

## Home assignment 3

### PMSM control with field weakening

#### Introduction

In this assignment you will study torque control of Permanent Magnet Synchronous Machines, and develop your own additional field weakening algorithm. The field-weakening algorithm is needed to limit the voltage requirement at high speeds. The general approach is described in the text book.

#### Vector control

The current control of a PMSM is almost identical to the one used for vector control of a generic three phase load. Use the program *PMSM1* to recognise the control system you studied in vector control of a generic three phase load and applied to active filter control. Use the following settings:

```
Rs=0.5;
p=6;
Lsx=0.003;
Lsy=0.003;
Psim=0.16;
Udc=250;
J=0.02;
di=1;
Ts=0.0002083;
```

Run the following cases:

CASE	References & settings	Simulation results	Your comment
1	$I_{sx}^*=0$ $I_{sy}^*=10\text{ A @ }0.005\text{ s}$ $I_{sy}=5\text{ A @ }0.05\text{ s}$ Sampled current control.	The “currents” window	The d-axis current is disturbed when the y-axis current changes fast. Why is that?  <i>Think carefully on the time interval where the disturbance takes place, and what vectors are involved before you answer.</i>
2	Same as case 1, but with DCC.	The “currents” window	The x-axis current is not disturbed in this case? How come, since there was a disturbance in the previous case?

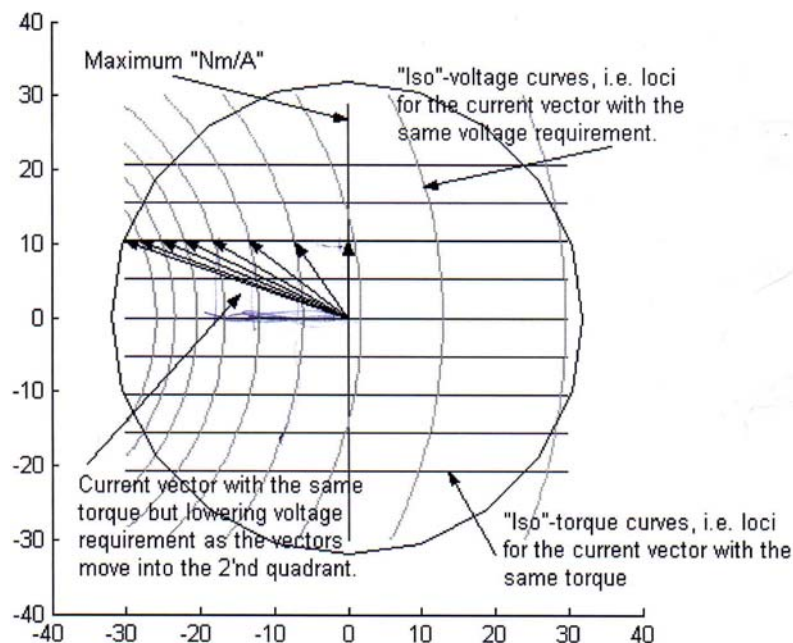
3	Same as 1 (with sampled current control) but with the inertia (j) decided by 10.	The “currents” window	The y-axis current is not able to reach the reference level perfectly. Why is that?
---	--	-----------------------	---

Add functionality to the current controller to eliminate the problem shown in case 3, and run case 4 to prove that you did it right.

4	Same as 3 but with your upgraded controller	The “currents” window	OK?
---	---	-----------------------	-----

### Field weakening

A certain torque can be achieved by the use of an infinite number of combinations of the stator current components in the x/y-reference frame. As long as the stator voltage required to achieve any of these currents is lower than the highest achievable, a common strategy is to use the shortest possible current vector, thus maximizing the “torque/current”-ratio. When the speed increases the voltage requirements also increases and its is necessary to move the stator current vector along the “constant torque line” (line along which all current vectors produce the same torque) in such a way that the stator flux linkage and thus the induced voltage is limited.



A particular case is that when  $L_{sx}=L_{xy}$ , i.e. the reluctance torque contribution is zero. The figure above illustrates that the torque is the same independent of the  $i_{sx}$ -current. The green curves describe where the stator current must be for constant voltage, and are parts of circles with a radius that shrinks as the speed increases. To run the machine into high speed with constant torque it is necessary to force the current vector into the 2'nd quadrant along the “Iso”-torque curve with the particular desired torque, until the current limit is reached. In this particular case it means that the  $i_{sy}$ -current (that produces torque) is kept konstant, but the  $i_{sx}$ -current is increased along

### SED, home assignment 3 – PMSM control with field weakening

the negative  $x$ -axis. When the current limit is reached, the  $i_{sy}$ -current has to be reduced accordingly to stay within the current limit.

Use the program *PMSM2*. To allow acceleration to high speeds, we need to simulate about 2 seconds of real time. This takes far too long time unless you have a very fast computer, and in order to speed up the simulation we replace the PWM-modulated voltage source with a continuous one. The continuous one sets an output voltage equal to the voltage reference but constant during the sampling interval. It is the switchings that is difficult for the simulation program to resolve exactly in time, and that's why the simulation is rather slow. By removing the switchings, the simulation runs much faster, as you will see with *PMSM2*.

Run the following cases:

CASE	References & settings	Simulation results	Your comment
5	Same as case 1, but this time 2 seconds simulation time.	The “currents” window	We are gradually losing the current after 1.5 seconds. Why?

The answer to the question in case 5 is related to the need of field weakening. Build a simple field weakening function into the simulation program and run case 6.

CASE	References & settings	Simulation results	Your comment
6	Same as case 4, but upgraded with a field weakening controller.	The “currents” window	Are you happy with the results?

You notice that the  $x$ -axis current increases in the negative direction, eventually to a level that may be too high for the equipment.

QUESTION TO BE ANSWERED: Which is the highest current modulus that is needed to run at extremely high speeds, with the parameters given?

### **Report requirements:**

The report should be handed in to Jonas on Friday December 2.

All comments must be made according to the case descriptions above. The form of your comment is free, but the questions should be answered in a way that convinces Mats and Jonas that you do understand your own answer.