EE 7566 Homework 2: Finite Element Method Analysis of an IPMSM

Total points: 10 x 10 + 2 x 5 = 110, due on May 5th, 2019 @ 23:59

Build the IPMSM model according to the instructions given in "Study of a Permanent Magnet Motor with MAXWELL 2D: Example of the 2004 Prius IPM Motor". After you complete this tutorial, you have both magnetostatic and transient models, you only need the transient model (5_Partial_Motor_TR) in this homework. Add the following variables to your transient model and change the air-bridge shape as described.

Speed_rpm: *variable* (make sure that Speed_rpm is a unitless variable)
T_elec=1 / (Speed_rpm*4/60)
n_points= 100
t_end= T_elec
t_delta= T_elec/n_points

Solver setup:

General Tab:

- Stop time: t_end
- Time step: t_delta

Save Fields Tab:

- Clear All → Add single point, only at **0s** should appear in the list.

Solver Tab:

- Nonlinear Residual: 1e-6

Motion setup1:

Type Tab:

- Rotation
- Global: Z and Positive

Data Tab:

- Initial position: *30 deg* as in the tutorial

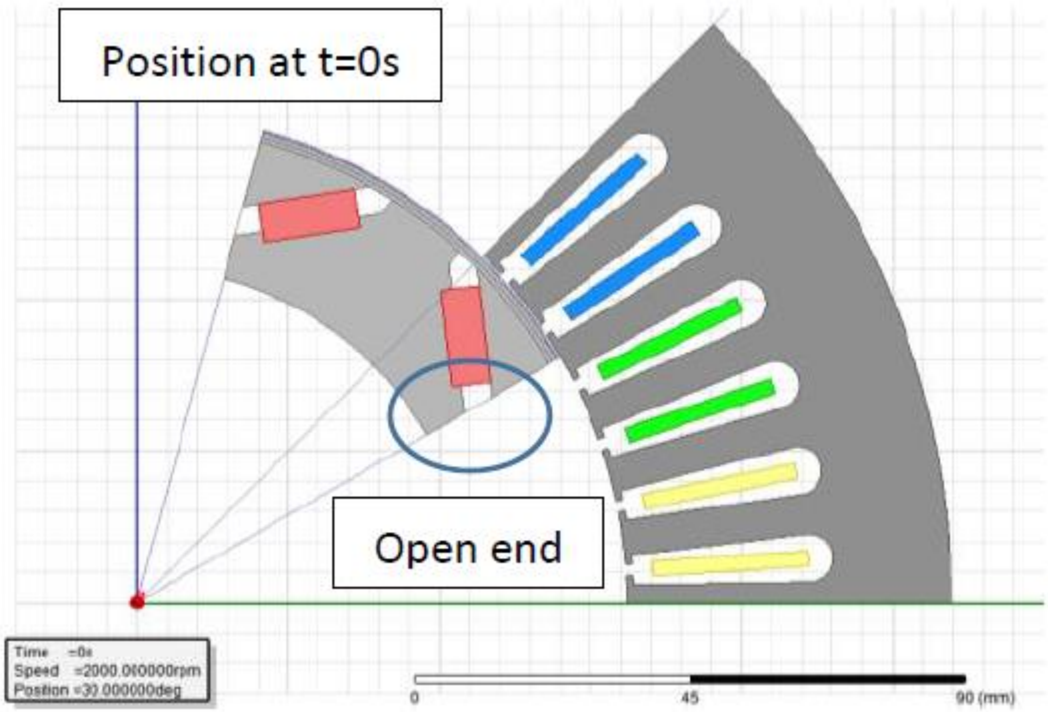
Mechanical Tab:

- Angular velocity: Speed_rpm/60*2*pi (you need to define it in rad/sec)

Adjust the air-bridge shape as in the figure (open end) by:

Rotor → Double Click on UserdefinedParts → Pole Type: 5

Now, your simulation time changes with the speed and you always simulate 100 points in an electrical period. For 1000 rpm, the variables are given in the following table, all variables are unitless.



Name	Variable	Unit	Evaluated value
Speed_rpm	1000		1000
T_elec	1 / (Speed_rpm*4/60)		0.015
t_end	T_elec		0.015
n_points	100		100
t_delta	T_elec/n_points		0.00015

Question 1: (No-load) Run the transient simulation for phase currents are equal to 0 (Imax = 0 A) at 1000 rpm rotational speed and show the following results and answer the question.

1. Show the magnetic flux density distribution B_mag at t=0 sec, set limits of color codes to 0 T-2 T.
2. Flux linkage of all three phases (FluxLinkage(PhaseA), etc.)
3. Induced voltage of all three phases (InducedVoltage(PhaseA), etc.)
4. Torque produced (Moving1.Torque)
5. What is the definition of the torque generated at no-load. Why do we call this operation no-load?

Question 2: (Load) Set Imax = 400 A, Speed_rpm=1000 rpm and prepare a parametric sweep for Thet_deg for 0, 15, 30, 45 and 60 (see page 86 of the tutorial). Run the parametric analysis and answer the following questions.

6. Torque produced at 400 A at all simulated Thet_deg values.
   To show all the results at the same time, make the following change in the report setup:
   Left click on Moving1.Torque→ Modify Report → Families →Click on Edit next to Thet_deg → Select: Use all values → X (close this window)→ Apply trace → Close (report setup)).
7. At which angle is the torque maximum? How does the torque output affect by angle Thet_deg?

Question 3: (Field weakening)

8. Run simulation with Imax = 0 A and Speed_rpm=6000. Show phase voltages and state their amplitude.
9. (5 points) What is the required output voltage of the inverter at the previous operation point, phase terminals are wye-connected?
10. Run simulation with Imax = 100 A, Thet_deg = 90 and Speed_rpm=6000. Show phase voltages and state their amplitude.
11. (5 points) The current you apply in the previous step corresponds to minus d–axes current. Explain the effect of applying only a negative d-axes current on phase voltages.
12. State the torque equation of an IPMSM in d-q coordinates. Explain if there is a net torque produced when only minus d-axes current is applied.

Good Luck,
Dr. Emine Bostancı