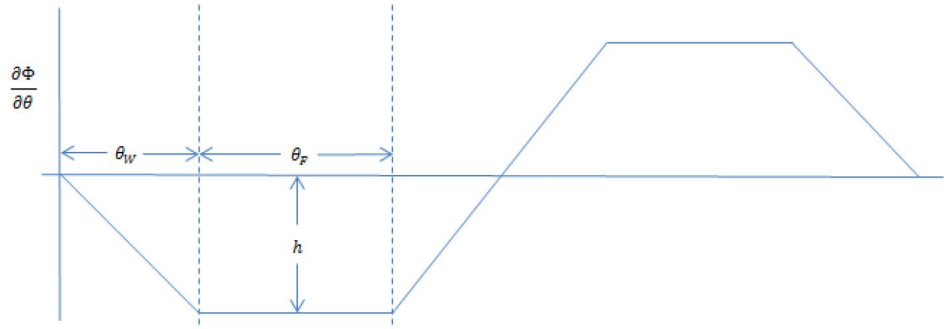
Speed control of a BLDC motor

A three-phase surface mounted permanent magnet (PM) synchronous motor (PMSM) is Y-connected in the stator windings. The motor has the following parameters:

Number of pole pairs p=3
PM flux linkage ψ_f=0.1057 Wb
Stator resistance R_s=1.8 ohm
Stator phase self-inductance L_s =10 mH
Rated torque T_N=4.5 Nm
Inertia: J=0.002 kg*m^2
DC bus voltage U_{dc}=200 V

The flux leakage can be ignored and the inductance fluctuation is negligible.

Assume that the waveform of the PM flux linkage partial derivative with respect to rotor angle is below



where θ_W=45 electrical degrees and θ_F=90 electrical degrees.

Using the BLDC control strategy, the motor speed is required to be the following pattern:

t=[0, 0.1] s, w=0
t=[0.1, 0.2] s, w increases linearly from 0 to 1000 rpm
t=[0.2, 0.4] s, w=1000 rpm
t=[0.4, 0.5] s, w increases linearly from 1000 to 2000 rpm
t=[0.5, 0.7] s, w=2000 rpm
t=[0.7, 0.8] s, w decreases linearly from 2000 to 1000 rpm
t=[0.8, 1] s, w=1000 rpm

The corresponding load torque profile is

t=[0, 0.25] s, T=0
t=[0.25, 0.45] s, T=4.5 Nm
t=[0.45, 0.85] s, T=2.25 Nm
t=[0.85, 1] s, T=4.5 Nm

please provide:

(1) Briefly state the control theory and basic analytical formulas for motor performance analysis.
(2) Calculate some steady-state performance using the analytical formulae, e.g. the maximum phase back EMF at rated speed, phase current at full-load and half-load, etc. Note that these results might be used to validate your Simulink simulations later.
(3) Build a Simulink model of BLDC for controlling the motor speed as required. Report your model and machine and control parameters. The models should be attached for checking if they functions well.
(4) Report various dynamic and steady-state performance, e.g. the speed curve, torque profile, phase current waveforms, output power profile, etc.
(5) Analyse and validate your simulated results.
(6) Any further analyses for improvement.