The motor curve, which is displayed in Figur 9 is computed with the transient solver of Ansoft Maxwell 12 2D. This natural curve of the EC motor has a linear characteristic. The idle speed is 3100 rpm and the calculated motor speed in the working point is 2900 rpm. The calculated motor characteristic is similar to the PMDC motor, but the speed drop over the torque is lower. In comparison to the PMDC motor, this EC motor has a higher efficiency and more power reserves.

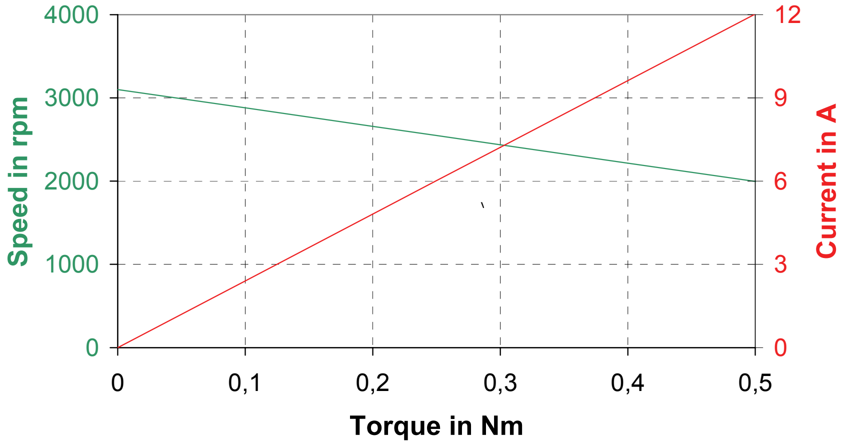

Figure 9: Calculated motor characteristic with the FEM model (Current on DC side)

6. SUMMARY

This lecture demonstrates the substitution of an EC motor for an established PMDC motor. For the simulation of both and optimization of the EC motor the program Ansoft Maxwell V12 was used. The comparison of the measurement and simulation results of the PMDC motor shows a good correlation between them. As a consequence of the usage of high energy magnets the volume of the EC motor is reduced up to 30%. Furthermore the motor efficiency could increase by 22%.

7. REFERENCES

1. G. Müller, K. Vogt, B. Ponick: Berechnung elektrischer Maschinen, Wiley-Vch, 2007

2. H.-D. Stoelting, E. Kallenbach, W. Amrhein: Handbook of Fractional-Horsepower Drives, Springer, Berlin 2008

3.. L. G. Cravero: Entwurf, Auslegung und Betriebsverhalten von dauermagneterregten bürstenlosen Motoren kleiner Leistung, ISLE Verlag, Ilmenau 2006