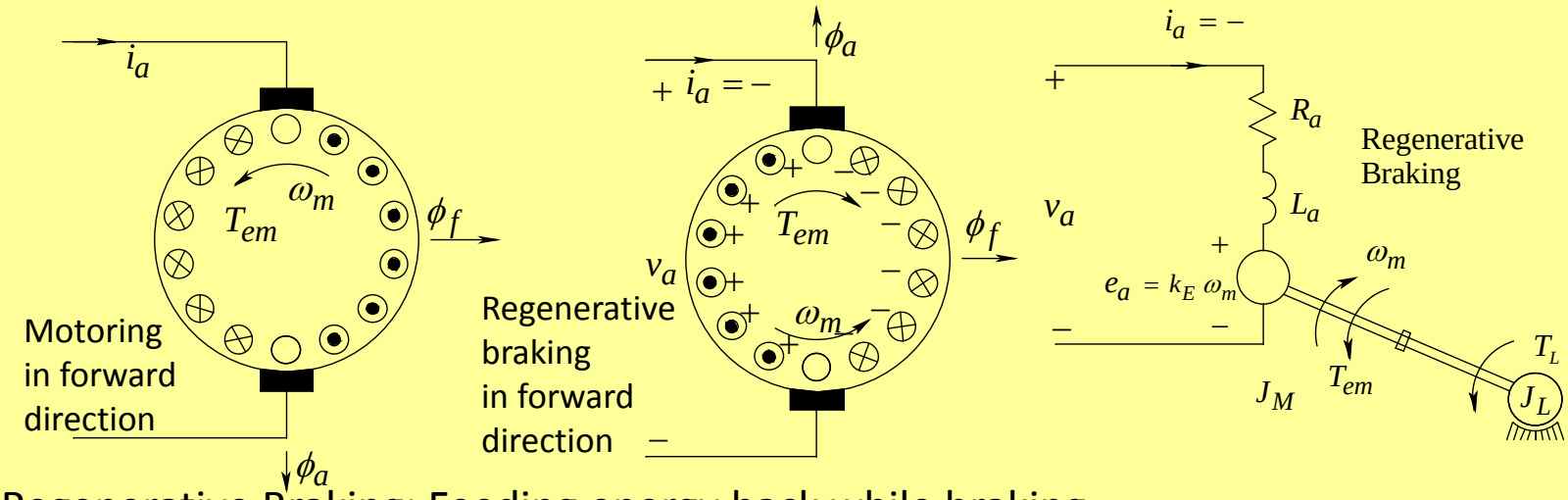
DC Motor Drives

- Operating Modes
- Four-Quadrant Operation
- Flux-Weakening
- Power-Processor Unit (PPU)
- Electronically-Commutated Motor Drives

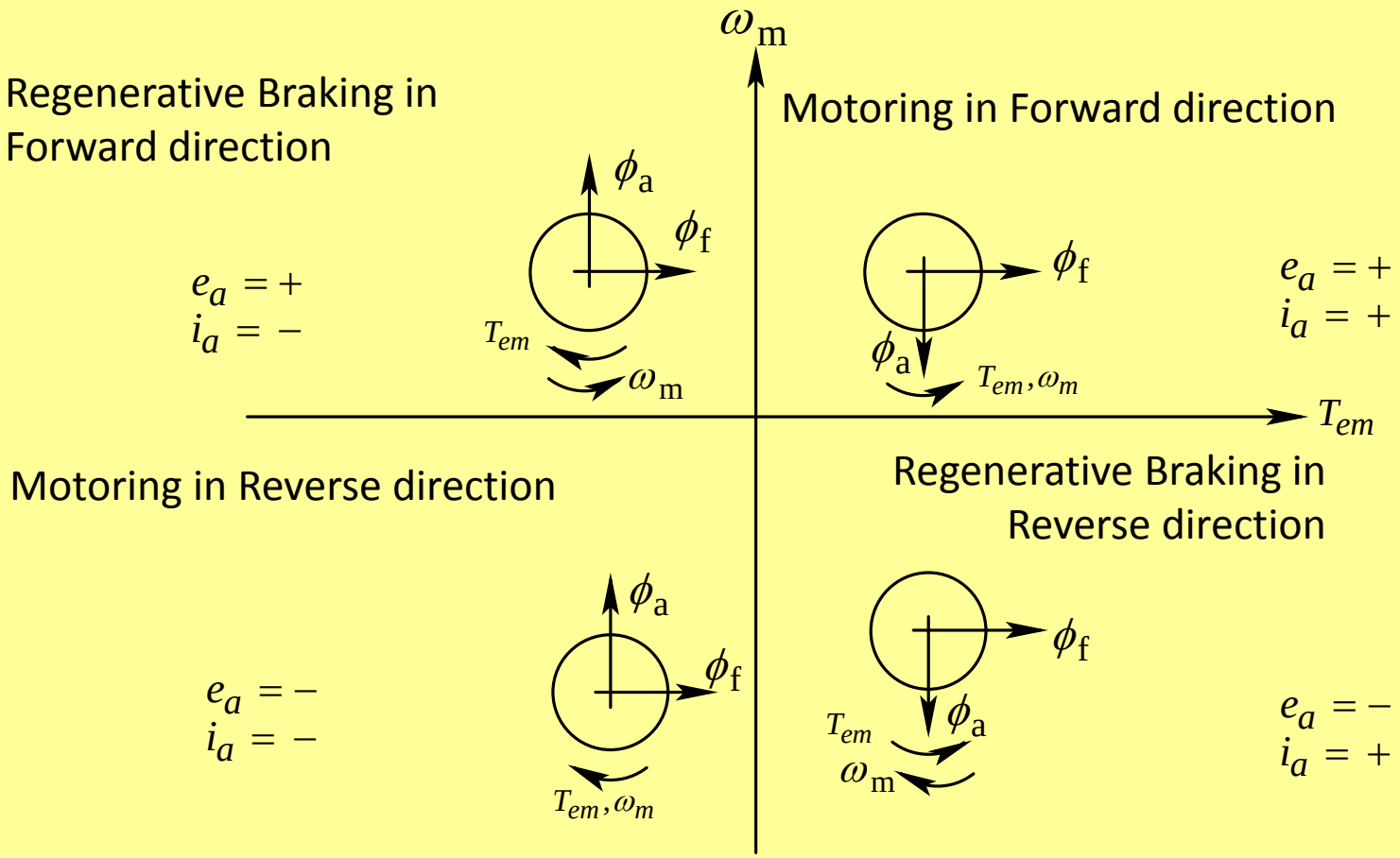
Operating Modes



- Regenerative Braking: Feeding energy back while braking
  - current and torque direction reversed
  - same polarity of induced emf

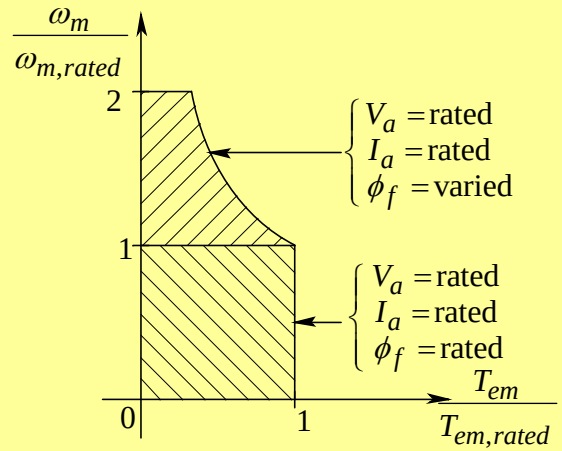
- Operation in reverse direction: polarity of applied voltage reversed
  - Motoring $i_a < 0$
  - Regenerative braking $i_a > 0$

Four Quadrant Operation



Flux-weakening in wound field machines

to Allow Overspeed Operation

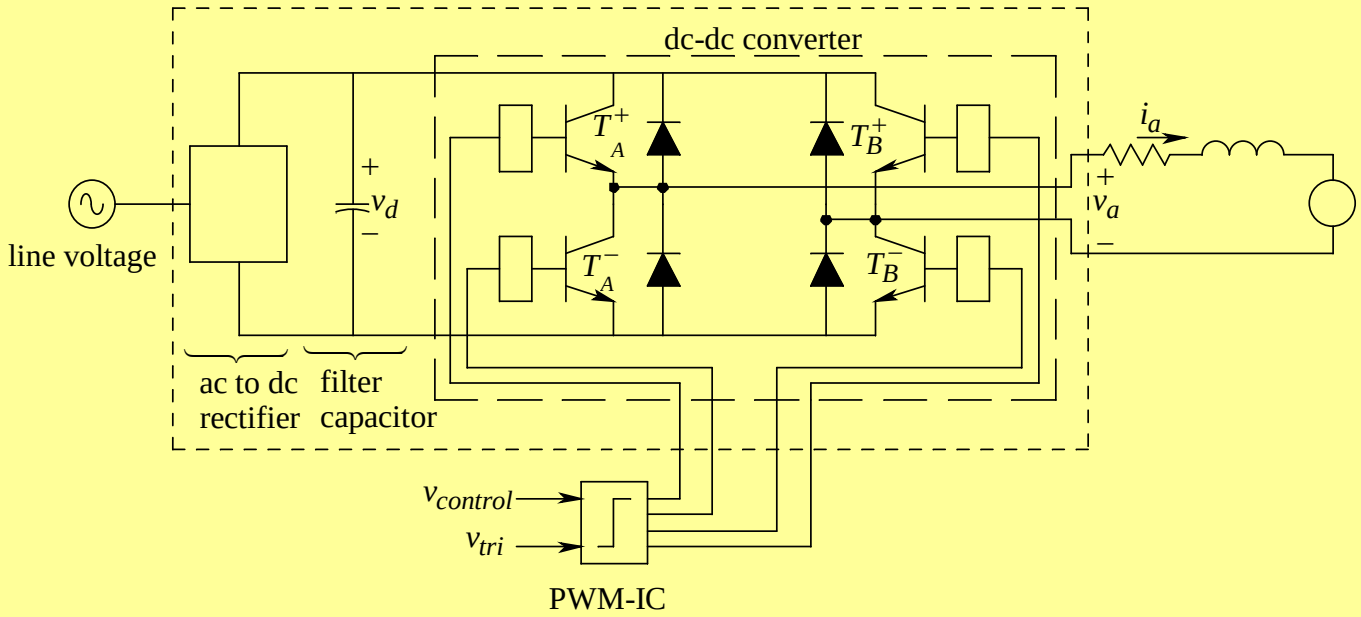


- Below rated speed, k_T maximum to ensure maximum torque/Ampere thereby minimizing resistive losses
- Above rated speed, B_f reduced to keep V_a at its rated value.
- B_f reduced by reducing I_f
- k_T and k_E changed; $k_T = k_t B_f$; $k_E = k_e B_f$; $k_t = k_e$
- Since I_a is limited to its rated value maximum, T_{em} reduces

Power Processing Unit for DC Drives

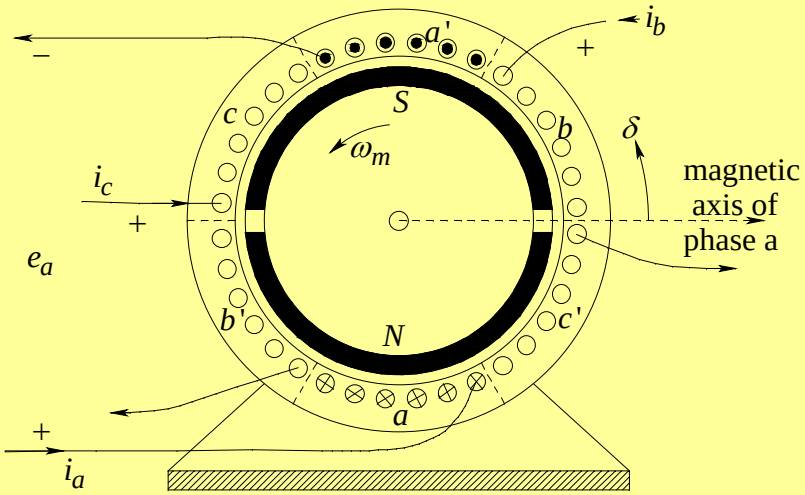
- Draw power from utility - power quality problems

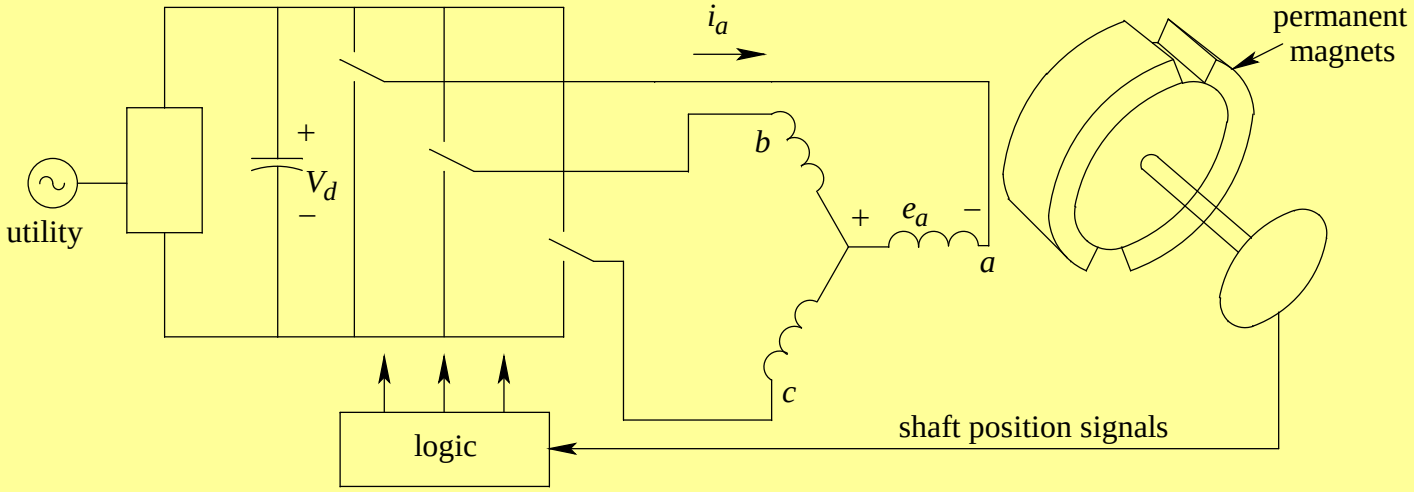
  Ideally power flow should be reversible
- Provide nearly dc voltage and current to the dc motor



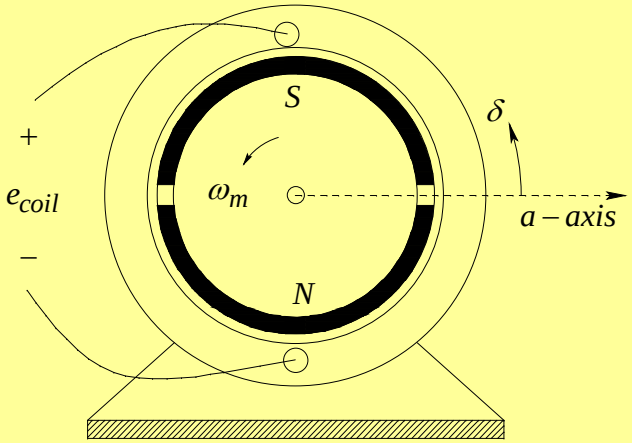
Electronically Commutated Motor Drives (Trapezoidal waveform brush-less dc)

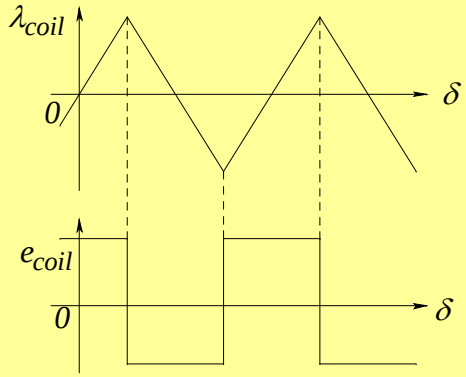
- "Inside out" machines
- Electronically commutated armature
- At any instant, only two sets of windings carry currents. As the rotor turns, different pairs of windings are chosen.

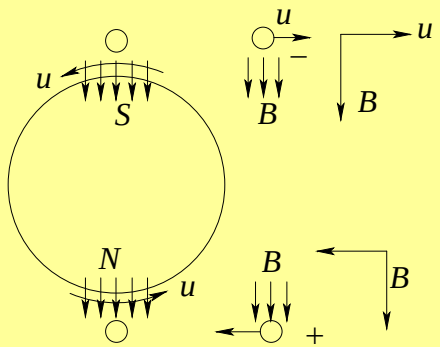




Rotating Field & Stationary Conductors







- Flux linkage of a single turn coil

$$\lambda_{coil} = (\pi r l) B_f \left(\delta / (\pi/2)\right) \qquad (-\pi/2 \le \delta \le \pi/2)$$

- emf induced

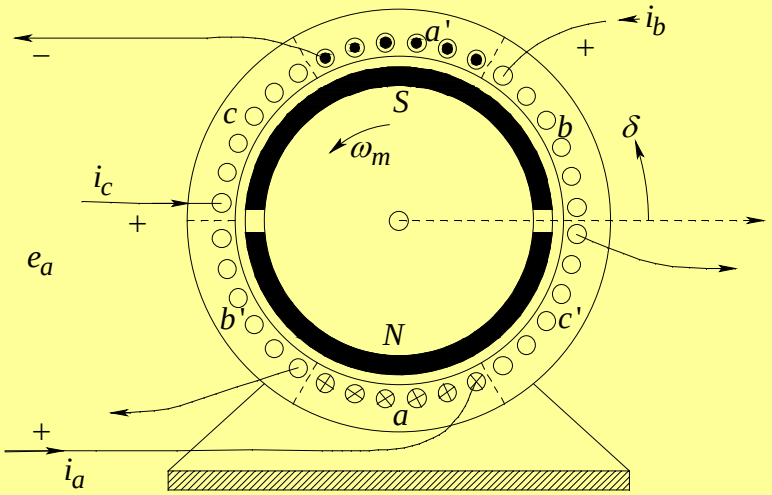
$$e_{coil} = \frac{d\lambda}{dt} = \frac{d\lambda}{d\delta}\frac{d\delta}{dt} = \frac{\pi r l B_f \omega_m}{\pi/2} = 2\underbrace{B_f l r \omega_m}_{e_{cond}}$$

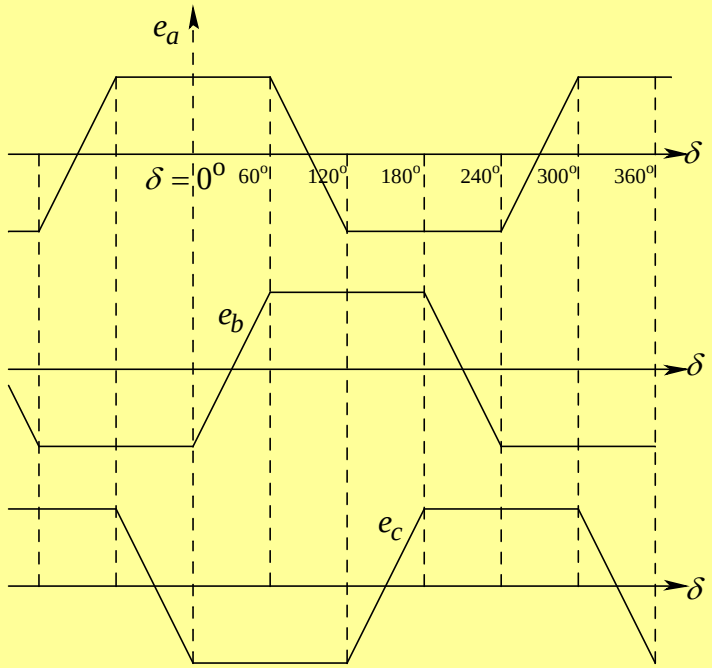
total induced emf = $2N_s B_f l r \omega_m$

(when all turns are under common pole)

- Polarity determined by assuming field to be stationary and and the conductor moving in opposite direction

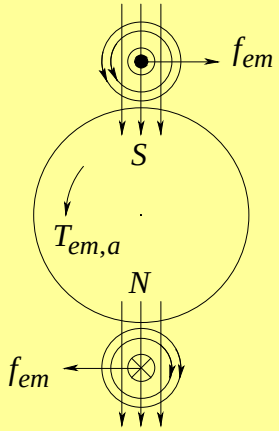
Induced emf





- In flat regions all turns are under same pole
- In sloped regions some turns are under *N* pole while others are under *S* pole

Torque Production

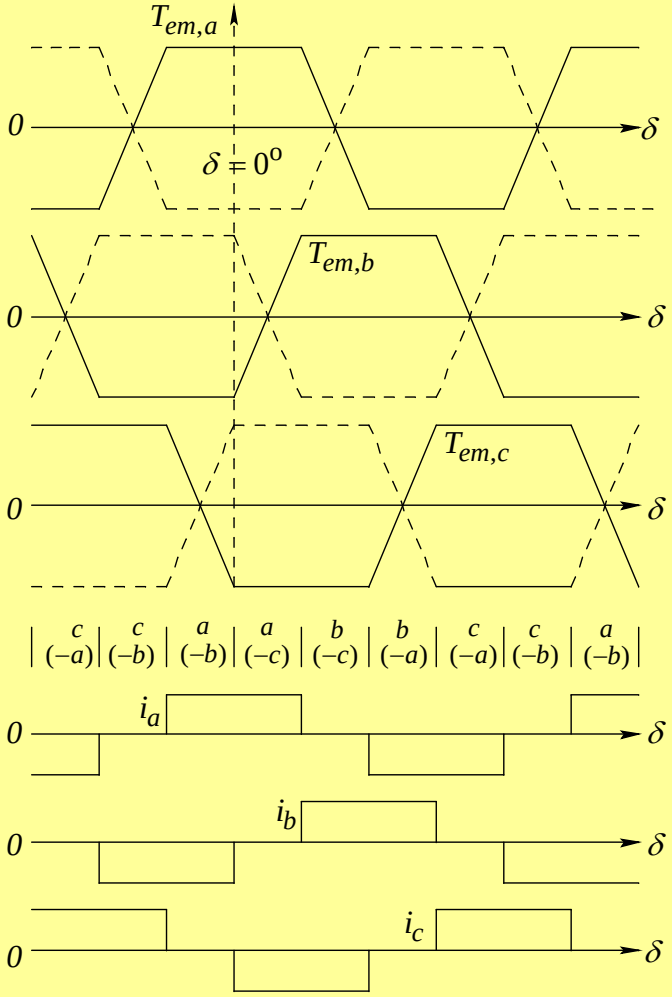


- Force on conductors $f = Bli$

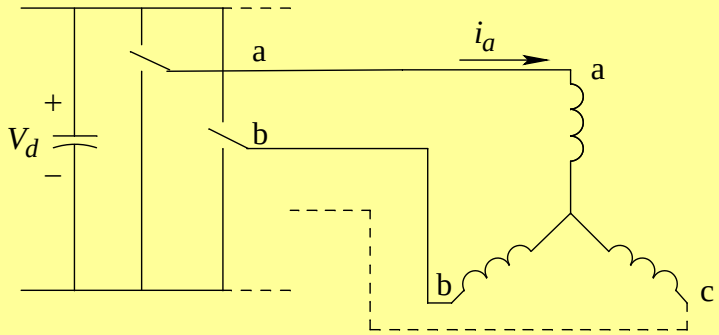
  torque on rotor CCW

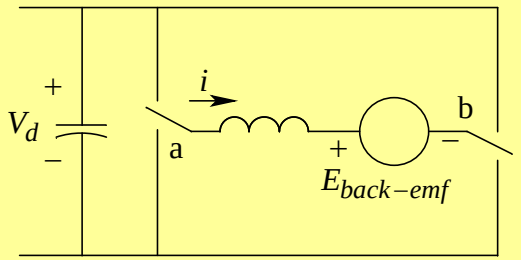
- Excite two phases simultaneously

  Total $T_{em} = 2 \times (2N_s B_f lr)\ I = k_T\ I$



Equivalent circuit

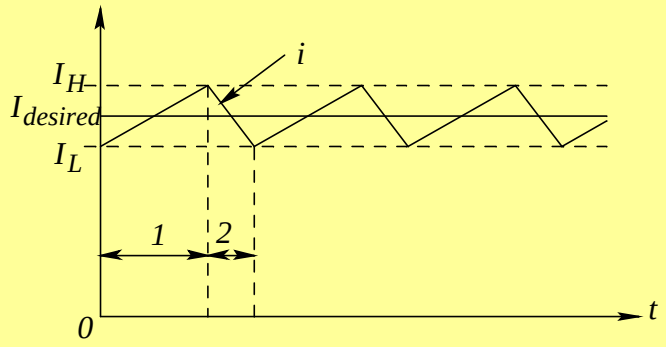




Phase-to-phase back induced emf

$$e_{back-emf} = 2e_{ph} = 2 \times (2N_s B_f lr)\omega_m = k_E \omega_m \qquad k_E = k_T$$

Hysteresis current control



Position 1: Pole *a* high, Pole *b* low
Position 2: Pole *a* low, Pole *b* high
After 60^o rotor rotation, a new pair of poles (*a*,*c*) are used

Summary

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