

- The **start of back EMF** in current and torque is that they: When a DC electric motor is first started, the **total EMF is high and low**. **Current flowing through the coil is high and input to the motor is current**. **As the coil rotates faster**, the **back EMF increases** so the **total current flowing through the motor is reduced** since the motor is in motion. Due to mechanical resistance in the motor, the back EMF is never equal to, but always less than, the supply EMF. The increase in total current with decrease in speed makes a motor self-regulating to some extent.



$$I_{\text{coil}} = I_{\text{ext}} - I_{\text{back EMF}}$$



- When the motor is spinning at high revolutions, the **back EMF is large and the current passing through the coil is small**. Therefore the motor is protected from the risk of burnout.

$$I = \frac{V}{R} \quad V_{\text{ext}} \rightarrow I \times R$$

- However, a motor at start-up **has no back EMF** - it can draw too much current and overheat and burnout. $V = IR$, $I = \frac{V}{R} \rightarrow V \uparrow \therefore I \uparrow$
- To protect the motor on start-up, an adjustable starting resistor is placed in the circuit.
- The resistor is removed when the motor's speed increases.

$$V = IR, \quad I = \frac{V}{R}$$

Energy Transformations in DC Motors

- The **mechanism of back EMF** means that an electric motor draws less current and **transfers energy at a slower rate**. This is due to the **decreased net torque** at high rotor speeds, which results in a **lower acceleration** and **less kinetic energy** released at a **lower rate**. The motor's energy must come from the electrical supply. It **transfers less energy** than the supply must be **supplying**.

- Consider an ideal motor with no friction. The energy transformation depends on rotation speed as summarised below:

	Low speed	Maximum speed
Back EMF	Low	High (equal to supply EMF)
Total EMF		
Total current		
Total torque		
Power from power supply ($P = VI$)	High	Zero
Result	Coil accelerates	Coil rotates at constant speed
Energy transformation	Electrical energy is taken from the power supply and increases the mechanical energy of the coil	No energy taken from power supply. Coil's mechanical energy remains constant

- Recall that torque is analogous to force.
 - An object travels at **constant velocity** when the **net force is zero**.
 - An object rotates at **constant speed** when the **net torque is zero**.
- Note that the above is an ideal case - **in reality, there will be inefficiencies** (such as friction) in the motor that mean it will **never draw zero current to maintain a constant rotational velocity**.

Handwritten notes:

- ↳ due to friction between coil and magnet
- (mechanical resistance of coil)
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