Control of Electrical Drives

Home assignment A1: Speed Control with DC mchine

Introduction

This assignment aims at detailed simulation of a speed controlled DC motor. In the assignment several speed and current control methods will be studied when supplying an idealised load. Finally one of the speed control methods and one of the current control methods in combination with a 4-quadrant DC converter will be used to control the speed of a DC machine. There are 3 subtasks:

1. Speed control. P- and PI controllers for speed will be used with and without a torque source model.
2. Current control. Sampled and Direct modulation and current control methods will be applied to a 2- and 4-quadrant converter.
3. Full System. Any speed controller and any current controller of your choice that works with a 4-quadrant DC converter will be simulated with a DC motor.

The system you simulate under subtask 3 will be implemented in a laboratory assignment. Download the Zip-file "SED1" from the course homepage. Unzip and store all the files in your workning directory of Matlab."

Speed control

Open the Speed.mdl". The model contains all the elements you need to simulate some different speed control systems. On the top level you see the systems in figure 1.

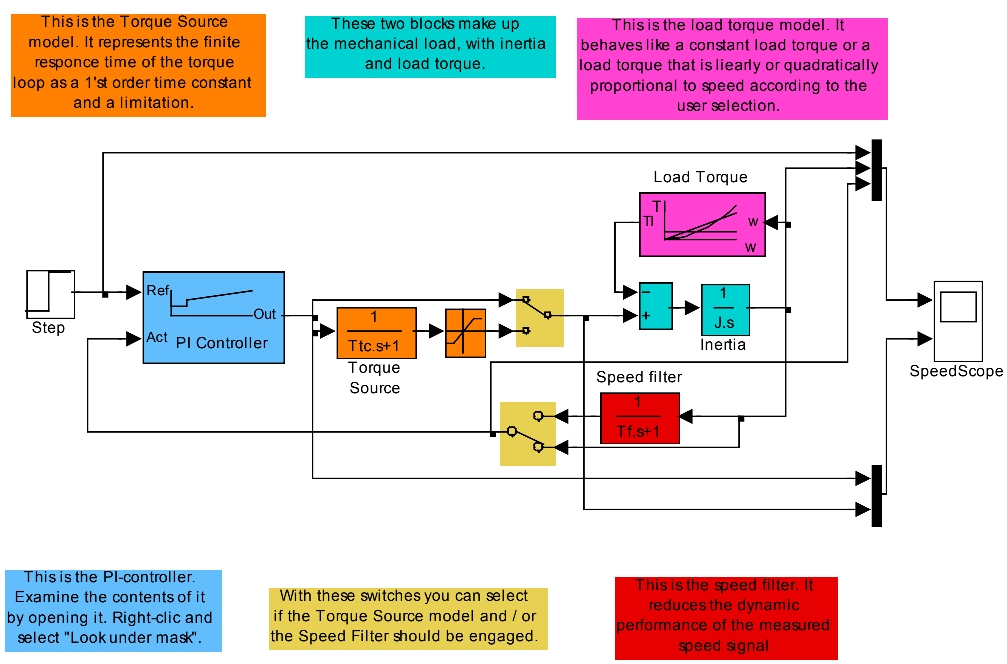


Figure 1. The topmost level of the Speed Control System.

You are going to investigate a speed control system with the following properties:

>> J=0.034; This is the inertia of the DC machine.

>> La=0.02; This is the inductance of the DC machine

>> Ra=2.5; This is the resistance of the DC machine

>> Udc=250; This is the DC link voltage we are going to use in the lab

>> Ts=0.001; This is the sampling time of the control system (T_s), which in this case is the same as the time constant of the torque source dynamics (T_{tc}).

>> Ttc=0.001; This is the time constant of the torque source dynamics (T_{tc}), which in this case is the same as the sampling time of the control system (T_s).

>> Tf=0.05; Filter time constant.

>> Tmax=round(10*(16+rand*4))/10; This is the maximum torque the torque source is able to. The maximum torque is expressed as a random function in the interval [16.0 ... 20.0], so you will have your personal value of this parameter.

Apart from these parameters and limitations, the controller and the speed filter need to be specified in detail.

The *Speed Controller* can be of P- or PI-type. A Controller Output limitation can be introduced; including an Anti Windup function that stops the Integration of the Controller Output exceeds the limits. All these settings are done by clicking on the PI controller block.

The *Torque Source* can be ideal or represented by a 1'st order time constant and a maximum torque limitation. You choose between ideal and the more realistic model by flipping the switch after the models.

The *Load Torque* is set by double clicking the load torque block and selecting the characteristic (which in this lab will be "constant"). Note that the speed setting is irrelevant in the "constant" case.

The *Speed Filter* is engaged by flipping the related switch.

The simulation time is set to 1 second. In the last case you may need to extend it to 2 seconds. This is done in the "*Simulation/Simulation parameters*" menu.

Table 1 Speed control cases to investigate.

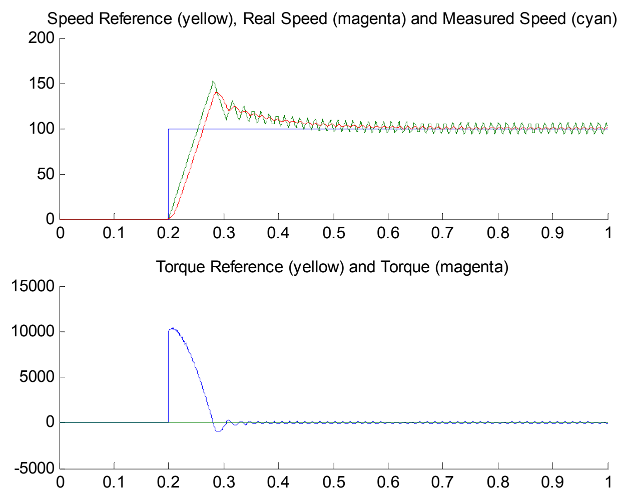
Case	Controller	Torque Source	Load Torque	Speed filter
1	P-controller No Limit / Anti Windup	Ideal	Tl=0 Nm	No
2	P-controller No Limit / Anti Windup	Delayed and limited. Ttc, Tmax		
3	P Controller No Limit / Anti Windup		Tl=10 Nm, constant.	
4	PI Controller No Limit / Anti Windup			
5	PI Controller Limit / Anti Windup			
6	PI Controller Limit / Anti Windup			Yes, Tf

Report requirements on this task

The report should contain your personal choice of controller parameters, with motivation, and comments to the results of the 6 different cases of table 1. The comments should be on aspects like maximum used torque, overshoot, stability, remaining errors etc, and related to the choice of parameters or controller type, controller limitation etc.

To each case, the plot from the simulation should be attached. Figure 2 suggests a way to arrange the presentation, but feel free to do it your own way. To get the plot from the "Scope" window in Simulink, to a "Plot" window in Matlab, just run the file "Plothelp" that can be downloaded from the same location as the simulation file. NOTE! With the Scope open, click the second left icon in the scope menu bar and select data "*history/save data to workspace/ScopeData*". Thereby the signals and settings of the scope will be stored to Workspace during the simulation and can be processed by "Plothelp".

<table>
<tr><td>Case</td><td>Choise of parameters with motivation, plot and comment</td></tr>
<tr><td>X</td><td>Your choise of parameters like Kp = ..., Ti = ...with motivation...



Your personal comment to the results of this case ...</td></tr>
</table>

Figure 2. One way to present the results of the different simulated cases ...

Current Control

Open the files "Current2Q" and "Current4Q". The "Playsound" file gives you a chance to listen to the sound a certain controller makes in the lab, of course requiring that your computer is rigged with loudspeakers etc. You are going to investigate two current control methods (sampled and direct) in two different converters (2-quadrant and 4-quadrant), i.e. 4 cases. Apart from the settings you made above, you need to set the Direct Current Controller tolerance band *di*. To start with, set it to

>> di=5;

but you will need to change it later.

The current reference is preset to 20 Hz, +/- 5 A. The load is preset to have a back-emf of 40 V. You will change these values during the simulation task.

Table 2 Current Control cases to investigate

Case	Circuit	Controller	Controller setting	Comment
1	2-quadrant (Default controller setting: Fixed frequency)	Sampled	Fast computer	Use deadbeat gain.
2			Slow computer	Use a gain that gives a stable step response.
3			Slow with Smith Predictor	Use deadbeat gain.
4			Slow with Smith Predictor Random modulation	
5		Direct		Select a hysteresis with that gives the same current ripple as with the sampled controller.
6		Either Sampled or Direct	-	Set the back emf to 0 V. Why does the current not become negative????
7	4-quadrant (Default controller setting: Fixed frequency and Symmetric)	Sampled	Fast computer	Reset 40 V back-emf before you proceed. Use deadbeat gain.
8			Slow computer	Select a gain that gives a stable step response.
9			Slow with Smith Predictor	Use deadbeat gain
10			Slow with Smith Predictor Random modulation	
11		Direct		Select a hysteresis with that gives the same current ripple as with the sampled controller.
12		Either Sampled or Direct	-	Set the back emf to 0 V. Why does the current become negative????

Apart from these tasks you are encouraged to play with the modulation and sound aspects. The best sound impression is made if you set the current reference constant, e.g. zero, and uses the “Playsound” command after a simulation according to:

>> Playsound(snd(:,1),snd(:,2))

Try out the sound of a fixed frequency, and of random modulation. Think of what you prefer. The fixed frequency has a “penetrating” pitch and can be annoying, but on the other hand it is clear and “clean”. The random modulation gives a “crunchy” sound that is easier to disregard in an otherwise noisy environment, but sound like “sand in the gearbox” which may be annoying to an engineering ear.

Report requirements on this task

The report should contain your personal choice of controller parameters, with motivation, and comments to the results of the 10 different cases of table 2. The comments should be on aspects like response time, stability etc, and related to the choice of parameters or controller type, controller limitation etc.

To each case, the plot from the simulation should be attached. Figure 3 suggests a way to arrange the presentation, but feel free to do it your own way.

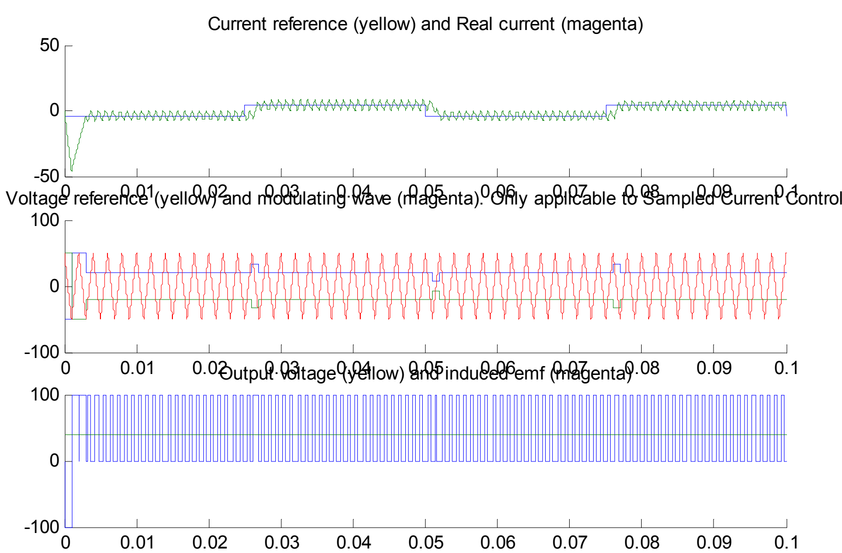
Case	Choise of parameters with motivation, plot and comment
X	Kp = ..., Ti = ... since ...  Comment ...

Figure 3. One way to present the results of the different simulated cases ...

Full System

Use the model “DCM”. This contains a DC machine model. Your task is now to put together a new model for a speed control system, which contains the DC machine and the necessary power electronic control system. You are free to do it as you prefer, but here is some advice:

1. Use the “Speed”-program, and save it under another name, like “FullSpeed” or whatever you like,

2. Select the torque source model, the torque summation point and the inertia model and use the menu-command “Create Subsystem”.
3. Open the new subsystem. It contains input nodes for torque reference and load torque and output nodes for torque and speed. Delete the contents except for the input and output nodes.
4. Copy the contents of the “Current4Q” model and paste it into the empty subsystem you just have created.
5. Delete the Load model and copy and paste the “DCM”-motor into the place where the load model was.
6. Connect all the input and output nodes to the proper places.
7. Voila – you now have a torque source and mechanical dynamics model representing the real control system in very good detail.

Table 3 Speed control cases to investigate with the full system.

Case	Controllers	Torque Source	Load Torque	Speed filter	Comment
1	• PI Speed Controller with Limit / Anti Windup • Current controller of your choice	Full	No	Yes, T_f	Run Case # 6 from Speed Control, but without load torque., just to check that your solution works.
2	• PI Speed Controller with Limit / Anti Windup • Current controller of your choice				Set the speed reference to a step to 400 rpm.

Report requirements on this task

The report should contain simulation plots and your personal comments, and in particular your analysis of the following two issues of case 2:

The current ripple. - Why is it biggest in the middle of the speed range when you use the sample controller.

The Torque. - Why do you loose torque in the end of the acceleration.

Student cooperation and reporting.

You are free to cooperate as much as you like, but you would hand in your own report. Your report will be unique even in the sense that you do not have the same maximum torque in your simulation as other students. Thus, use your friends - and the teachers of course, to understand what you are doing but deliver your own report.

Simulink

For those of you who have not used Simulink before, there is a good introduction available from the Simulink Help menu. Start Matlab, type “Simulink” at the command prompt, and select “Help/Simulink Help” from the Simulink Menu bar. The window that opens looks like in **Figure 1**. From there you will get a quick introduction to the software. Then, experiment on your own, and ask David or Mats if you run into trouble.

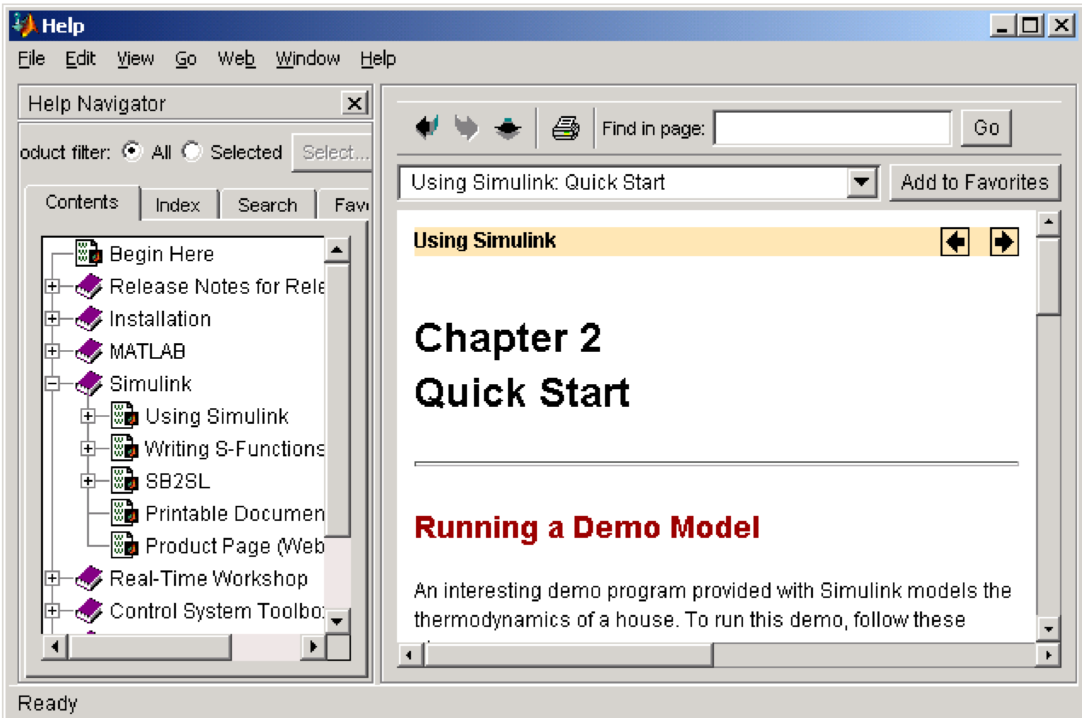


Figure 1 Simulink help window.

Dates and deadlines:

3/11, 24.00 h. The report should be handed in to Jonas or Mats. We want the report printed on paper, NOT as an e-mail. You will get it back with our comments before the lab. In case that the report is not good enough, you will have a chance later to upgrade it according to our recommendations.