20-Generator Torque and Back EMF

ECEGR 3500

Text: 12.7

Electrical Energy Systems

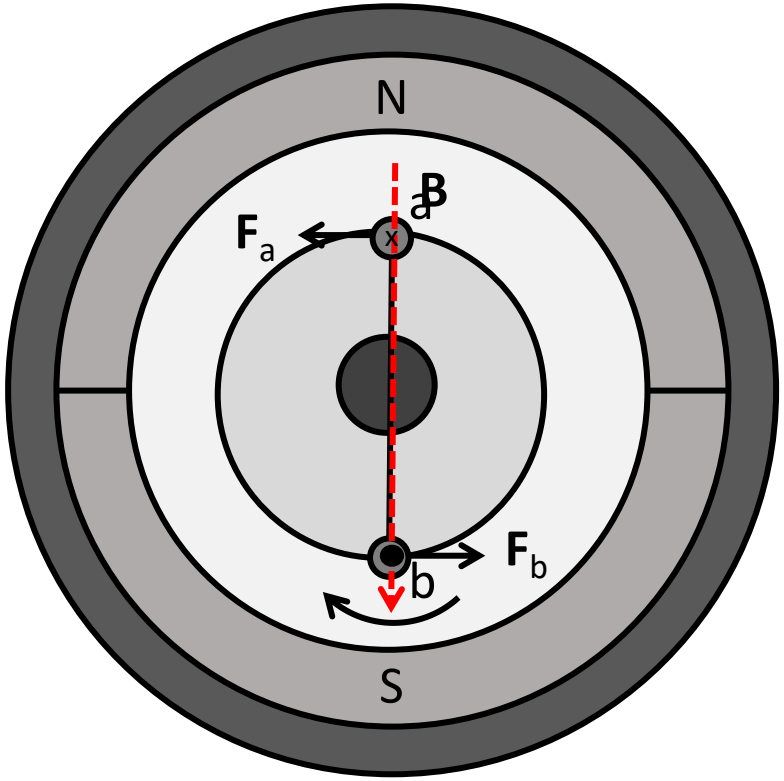
Professor Henry Louie

Overview

- Generator Torque
- Back EMF

Generator Torque

- Consider a generator whose shaft is rotating with torque T_m (supplied by prime mover) in CW direction at speed ω
- Conductors experience Lorentz Force
  - Torque T_e in CCW direction



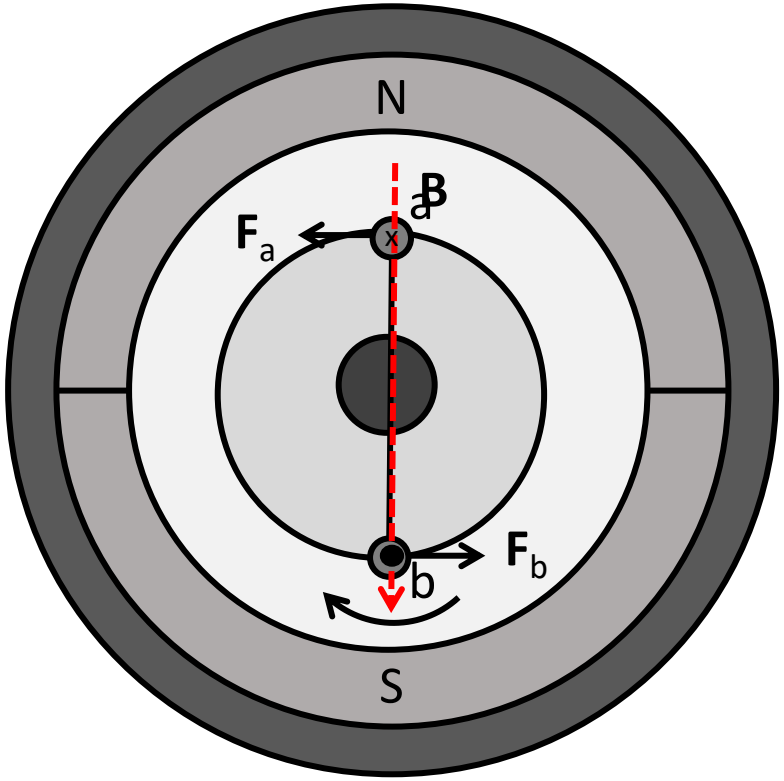
Generator Torque

- Magnitude of the force experienced by the coil is: $\mathbf{F} = 2iLB$
  - L: length of conductor
- electrical torque is

$$T_e = F_e r = 2i\mathbf{B}Lr$$

  - r: radius where the conductors are located (m)

Same force and torque equations can be applied to motors



Generator Torque

In generators, applied mechanical torque is opposed by electromagnetic torque

- $T_e > T_m$: shaft decelerates
- $T_e < T_m$: shaft accelerates
- $T_e = T_m$: shaft continues to rotate at ω

Example

Consider a generator supplying a load of 1MW at a constant voltage at 3600 rpm. The load suddenly increases to 1.1MW. Which of the following statements are true?

A. The generator will begin decelerating.
B. The generator will continue to operate at 3600 rpm.
C. The generator will begin accelerating.
D. The electric torque is higher at 1.1 MW than 1MW.
E. The electric torque is lower at 1.1 MW than 1MW.

Example

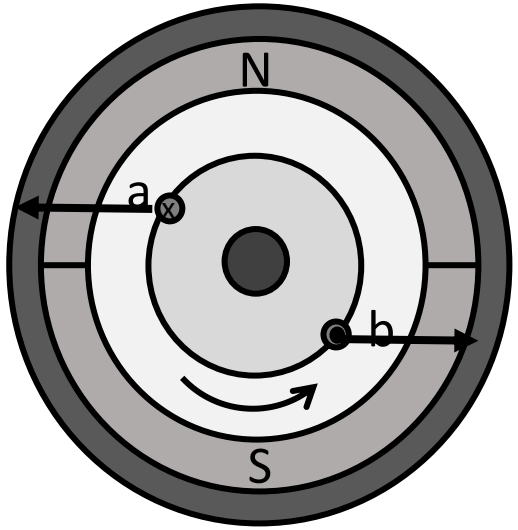
Consider a generator supplying a load of 1MW at a constant voltage at 3600 rpm. The load suddenly increases to 1.1MW. Which of the following statements are true?

A. The generator will begin decelerating
B. The generator will continue to operate at 3600 rpm
C. The generator will begin accelerating
D. The electric torque is higher at 1.1 MW than 1MW
E. The electric torque is lower at 1.1 MW than 1MW

If voltage is constant and power increases, current must increase. Increased current will lead to increased electric torque. Unless mechanical torque also increases, the generator will decelerate.

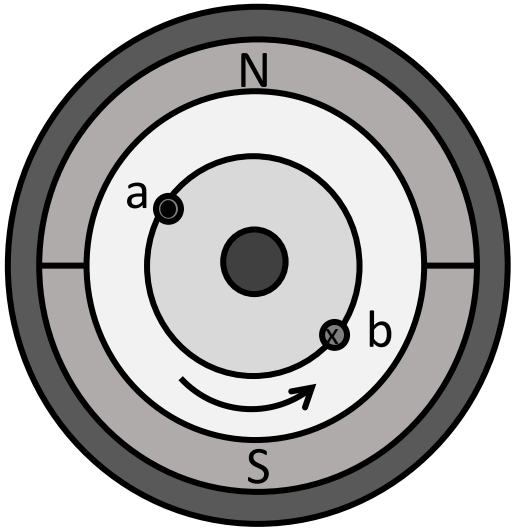
Back EMF

A motor with shown current polarity will rotate in CCW direction



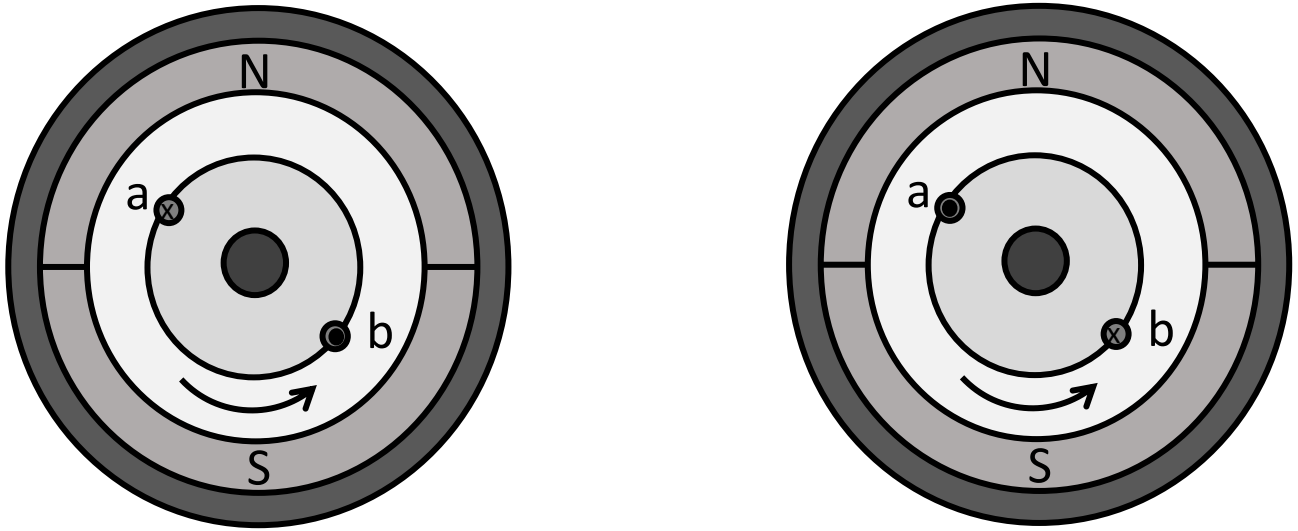
Back EMF

Recall that a generator rotating CCW will have induced current with the shown polarity



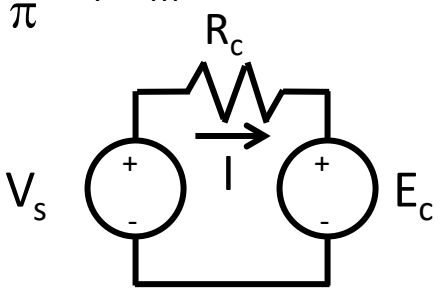
Back EMF

- Applied current (voltage) and induced current (voltage) oppose each other
  - Induced voltage is known as *back emf*
- Analogous to T_e opposing T_m in generators



Back EMF

- Consider the following scenario:
  - Applied voltage to stator is increased
  - I increases (Ohm's Law)
  - T_e increases (Lorentz Force equation) $T_e = 2I\mathbf{B}Lr$
  - ω increases $(\alpha = (T_1 - T_2)J)$
  - Back emf increases $E_c = \frac{P}{\pi}\Phi_P\omega_m$
  - Current decreases



Torque and Back EMF

- Counter torque and back emf exist in rotating electric machines
- Act to oppose change in operating state
- Account for torque, back emf in mechanical and electrical models of machines

Summary

- Generators producing current will experience a counter torque in opposite direction to the applied mechanical torque
- Motors drawing current will experience an induced voltage that opposes the applied voltage