E-Drives Modeling and Torque Control for Electrical Vehicles

Master Thesis Summary

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I. Introduction and Goal of the Thesis

The design of a traction e-Motor involves the simulation of the e-Drive for torque control calibration. The starting point of the thesis is a non-circuital, discrete-time average model, used as a benchmark and shown in Fig. 1.

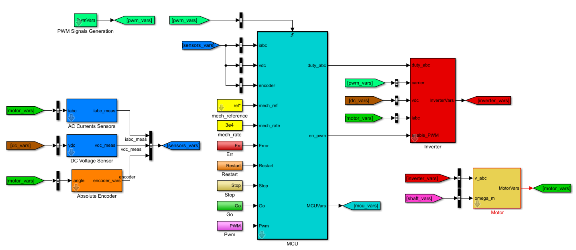


Fig. 1. E-Drive Simulink non-circuital, discrete-time average model

The benchmark model has two main limitations:

- It is time averaged and neglects the effects produced by the PWM voltage provided by the inverter supply.
- It cannot be used for fault analysis as it is not a circuital model.

The goals of the thesis are:

- Set up a new circuital model of the e-Drive, valid for instantaneous simulation, compatible with both Simulink and PLECS environments.
- Develop a Field Oriented Control (FOC) 4D technique to be implemented in Matlab/Simulink using C-language.

II. Description of the Work

The modelling approach considered for the e-Motor is the Voltage Behind Reactance (VBR) model shown in Fig. 2.

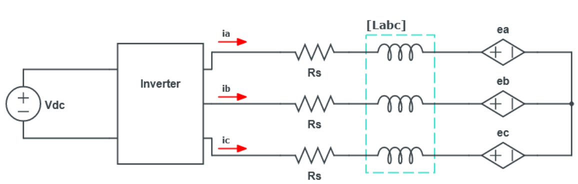


Fig. 2. Voltage Behind Reactance (VBR) model

The VBR model represents the motor as an RLE load, with coupled inductors and controlled voltage generators imposing the back EMF voltages computed by the motor model. This requires both the direct flux maps and incremental inductance maps.

The FOC solution has been developed for an Internal Permanent Magnet Motor (IPM) and it is based on multiple Look-up Tables (LUTs), as shown in Fig. 3.

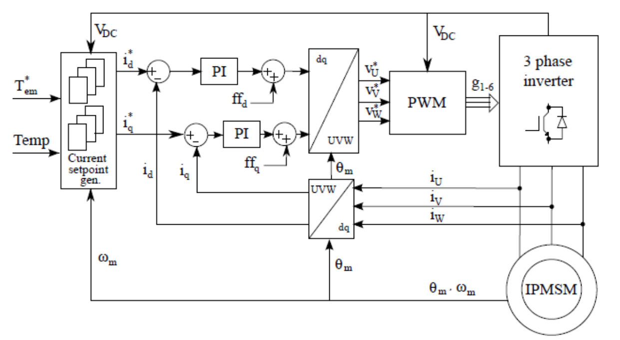


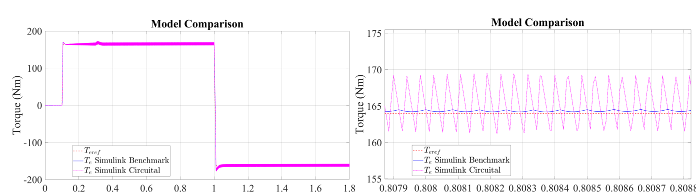
Fig. 3. General diagram of a 4D-LUT based IPMSM field oriented control

In this approach, the optimal current setpoints are calculated from the operation conditions of the machine and data stored in precalculated LUTs.

The developed FOC 4D has been compared with an existing Direct Flux Vector Control (DFVC) solution used as benchmark.

III. Simulation Results

The simulated IPM motor is a HSM1-10.18.13-D04 (BRUSA), rated 93 kW, 165 Nm, 13000 rpm. An example of simulation is given in Fig. 4, showing an almost perfect overlap between the benchmark model and Simulink VBR model simulated under DFVC torque control.



(a) *Max torque response as motor and as generator* (b) *Zoom-in*

Fig. 4. Torque response of the bechmark model and VBR model in Simulink

As can be seen the main difference between the models lies on the switching ripple, which is not present in the bechmarck non circuital model where the switching dynamic is not simulated.

A. 4D FOC vs DFVC

The last step is to compare the performance of the 4D FOC and DFVC utilizing the developed circuital model. The test chosen at this purpose is the square wave torque reference test.

The square wave torque reference test represents the most stressfull operating condition of an e-Drive as consists of the alternating motor-generator operation at the theoretical torque limit of the machine. The chosen frequency is 10Hz.

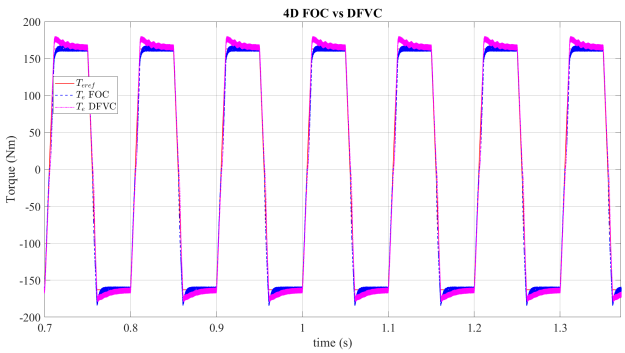


Fig. 5. Square wave torque reference test 4D FOC vs DFVC

Fig. 5 shows that both control solutions are able to follow the torque reference. The 4D FOC presents a higher overshoot with respect to DFVC when the transition is from motor to generator and an almost absent one when the transition is from generator to motor.

IV. Conclusions

The thesis contributed to set up a circuital model compatible with instantaneous simulations, and also eventually able to consider fault conditions. Using the model developed a detailed comparison between the DFVC take as benchmark and the producted 4D LUT FOC is possible. The results obtained attest that the 4D FOC represents also a valid control solution for the efficient control of the e-Drive taken into account.

References

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