Electric Drives and Machines Institute
Graz University of Technology

LABORATORY COURSE
CONTROL OF ELECTRIC DRIVES AND MACHINES
COURSE-NR. 431.312

Unit 2:

Control of DC-machine

Teaching goals
Compare real world measurements with simulation results. Check if expected behaviour, e.g. design criteria, meets the measurable one. Show that the more detailed model, compared to the transfer functions used for controller design, is able to give a proof for the proper functioning of the controllers.

In the lab
Apply current-, speed- and load reference steps and measure the system responses.

1 Structure

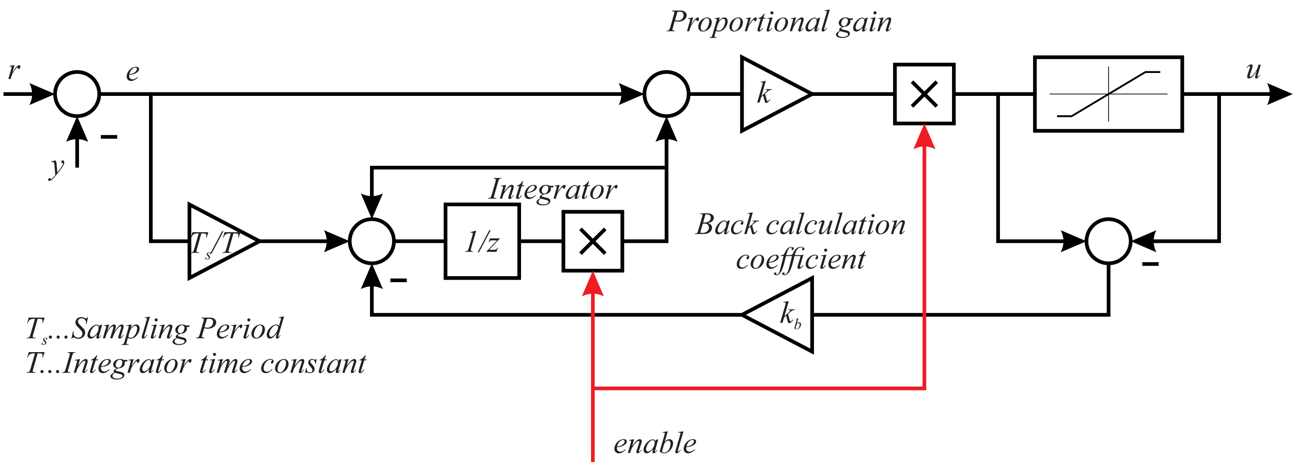

Figure 1: PI-Contoller

A PI-controllers z-transfer function is given by

$$C(z) = \frac{b_1 z + b_0}{z - 1} = b_1 \left[1 + \frac{(b_1 + b_0)}{b_1} \cdot \frac{1}{z - 1} \right] \tag{1}$$

Figure 1 shows the implemented controller structure. According to eqn. 1

$$\begin{aligned} k &= b_1 \\ \frac{T_S}{T} &= \frac{b_1 + b_0}{b_1} \end{aligned}$$

holds.

As long as the converter is turned off the integrator and the output is kept at zero to avoid integration of measurement offset.

Please deliver controller coefficients as struct *ctrl* for the current controller with fields

ctrl.i.k...proportional gain
ctrl.i.T...integrator time constant
ctrl.i.kb...back calculation coefficient

and with fields

ctrl.w.k...proportional gain
ctrl.w.T...integrator time constant
ctrl.w.kb...back calculation coefficient

for the speed controller.

If your back calculation scheme does not coincide with the one given in fig. 1, attach a sketch of it, to enable correct interpretation of your back calculation coefficients.

2 Experiments

Inspection of step responses of the controlled DC-machine.

	DC-machine	Induction machine
Nr.	i_{aref} A	n_{ref} rpm
1	$-1 \to 1$	0
2	$0 \to 10$	0
3	$10 \to 0$	0
4	$5 \to 10$	0
5	$0 \to 10$	1000
	n_{ref} rpm	i_{sqref} A
6	$0 \to 100$	0 or off
7	$0 \to 1000$	0 or off
8	$1000 \to 0$	0 or off
9	0	$0 \to -15$
10	1000	$0 \to -15$
11	$-2000 \to 2000$	break

Table 1: Experiments; x -> y stands for a setpoint step change from value x to value y; off means turned off converter; brake stands for the usage of the converter as a break chopper.

1. Inside the region of nonlinear converter behaviour.
2. Step out of the nonlinear region.
3. Step into this region.
4. Linear behaviour is expected, step response should look like it was designed for.
5. If system is linear, it should not matter if speed equals zero or 1000 rpm.
6. Linear behaviour is expected, step response should look like it was designed for. Adjust the speed step according to maximum armature reference current $n_{ref} < 30/\pi \cdot i_{amax}/k_\omega$ with $|i_{amax}| = 30$ A.
7. Speed controller output limit influences step response.
8. How does friction influence the step response in comparison to the preceeding experiment.
9. Step of load torque.
10. In the preceeding experiment frictional torque was supporting the speed controller, now the speed controller has to balance all of the load torque.
11. To show that the machine is able to work as a generator as well as a motor. This experiment offers a way to identify the moment of inertia of the induction machine.

3 Comparison

Beside the documentation of the control design the report for this unit should contain the following comparisons. Please keep in mind, that for the applied step changes the PI-controller should be able to bring the control error down to zero. So the interesting time interval for diagrams is very close around the step change.

3.1 Measured values

3.1.1 Current control

Normalise the reference value and the actual value of armature current to the interval [0 1]. Compare armature currents of experiments

- 1, 2 and 4
- 2 and 3
- 2 and 5

3.1.2 Speed control

Compare filtered rotor speed of experiments

- 7 and 8, normalise rotor speed to interval [0 1].
- 9 and 10, do not apply normalisation, subtract 1000 rpm from rotor speed of experiment 10.

3.2 Simulation vs. measurement

3.2.1 Current control

The interesting quantities for comparison of measurement and simulation are armature reference voltage, the current controllers output, and armature current (resp. armature reference current). Simulate the experiments 1, 2 and 4.
Since the speed control of the induction machine is not available for simulation yet, and a sufficient modelling of the frictional torque is very laborious use the following scheme for simulation.

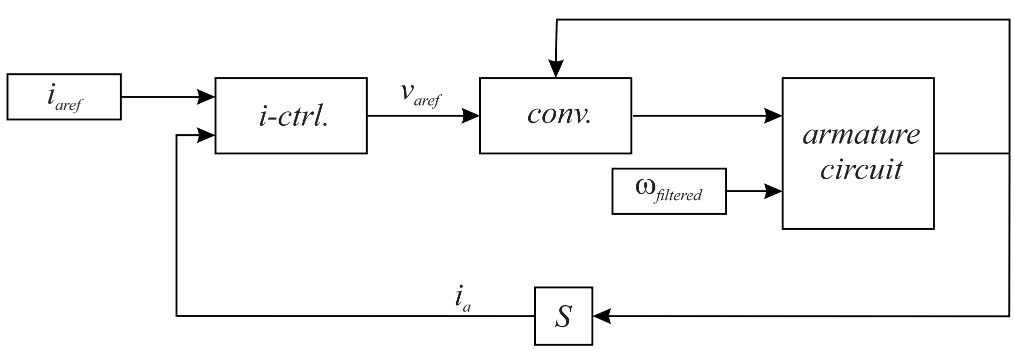

Figure 2: Simulation scheme for current control

The reference signal i_{aref} and the speed signal $\omega_{filtered}$ are the measured values imported from workspace. Manage that simulation output is produced at the same time instants as measured signals. The converter block has to incorporate a time delay of one sample period. If the pulse amplitude model is used, incorporate converter voltage drop dependent on armature current by a lookup table. If the pulse width modulation model with interlock time is used, consider voltage drop on IGBT and freewheeling diode.

3.2.2 Speed control

For this case the interesting quantities for comparison of measurement and simulation are armature reference voltage (the current controllers output), armature current, armature reference current (output of speed controller), filtered speed and reference speed.
Simulate the experiments 6, 7, 10 and 11.
Since the current control of the induction machine is not available for simulation yet, the mechanical system is cut through the middle of the torque transducer. Use the following scheme for simulation.

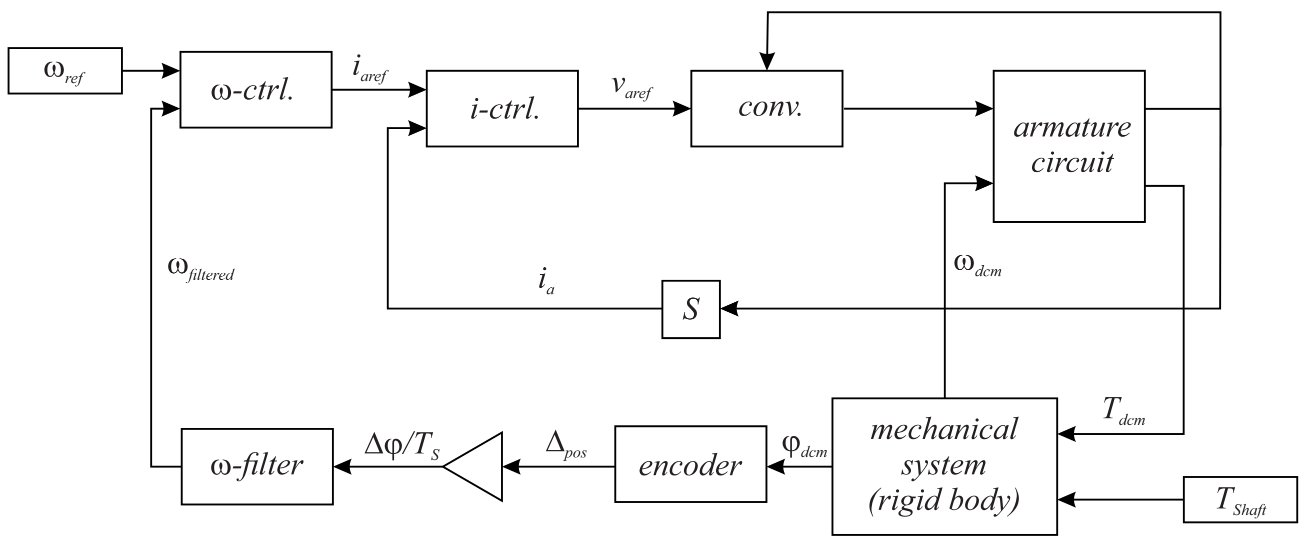

Figure 3: Simulation scheme for speed control

For the converter model applies the same as above. Input quantities are the angular reference speed and the measured shaft torque. The mechanical model consists of a rigid body (I_{dcm}) and the frictional torque ($T_{fric,dcm}$). Since the mechanical model is only a part of the whole system following approximations can be applied.

$$
\begin{aligned}
I_{dcm} &\approx 0.8 \cdot I_{total} \\
T_{fric,dcm} &\approx 0.92 \cdot T_{fric,total}
\end{aligned}
$$