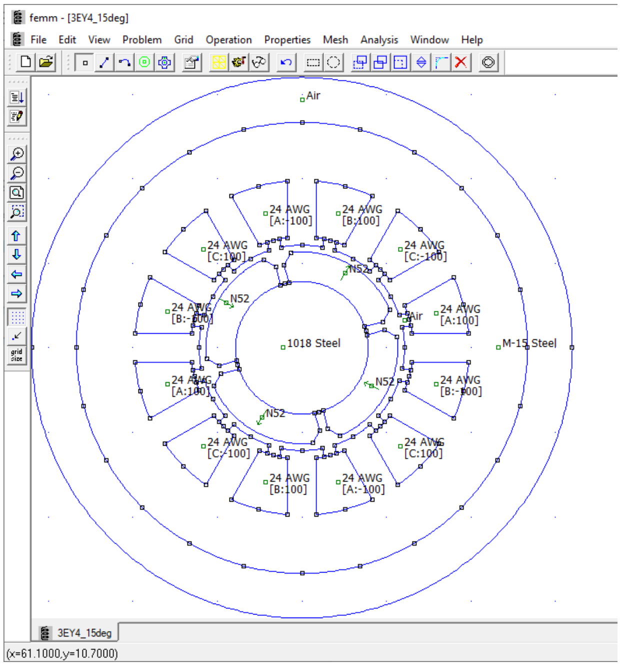
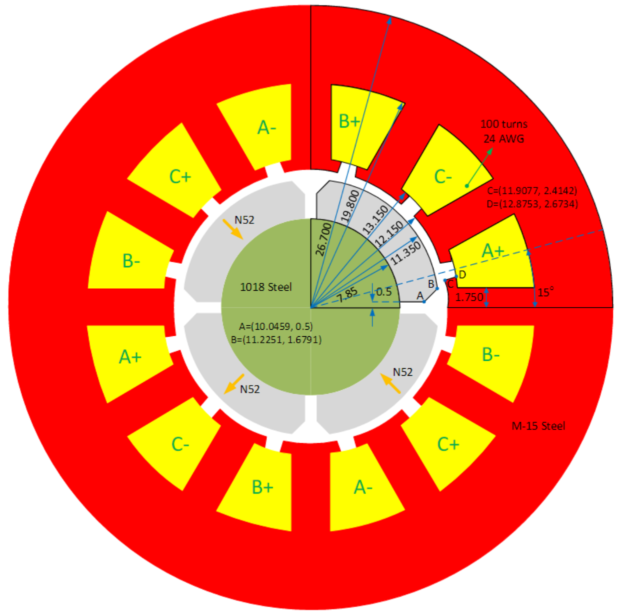
Finite Element Model of a Surface Permanent Magnet Synchronous Motor

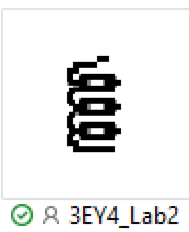
McMaster University

EE3EY4 Electrical Systems Integration Project - Winter 2021

1. Create FEM Model







2. Calculate Mechanical Properties of Motor

Rotor speed: $1500RPM\ or\ 25rev/s$

Mechanical frequency of the rotor: $f = \frac{1500rpm}{\frac{120deg/pole}{4poles}} = 50Hz$

Number of rotor poles: 4

Number of pole pairs: 2

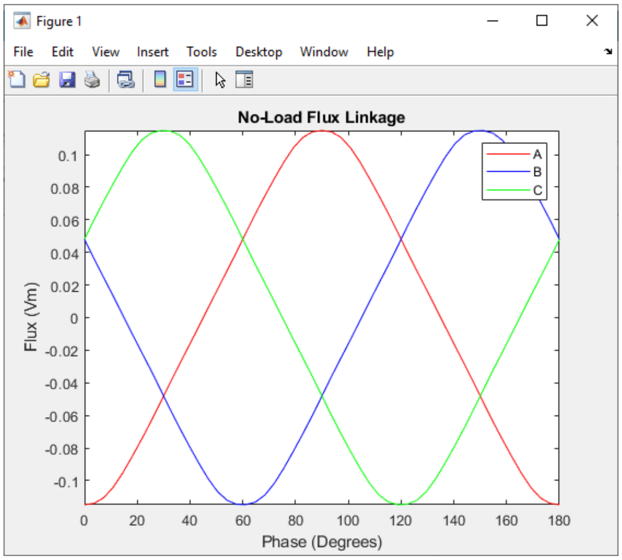
Mechanical degree of the rotor in 1s: $25rev/s * 360deg/rev = 9000deg$

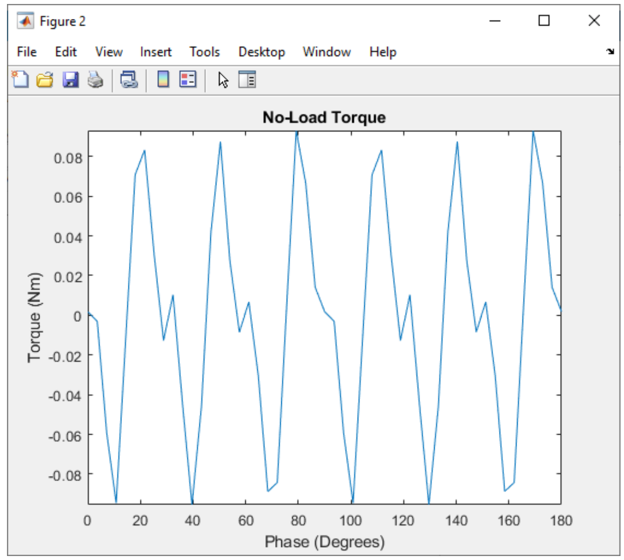
Time of the rotor to spin for half a rotation: $\frac{0.5rev/half\ a\ rotation}{25rev/s} = 0.02s/half\ a\ rotation$

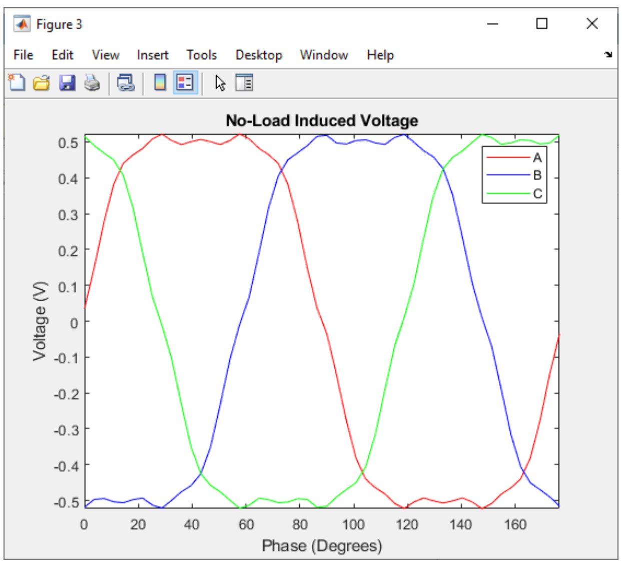
Step time if half a rotation is in 50 steps: $\frac{0.02s/half\ a\ rotation}{50step/half\ a\ rotation} = 0.0004s/step$

The angle of the rotor for each step: $\frac{180deg/half\ a\ rotation}{50step/half\ a\ rotation} = 3.6deg/step$

3. Simulate the No-Load Condition of FEMM Model for each Step





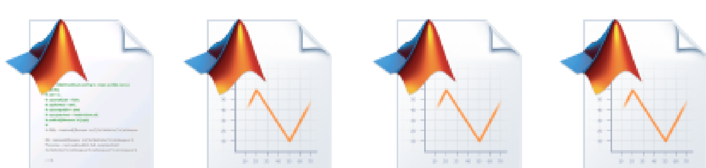


The induced voltage was calculated using Faraday's Law.

$$\varepsilon = \frac{d\lambda}{dt} = \frac{d\lambda}{d\theta}\frac{d\theta}{dt} = \frac{d\lambda}{d\theta}\omega \qquad\qquad \varepsilon_{calc} = \frac{\lambda_2-\lambda_1}{\theta_2-\theta_1}$$

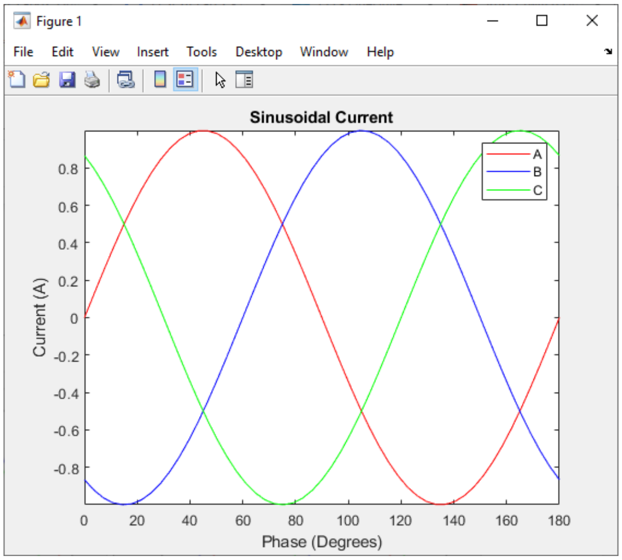
EMF = change in flux over the change in degrees times the angular speed

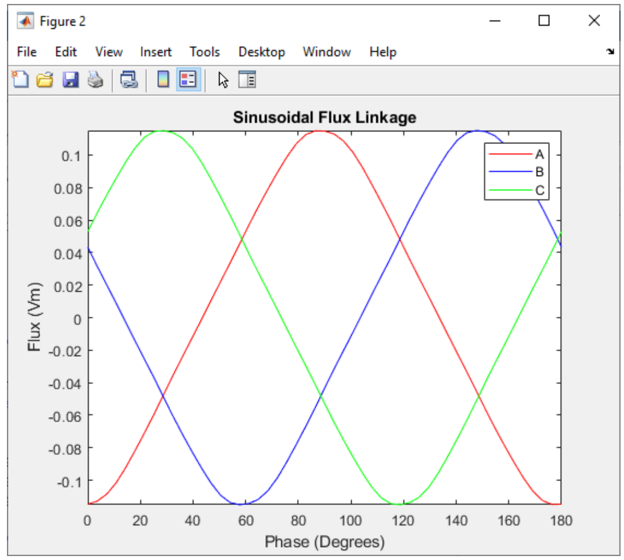
However, since FEMM was only able to provide discrete values of flux and position, it was necessary to find the slope between adjacent values to calculate the induced voltage.

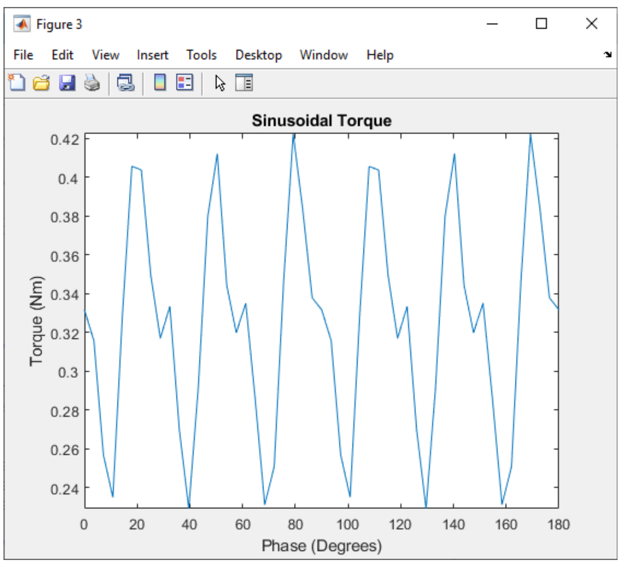


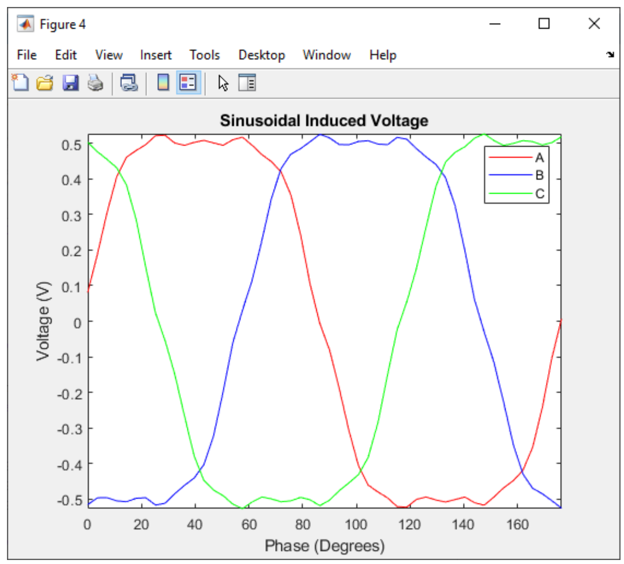
Q3 | No-Load Flux Linkage | No-Load Induced Voltage | No-Load Torque

4. Simulate the Sinusoidal-Load Condition of FEMM Model for each Step

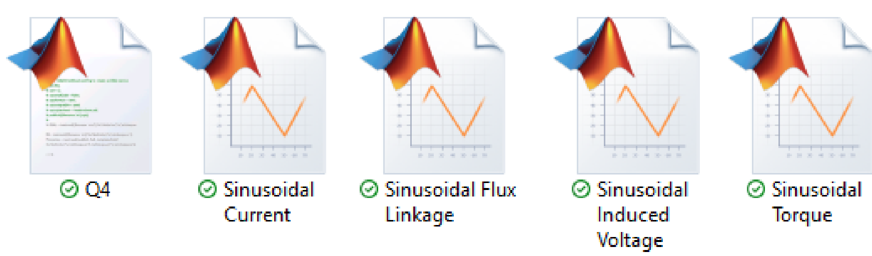




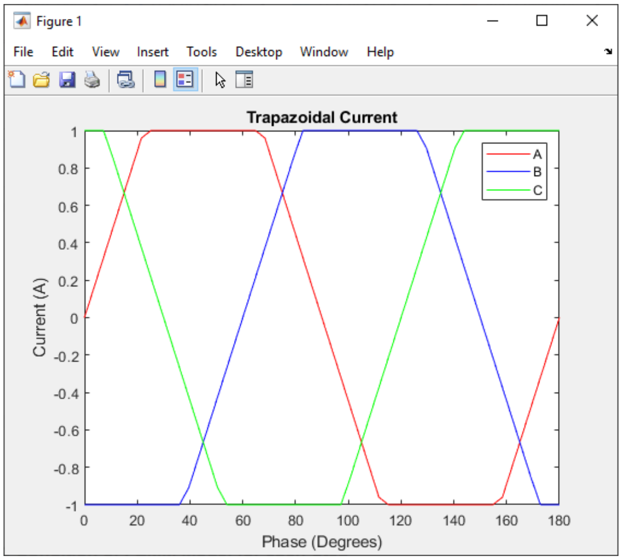


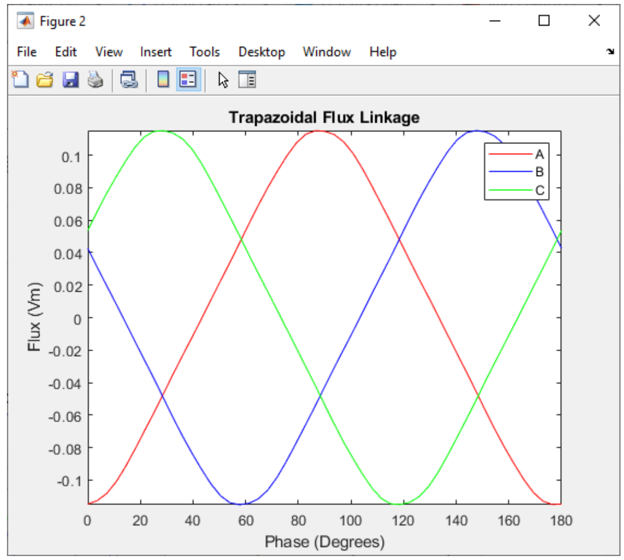


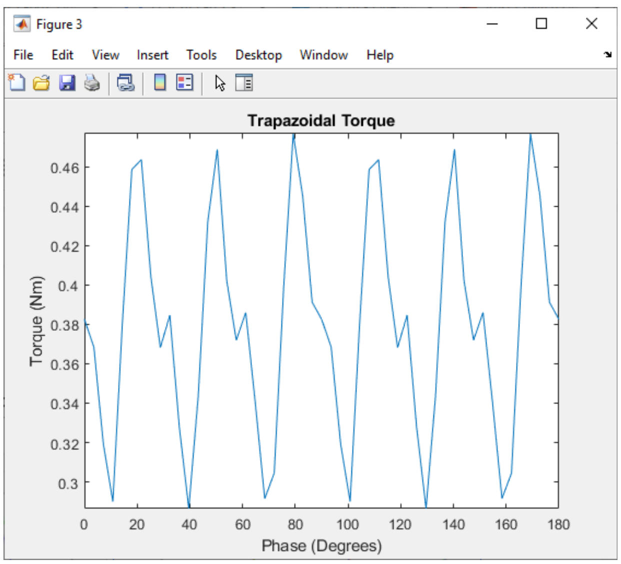
The current waveform was determined using the phase of the induced voltage, such that the current in coil A is in phase with the induced voltage in coil A, and so on. The amplitude was chosen arbitrarily. This provides a positive average torque due to the positive air-gap power from the back emf and the motor current. Compared to no-load torque, the current can generate a positive torque that averages around 0.33 Nm.

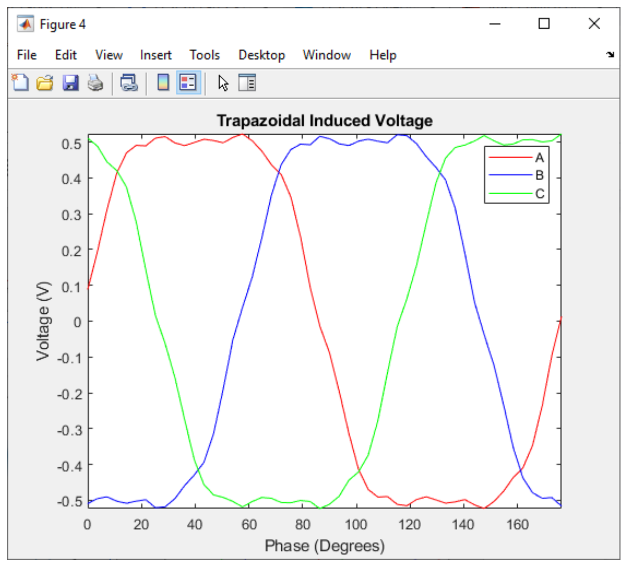


5. Simulate the Trapezoidal-Load Condition of FEMM Model for each Step









Once again, the current waveform was determined by making it in-phase with the induced voltage, according to the corresponding coils. Despite the different shapes of the waveform, this too has provided a positive torque. The torque response appears to be the same as the sinusoidal waveform, but the average torque is higher than the sinusoidal waveform at around 0.38 Nm. This increase in torque could be because the trapezoidal waveform is at its peak for a longer period compared to the sinusoidal waveform.

Q5

Trapazoidal Current

Trapazoidal Flux Linkage

Trapazoidal Induced Voltage

Trapazoidal Torque