FH AACHEN UNIVERSITY OF APPLIED SCIENCES

MSS Lab **Part A: Lumped Element Simulation (Saber)** **Exercise 5: Electronic Motor Controller**		Prof. Dr.-Ing. G.Schmitz **Flugzeug- Elektrik und Elektronik**
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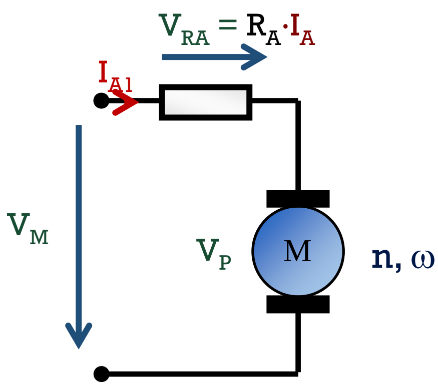
1 Introduction

In this part of the exercises the control of a DC-motor as well as the models for motors and transmissions are to be examined by means of the simulation system SABER

As background information concerning the DC motors you should remember the following:

We can regard a permanent excited DC-Motor using the following model for stationary operation:



We have now essentially two equations:

For the magnet wheel voltage (Back EMF): $V_P = k_1 \cdot \phi \cdot n$

For the torque: $M = k_2 \cdot \phi \cdot I_A$

Due to the equation for the mechanical power $P_{mech} = \omega \cdot M = U_0 \cdot I_A$ can be derived that there is only a constant discriminating k_1 and k_2:

$$k_1 = 2\pi \cdot k_2$$

For a DC- machine with a permanent magnet field excitation the magnetic flux is constant yielding the possibility to get included to the constants k_1 and k_2. Thus simplified equations are obtained:

For the magnet wheel voltage: $V_P = ke \cdot n$

For the torque: $M = kt \cdot I_A$

and the relation of *ke* and *kt*: $ke = 2\pi \cdot kt$

Attention: ke is given in Saber in V/rads^{-1}. So the usual ke has to be divided by 2π to get it in V/rads^{-1}. Thus we get the same numerical value for kt in Nm/A as for ke in V/rads^{-1}.

Due to the model, we have for the armature voltage measurable at the clamps:

$$V_M = V_P + I_A \cdot R_A$$

2 Execution of the exercises

2.1 Simulations

During the following exercises you have to design the circuit with SABER-Sketch and examine their function with the help of a transient analysis (course). Use *first* the elements and dimensioning suggestions given in the guidance. Accomplish own variations and observe the arising effects. Print out the achieved Status, the circuitry as well as the diagrams containing the courses.

2.1.1 Simulation of a close loop current control

Design a circuitry for a controlled current source. Use the following components:

- a Darlington- Transistor (Type 2N6388, SABER- Name: q2n6388),
- a 12V Voltage source
- a PWL- Voltage Source (PWL = piece wise linear). The parameter pwl is entered as paired values time, voltage, time, voltage, ….. It is suggested to use the following setting:

Time	Value
0	0
1	0
2	2
10	2
12	0
15	0
15.01	5
20	5
20.01	0

- an operational amplifier LF356 (set parameter “balance” to yes)
- a resistor for the measurement of the current of 100mΩ
- a DC permanent magnet motor “Motor, DC PM with brushdrop” (dc_pm2) with the following parameters:

Meaning	**Sabername**	**suggested value**	**Unit**
Motor inertia	j	10u	kgm^2
Torque constant	kt	5m	Nm/A
Back EMF constant	ke	5m	V/rad/s
Armature winding inductance	laa	1u	H
Armature winding resistance	ra	100m	Ω
Motor running friction	dft	8m	Nm

The voltage should be more positive at a1 than a2, so that the resulting values fort the engine speed are positive; the resulting values are indicated in rad/s, not in rpm. To obtain the values in rpm the values have to be multiplied by 60s/min and divided by 2π. Thus the total factor is about 10 (exactly: 9,55). In many cases it is also possible to select the results for display in rpm.

- some resistors for voltage dividers and/or protective circuit for the basis of the transistor

Dimension the circuit in such a manner that applying an input voltage of the control source of 1V a current flow of 1A to the motor is resulting.

Note: Remember to name the (important) nodes by yourself to avoid confusion afterwards. Switch on the display of essential parameters.

Now run the transient analysis including the DC-operation point analysis. Use the parameters: Tend: 25, Time Step: 0.01 (10ms).

Display the courses of the following signals: control voltage, Voltage across the clamps of the motor, current through the motor, engine speed. Save the circuitry and the courses.

2.1.2 Simulation with a controlled voltage source

Change the circuit in such a manner that setting the control voltage to 1V at the input, the motor is likewise operated with 1V (and for 2V -> 2V and so on)..

Display the courses of the following signals: control voltage, Voltage across the clamps of the motor, current through the motor, engine speed. Save the circuitry and the courses.

2.1.3 Simulation speed control

Extend the circuit now with a second motor with the same parameters as the first, the second motor however operating as a (Tacho-)generator. Feed the signal of the generator back to the circuit in a way that you get a speed control. Now make adaptions in such a manner that you will get an engine speed of 400 rad/s for a control voltage of 2V.

Display the courses of the following signals: control voltage, Voltage across the clamps of the motor, current through the motor, engine speed. Save the circuitry and the courses.

2.1.4 Simulation of the motors with a gearbox

Now add a gearbox to the design with a transmission ratio of 9.55 and display the speed at the outlet of the gearbox. Now add a mechanical load to it using “Torque velocity source pulse“. The parameters should be set to:

Meaning	**Sabername**	**suggested value**
Initial Torque	initial	0
Pulse Torque	pulse	50m
Rise time	tr	1m
Fall time	tf	1m
Delay time before first pulse	delay	4
Pulse width	width	5
Period	period	none (*opt*)

Alter your controlling voltage source to pwl [0,0,1,0,1.01,2].

Run the experiments now with

1. **the controlled current source**
2. **the controlled voltage source**
3. **the speed control circuit**

2.2 Finding the parameters of the real motor setup

Now find out all relevant parameters for the SABER models of the motor and the gearbox by performing measurements with the real hardware!

Note: the damping of the complete setup can be derived out of the measurement of the motor current in idle condition (without load).
Fill out the following table:

Meaning	Sabername	suggested value	Unit
Torque constant	kt		Nm/A
Back EMF constant	ke		V/rad/s
Total damping	-		Nm
Friction per motor	dft		Nm
Armature winding resistance	ra		Ω

2.3 Matching of Model and Simulation

Find out the value of the total inertia of the complete setup. To do this you should make experiments about the engine speed course when switching off the engine and compare this to the reality.

Inertia in total=_____________
Inertia per Motor (incl. Gearbox) = ________________

2.4 Simulation with the obtained parameters

Enter all the obtained parameters in SABER and do a simulation of the ready model.