EE462 & EE464 Project: Design of a SM-PMSM Variable Frequency Drive with Matlab/Simulink

The model that you will build and your results should be **completely on your own**.

Deadline: 29/05/2019 23:59

Definition

Please see the motor ratings of the surface mount PM synchronous machine (SM-PMSM) below.

$P_{nominal} = 80\ kW$

$T_{nominal} = 300\ Nm$

$n_{max} = 7000\ rpm$

Pole pair number: p=8

$Flux\ linkage$: $\lambda_{PM} = 0.2$ Vs (Wb-t)

$L_d = L_q = 500$ uH

$I_{nominal} = 250\ A$ (peak)

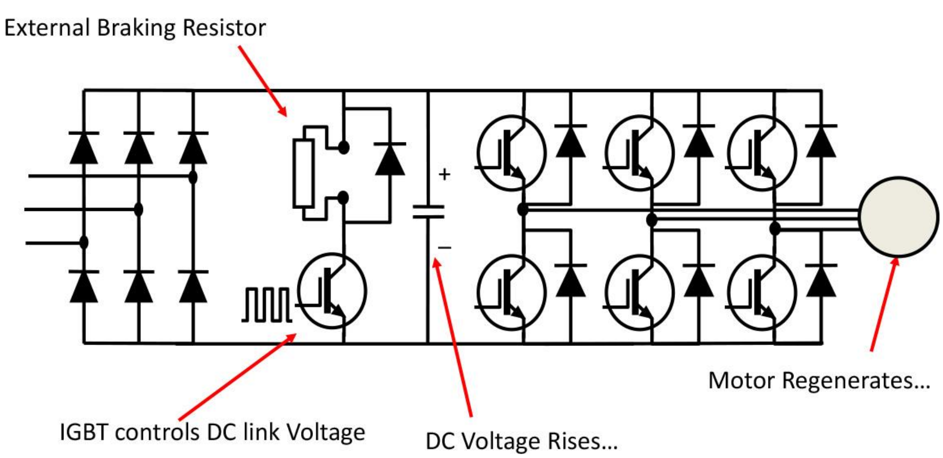
Phase resistance $R_s = 50$ mOhm

Equivalent inertia of the system: $J_{eq} = 10$ kg m^2

Ignore windage and friction losses.

The available supply is a three-phase AC source (50 Hz, $400V_{l-l}$) and the PM is a surface-mount motor.

Assume a 3-phase full-bridge diode rectifier is connected to the grid. The 3-phase motor drive inverter is connected to the diode rectifier as shown below.



Part A: Pre-design Stage

1. Calculate the rated speed and torque of the PMSM.
2. Calculate the maximum applied electrical frequency and choose a switching frequency for your inverter. You can refer to [1].
3. Design a reasonable DC-link filter for the rectifier block. Plot the DC-link voltage waveform by connecting a resistive load equivalent to motor at rated current. Calculate the DC-link voltage.

Part B: Sinusoidal PWM

Implement a motor drive using sinusoidal PWM (SPWM), and implement a current and speed controller using id-iq parameters. You need to implement your OWN Clarke-Park transformation blocks and PWM generation blocks.

1. 90% of the rated (nominal) speed to rated (nominal) speed at rated current while driving a constant torque load of 60 Nm.
   Plot speed vs. time
   Plot motor 3-phase line-to-line voltages and 3-phase line currents vs. time
   Plot torque vs. time
   Plot d-q currents
2. While the motor is running at rated speed, assume the load is removed (T_L=0 Nm) and the speed reference is kept constant. Show the performance of the drive by plotting relevant graphs.
3. While the motor is running at rated speed at no-load, assume the speed reference is reversed (i.e rotating at the opposite direction at rated speed). Comment on if this operation is feasible with the diode rectifier. Design a braking resistor system such that the DC-link voltage does not exceed 600 V.
   Plot speed vs. time
   Draw the 3-phase line currents during speed reversal and comment on the results.
   Plot d-q currents
4. While the motor is running at rated speed at half of the rated torque. Propose a method to run the motor at %150 of the rated speed without exceeding the rated currents. Calculate the required d-q currents.

Part C: (BONUS) Space Vector PWM (SVPWM)

1. Repeat part B using a Space Vector PWM algorithm. You are free to use readily available Simulink blocks in this stage.
2. Explain the main differences between SPWM and SVPWM. Which would you select for a high performance drive?
3. Plot the 3-phase reference voltage waveforms for the SPWM and SVPWM for rated operation and comment.

4. Compare the FFT components of the line currents for SPWM and SVPWM. Comment on the frequency spectrum and amplitudes. Calculate and compare the THD of the line current at rated operating conditions.

Part D: Component selection and verification

1. Select suitable **power semiconductor devices** (diodes, IGBTs etc.) for your motor drive system using commercially available product catalogs. **Give your reasonings.**
2. Approximately calculate **semiconductor device power losses** using simulation outputs, and device data-sheet parameters. Explain each method, parameter, indicate any external source you have used. It is highly advised to use **application notes** published by the semiconductor device manufacturers.
3. Find the **efficiency** of the motor drive system at the rated conditions. Then calculate the overall efficiency (including the efficiency of the motor). Comment on the results you found.

NOTES:

- There are several ways for loss calculation. Getting accurate results takes too much effort. Therefore, use approximate methods from applications notes.
- The aim of this project is not designing the most optimum or the most efficient motor drive system. Whenever you think the performance of the motor drive is not good, just comment on it and discuss how it can be improved.
- If you find unrealistic values (for example 10% efficiency), go back to your design. It's highly probable that you made a calculation mistake, but if it's really that low, then you need to modify your design.

HINTS:

Comments are the most important section of your project report. Please explain both your models and results as detailed as possible. Please refer to evaluation sheet for details.

- When constructing the models, go **step-by-step**. First built a few components, check if it is working as intended, if it works then add new components. Do not try to implement the whole model at once, expect it to work without any problems.
- Always be aware to use **correct units**.
- Understand the **requirements** before propositions.
- If you have any problems with your models, you can always open an issue in GitHub for online feedback, or visit the course assistant and lecturer during their office hours.
- Do not forget to cite to any external sources you used.

Submission

You have to commit at least the following files until the deadline:

- The Simulink models and/or Matlab .m files
- A project report describing your models in detail (Your simulation results should be embedded in your report).

References

[1] R. Teichmann and S. Bernet, “A comparison of three-level converters versus two-level converters for low-voltage drives, traction, and utility applications,” Industry Applications, IEEE Transactions on, vol. 41, no. 3, pp. 855 – 865, 2005.