Electric Vehicle (EE60082)

Lecture 6: Motor drive for EV (part 2)

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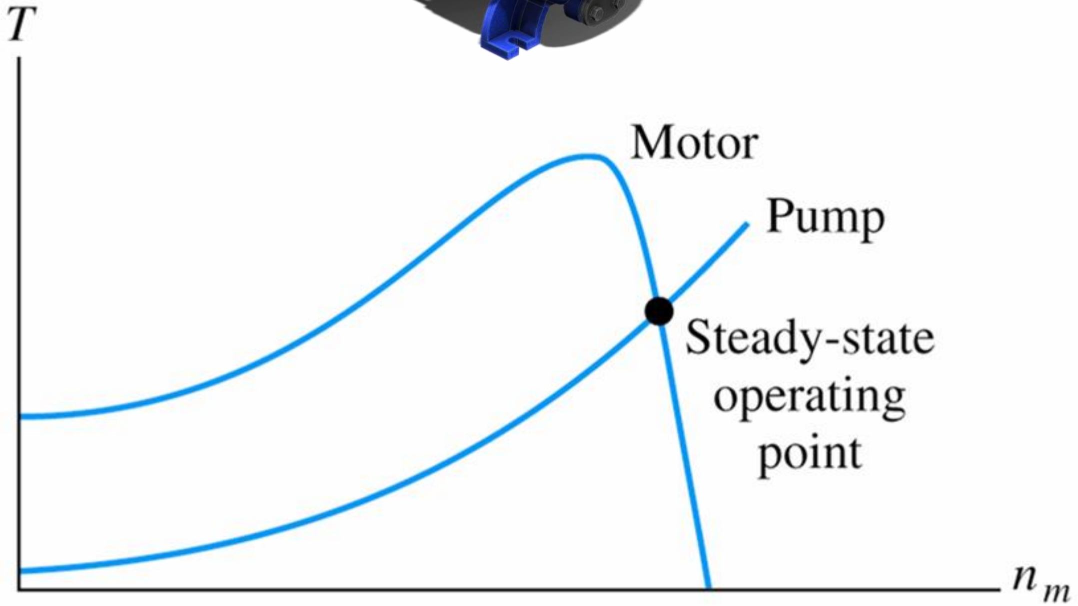
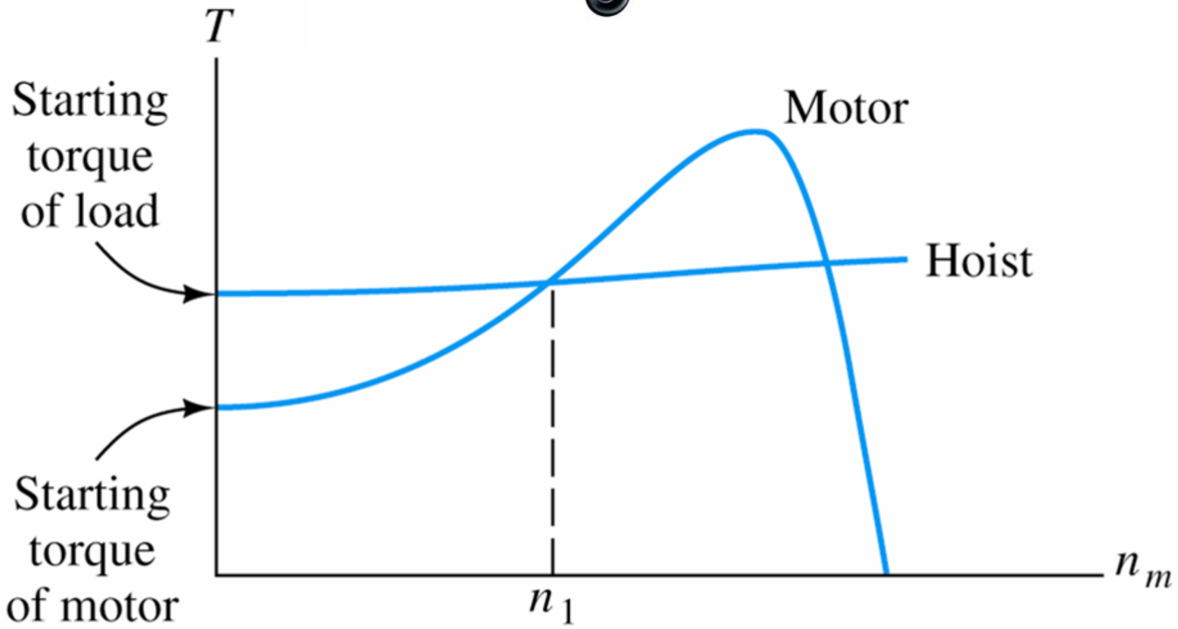
Traction motors for EV (recap)

Commonly used motors:

- Brushed DC motor
- Brushless DC motor (BLDC)
- Induction motor
- Permanent magnet synchronous motor (PMSM)
- Switched reluctance motor (SRM)

Torque-speed requirement (recap)





Torque-speed requirement for EV (recap)

High-way Drive: high speed, torque can be low;

Climbing Hills: high torque, speed can be low;

Motor speed range: wide, otherwise gear box is needed.

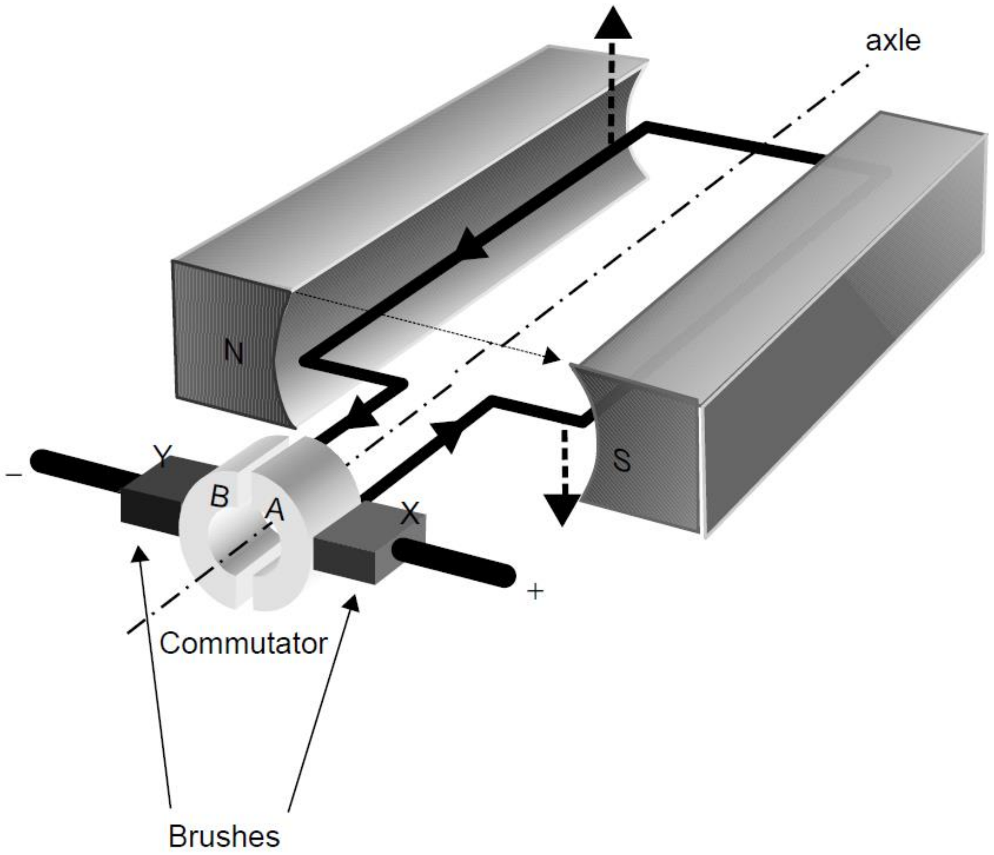
Common electrical machines-DC machine (recap)

- Force on a current carrying conductor

$$F = I \cdot L \cdot B \cdot \sin(\theta)$$

- Force on two conductors are in opposite direction
  - follows right hand rule
  - Creates torque that rotates the coil

- Commutator ensures that the coil rotates in the same direction



Common electrical machines-DC machine (recap)

- Torque generated by one coil,

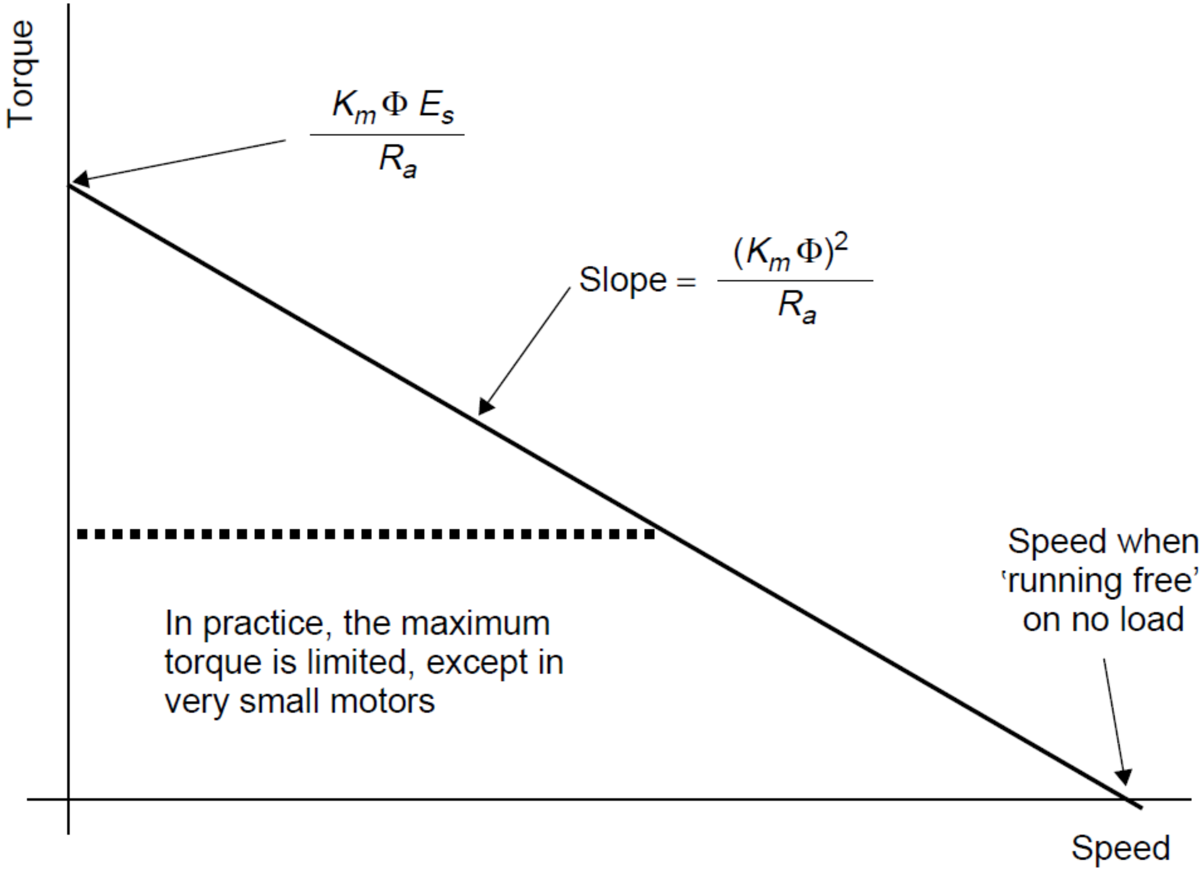
$$T = n\Phi I$$

- Overall torque $T = K_m \Phi I$
- Coil current

$$I = \frac{V}{R_a} = \frac{E_s - E_b}{R_a} = \frac{E_s}{R_a} - \frac{K_m \Phi}{R_a}\omega$$

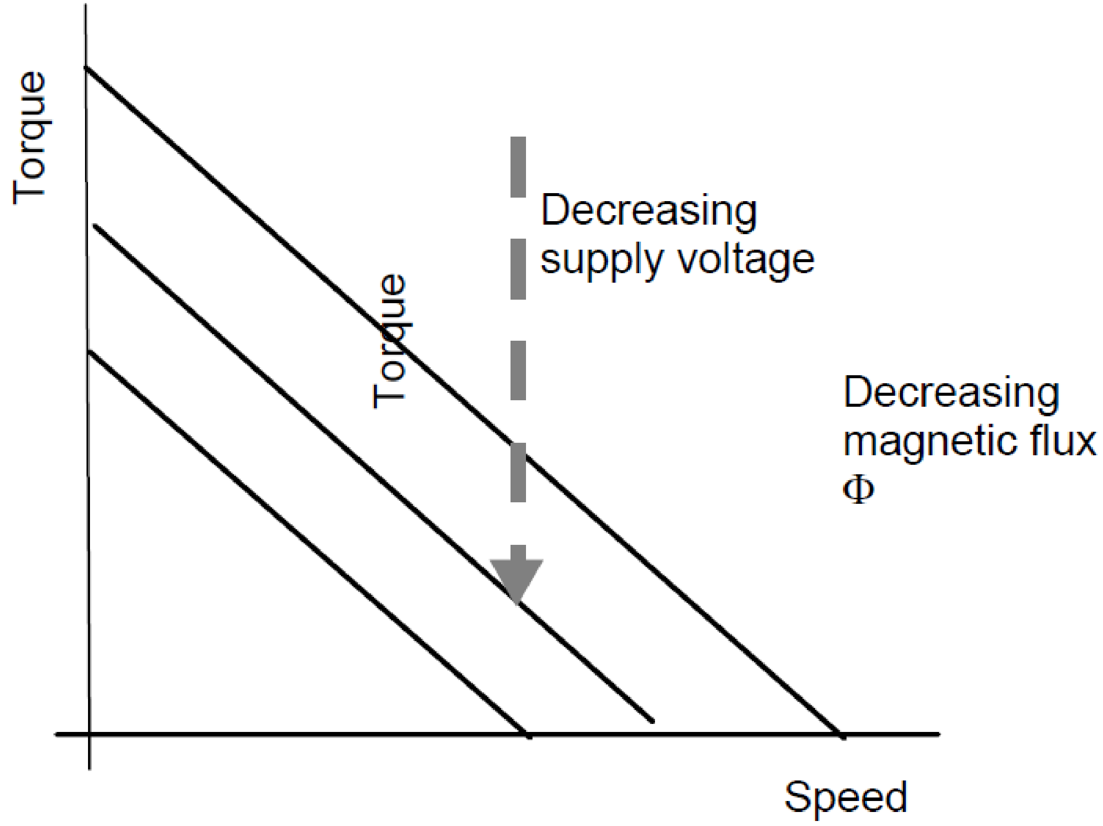
- Torque equation

$$T = \frac{K_m \Phi E_s}{R_a} - \frac{(K_m \Phi)^2}{R_a}\omega$$



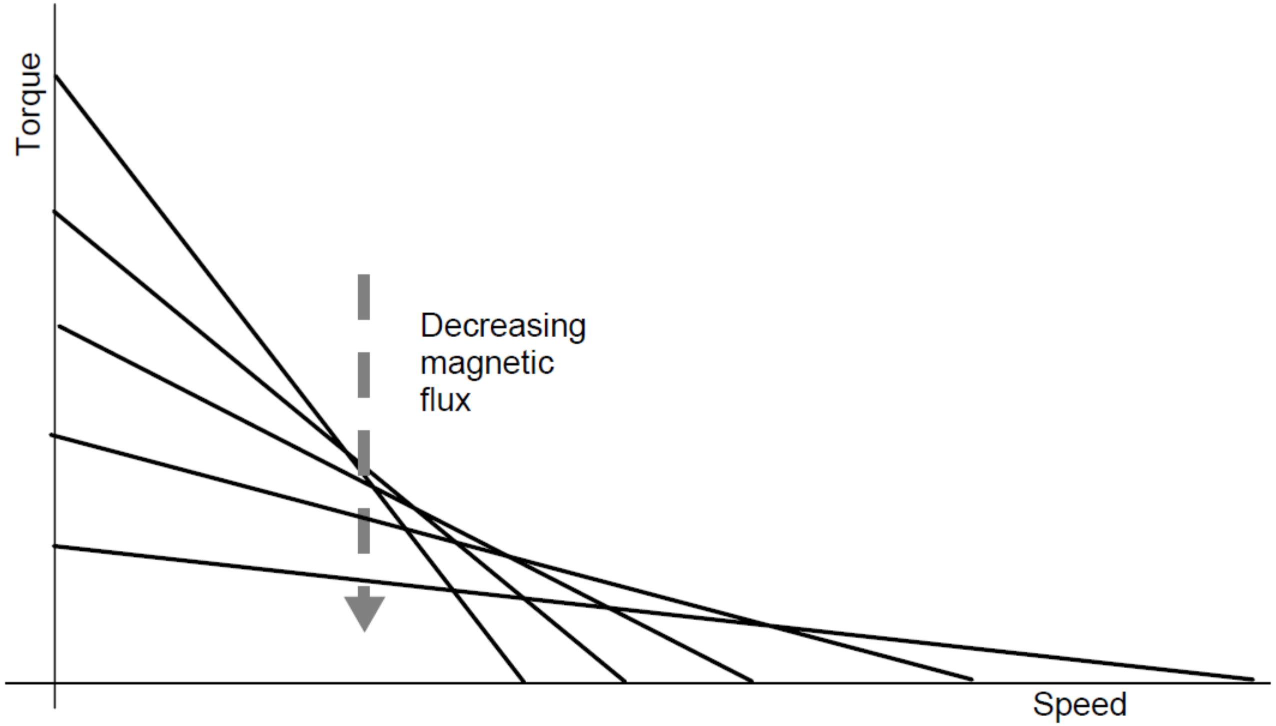
Common electrical machines-DC machine (recap)

- Control with supply:
  - supply voltage is reduced
  - maximum torque falls in proportion,
  - slope of the torque/speed graph is unchanged
  - any torque and speed can be achieved below the maximum values



Common electrical machines-DC machine (recap)

- Control with magnetic field:
  - magnetic flux can be controlled in some DC machines
  - Magnetic field is produced by coil, not by permanent magnet
  - higher speed can be achieved during low torque operation
  - Main advantage: produce strong magnetic field at lower cost
  - Main drawback: additional losses in the field winding
    - Can be somewhat compensated by more efficient operation of motor

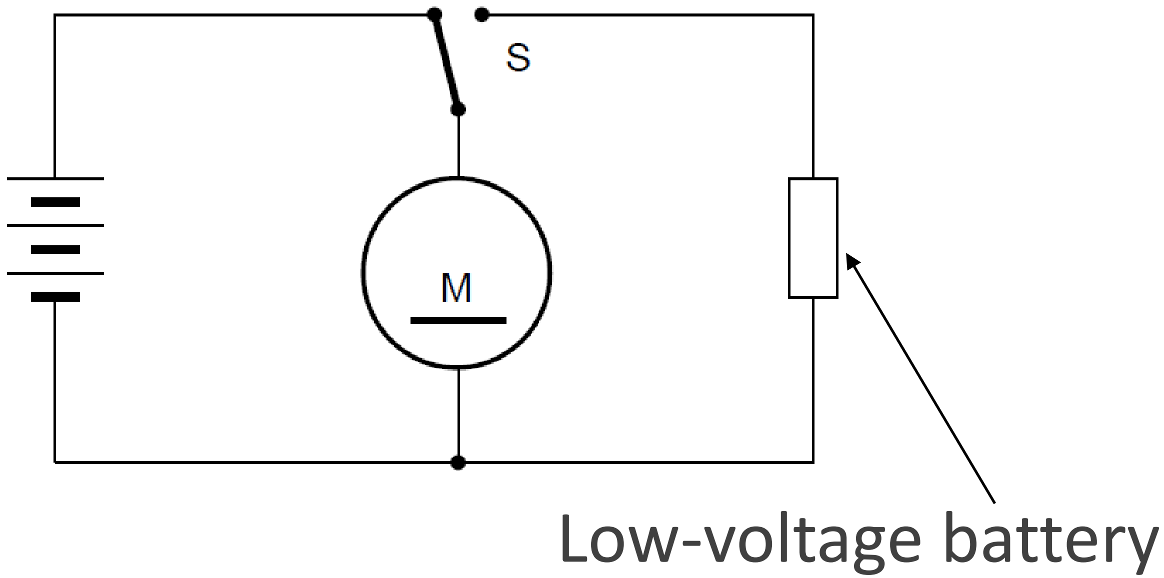


Electric braking – regenerative (recap)

- In braking mode, motor is connected to a low voltage battery
- Current into battery is,

$$I = \frac{V}{R} = \frac{K_m \Phi \omega - V_b}{R_a}$$

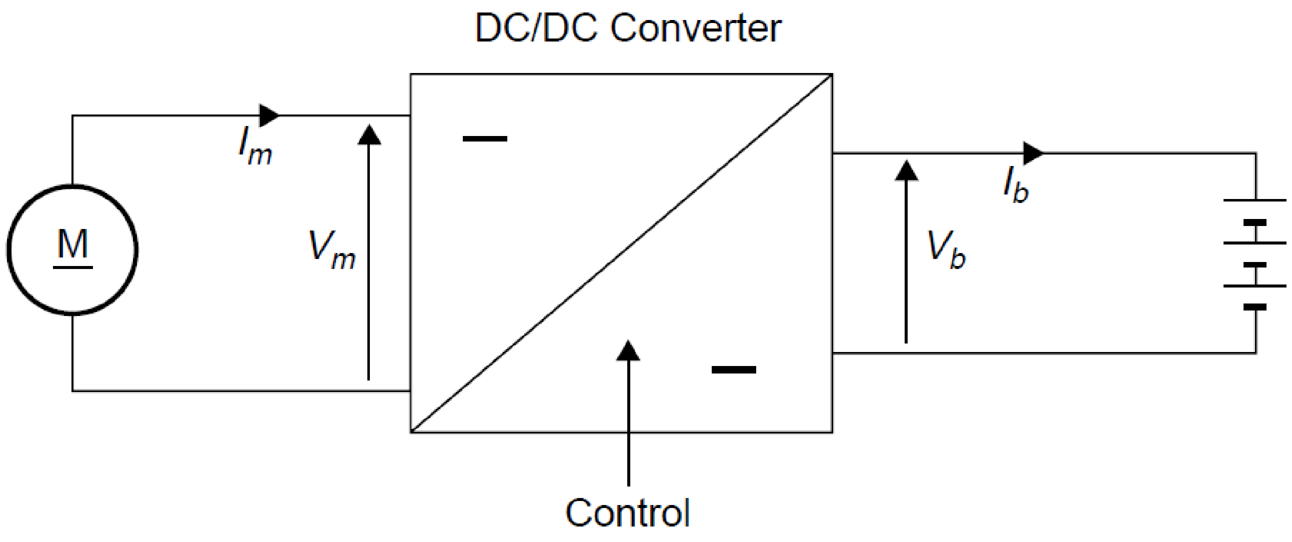
- This current flows out of motor, producing a reverse torque (braking action)
- This is called regenerative braking



- Large uncontrolled current
- Regeneration not possible at low speed

Electric braking - regenerative (recap)

- Energy transfer to a battery with controlled current possible with a DC-DC power converter
- Can support wide rage of battery voltage
- No need for a separate low-voltage battery
- Effective for entire range of speed
- Highly efficient energy transfer
- Fast control of braking power



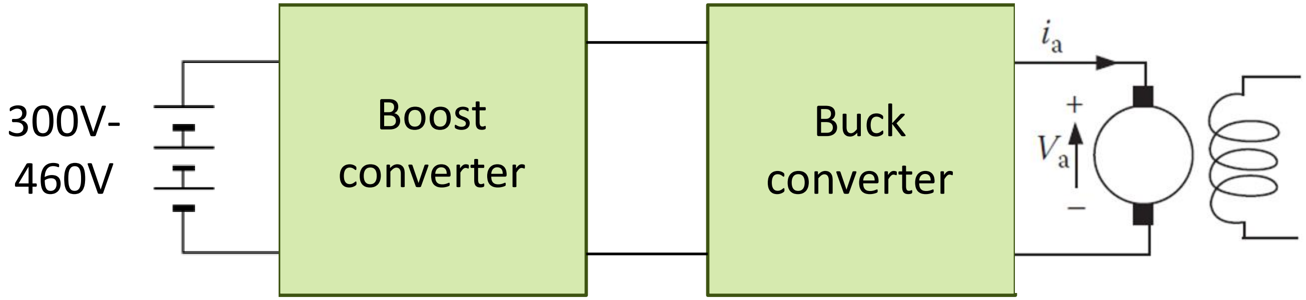
Choice of converter (recap)

- basic DC-DC converters: buck, boost, buck-boost

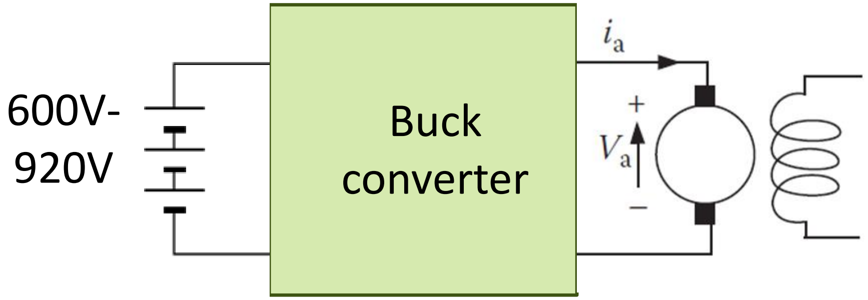
- Ex1: motor rated voltage 550V, battery nominal voltage 400V, range of battery voltage 300V-460V

- Which converter to choose?

DC motor drive

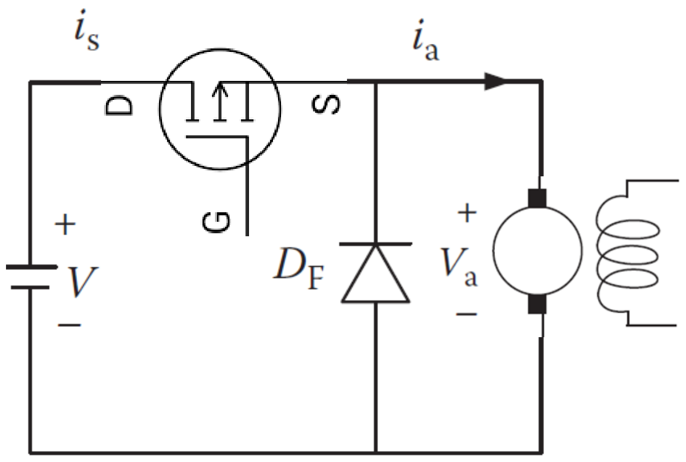


Lower battery voltage



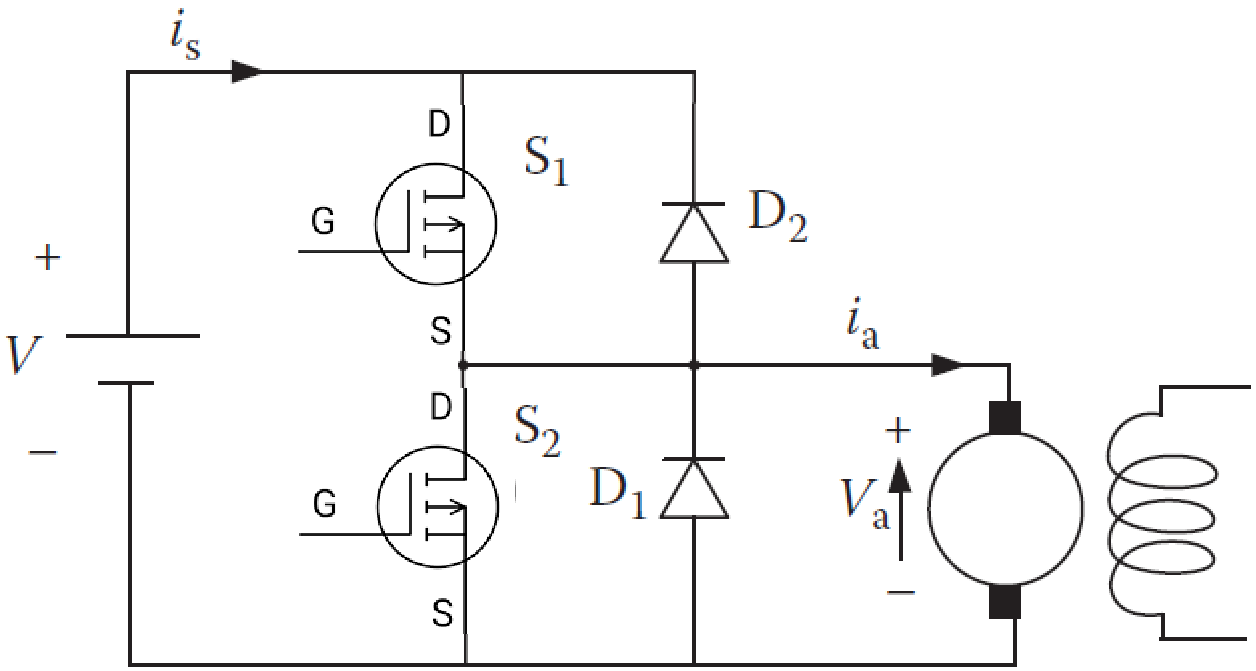
Higher battery voltage

DC motor drive – buck



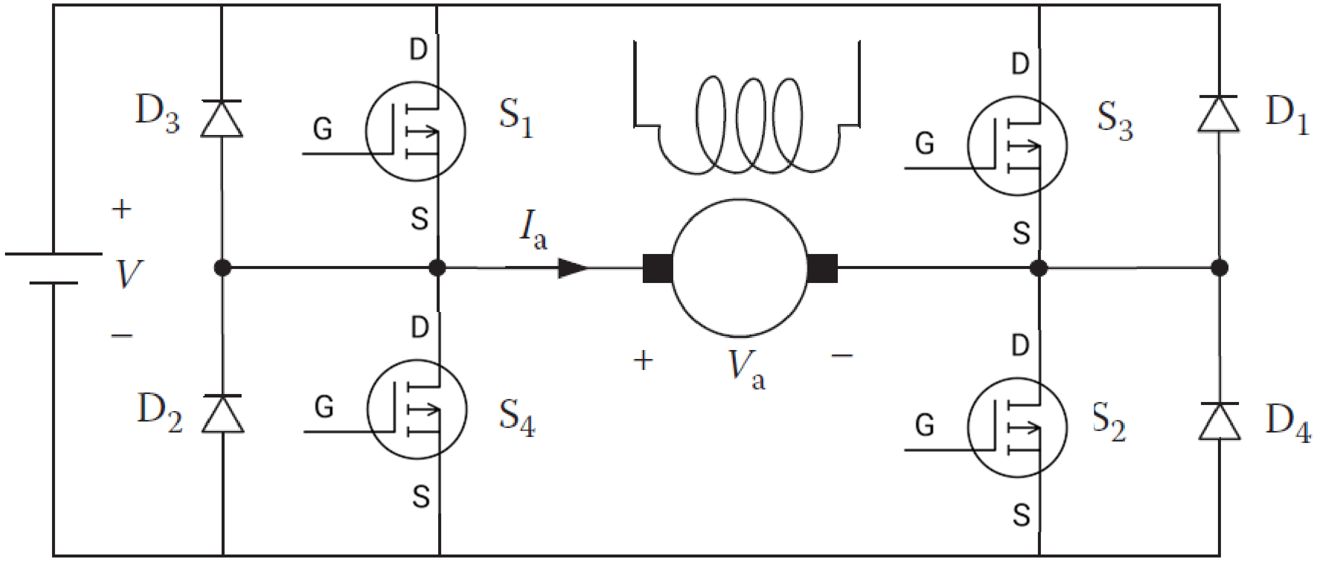
- Buck converter without filter?
- Filter not needed for motor
- also called DC chopper
  - Class A chopper
  - Single quadrant chopper
- What about regenerative braking?

DC motor drive – synchronous buck



- Synchronous buck
- bidirectional power flow
- Two-quadrant chopper
- Class C chopper
- How to drive in reverse?

DC motor drive – 4 quadrant chopper

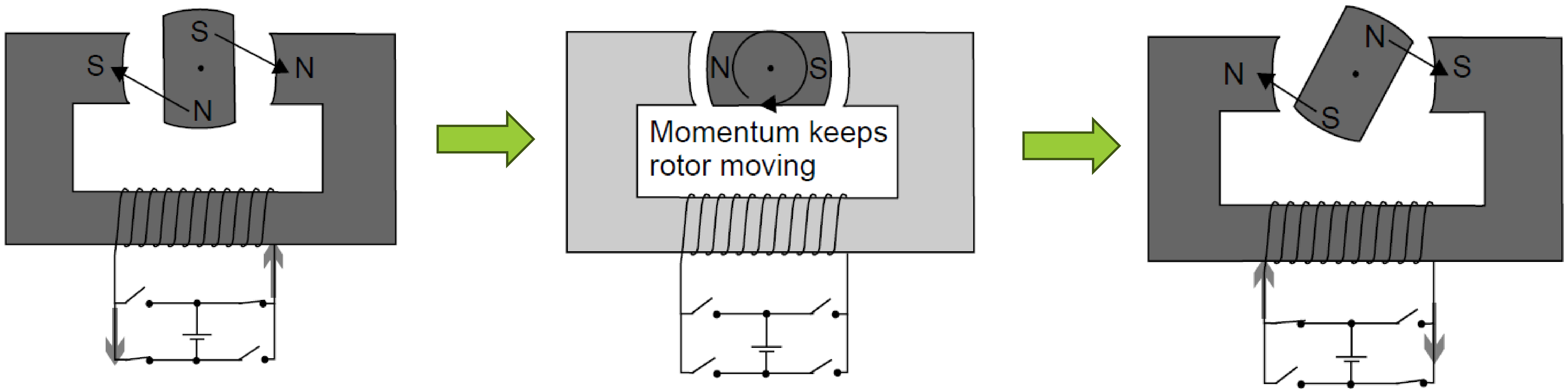


- Full bridge
- bidirectional power flow
- Four-quadrant chopper
- Class E chopper
- Drive in reverse-
  - 4 quadrant chopper vs. gear box

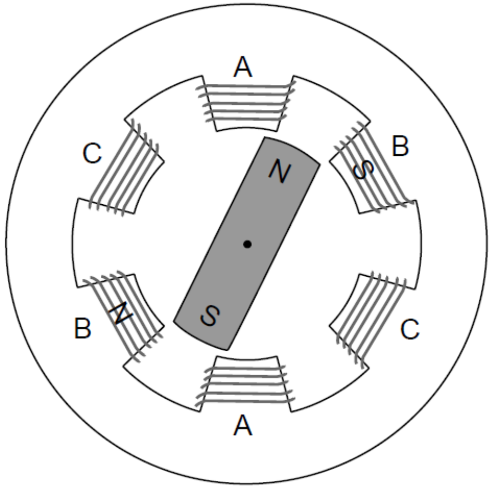
DC machine drawbacks (recap)

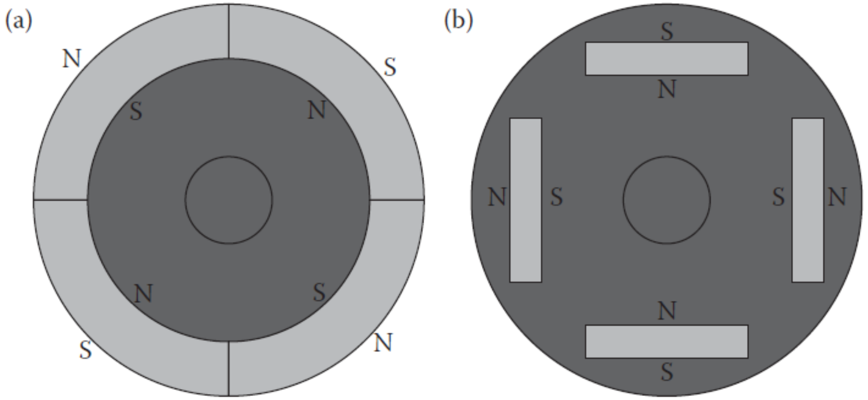
- Wear and tear of brush and commutator
  - High maintenance
  - Limited life
  - limited speed range
- Sparking at the commutator
  - sparking at brush contacts, especially under heavy load and high speed
  - EMI noise due to sparking
  - Potential safety hazards
- Higher weight and volume
- Lower efficiency

Requirement for rotor rotation



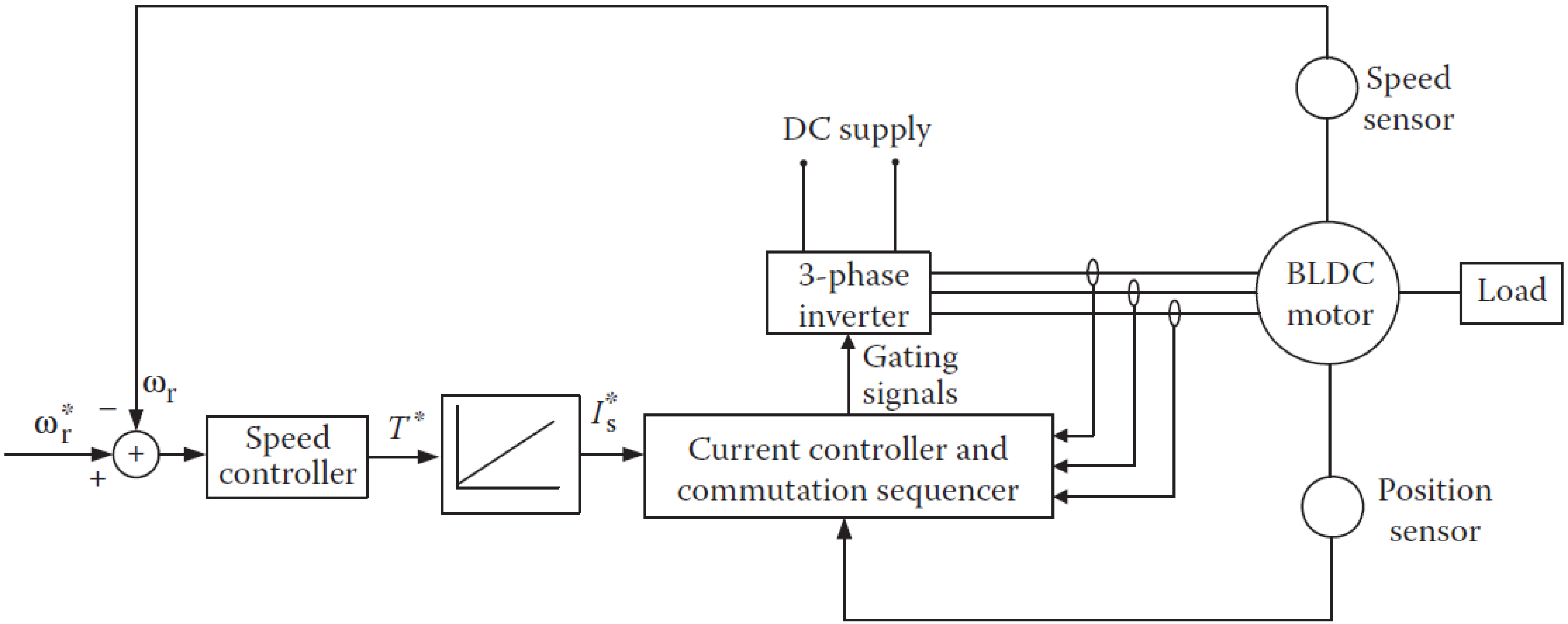
Coil arrangements in a BLDC





- Multiple coils to increase torque
- Strong magnet needed for rotor
- No current flow in rotor
- Only stator cooling required
- Two types of PM mounting
  - Surface and interior mounting

BLDC control loop



BLDC- advantages and limitations

- Advantages:
  - no brush, commutator
  - Low maintenance
  - Higher efficiency
  - ease of cooling
  - Low noise
- Drawbacks:
  - Higher cost of magnets
    - Cost and availability of rear earth elements
  - Limited high speed capability
    - limitation of magnet assembly strength
  - large fault current in case of drive failure
    - Can causse wheel block
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  - Limited constant power range
    - Lack of field strength control
  - Need for position sensors
    - costly
    - can lead to reliability issues

Thank you!