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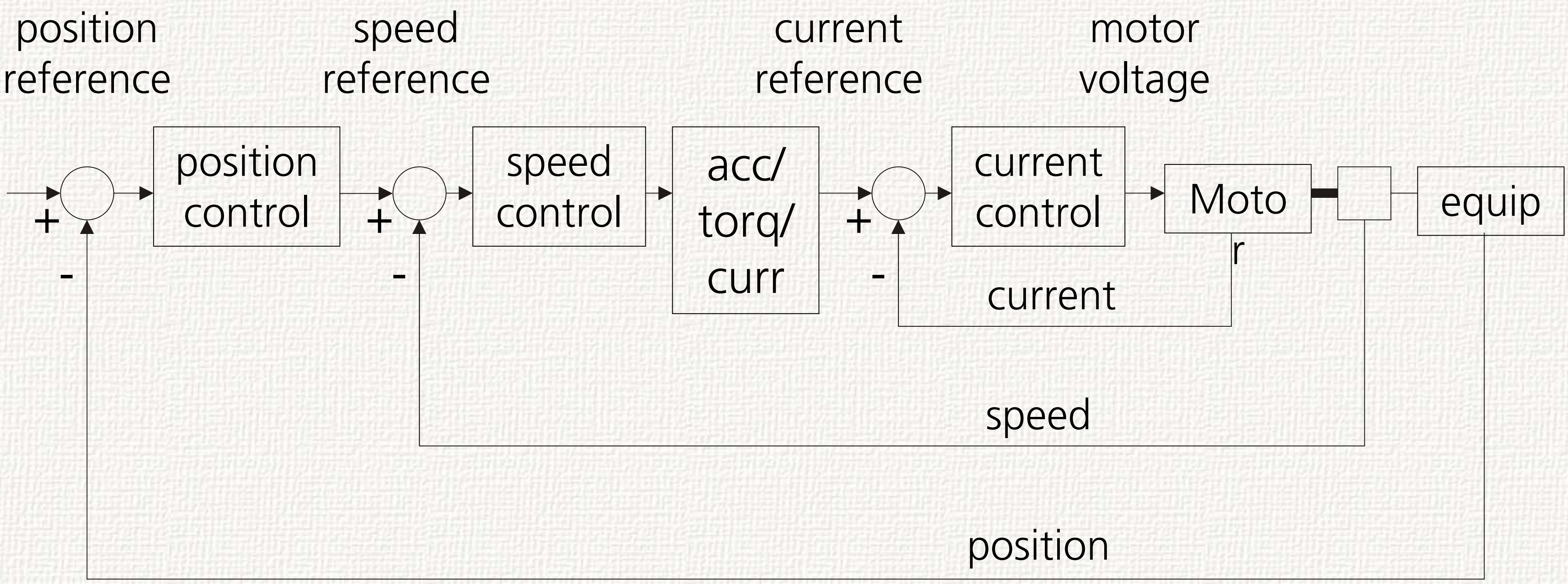
Control

Position control



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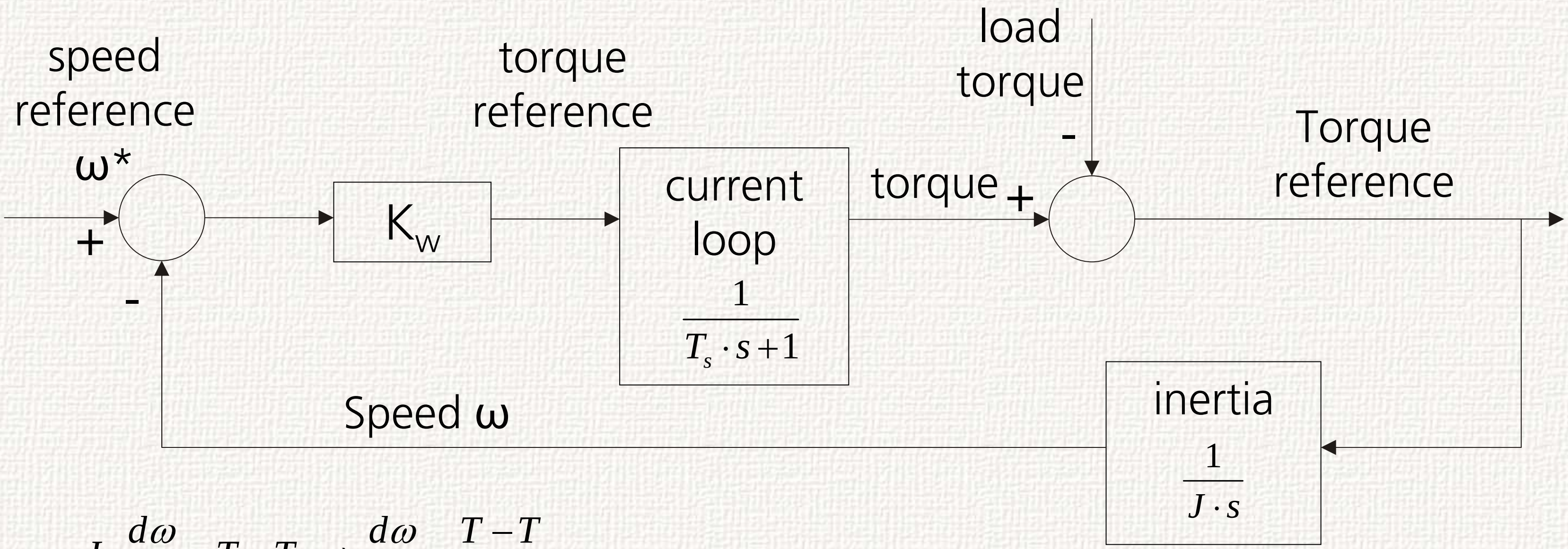
Speed control



$$J \cdot \frac{d\omega}{dt} = T - T_L \Rightarrow \frac{d\omega}{dt} = \frac{T-T}{J}$$

$$\frac{\omega}{\omega^*} = \frac{1}{1 + s \cdot \frac{J}{k_w} + s^2 \cdot \frac{J \cdot T_s}{k_w}}$$

$$s = -\frac{1}{2 \cdot T_s} \pm \sqrt{\left(\frac{1}{2 \cdot T_s}\right)^2 - \frac{k_w}{J \cdot T_s}}$$

$$k_w = \frac{J}{4 \cdot T_s}$$

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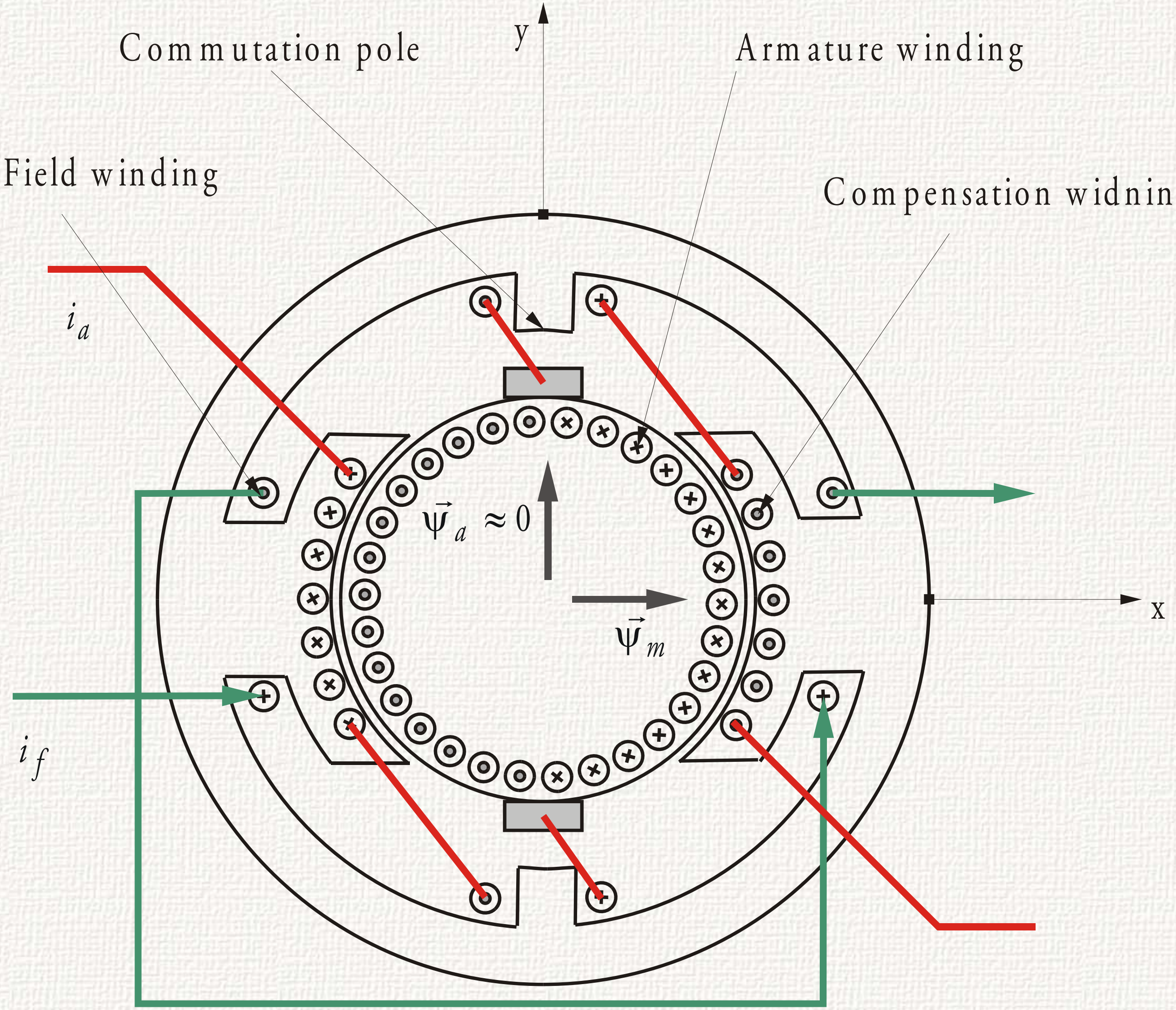
DC-motor



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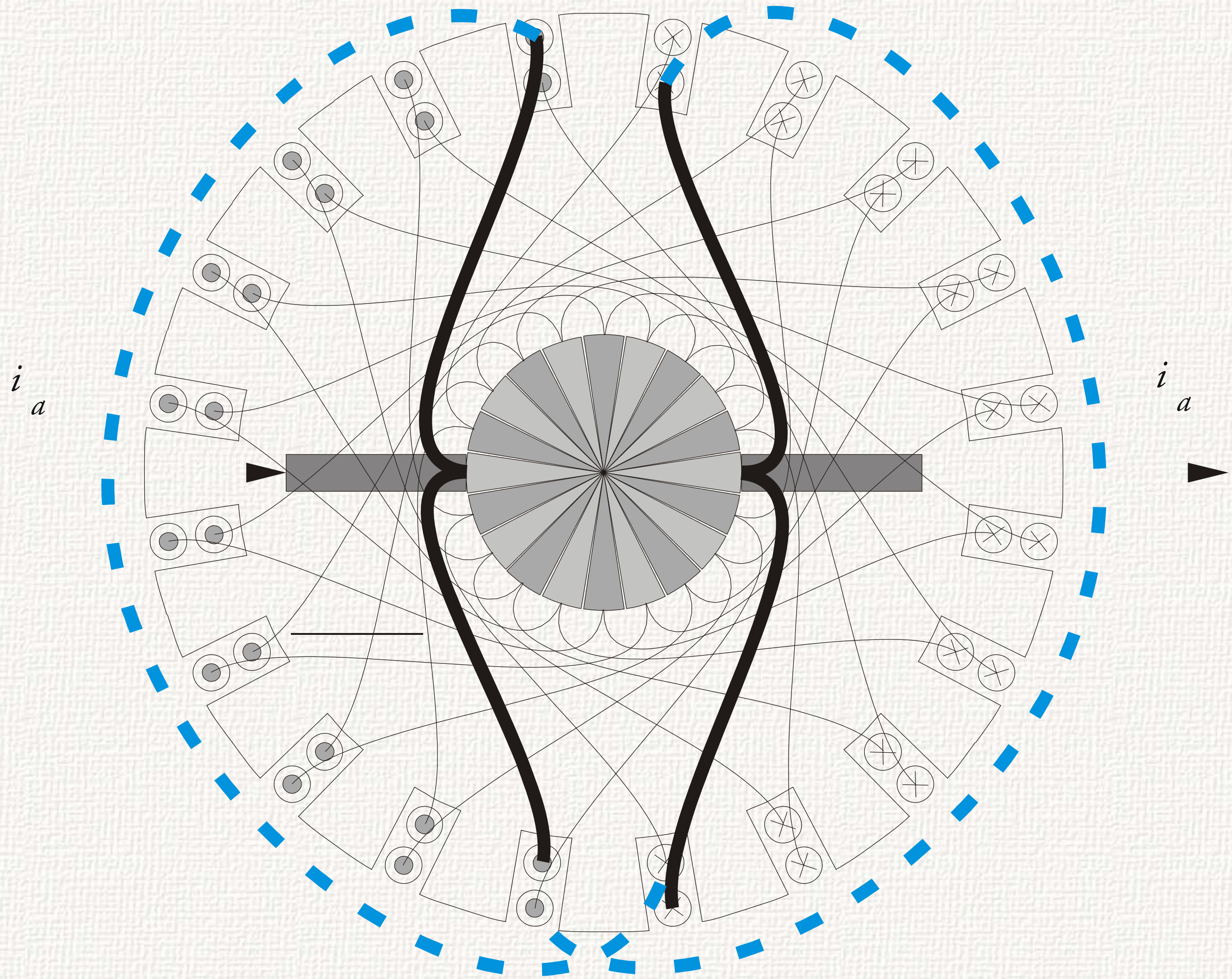
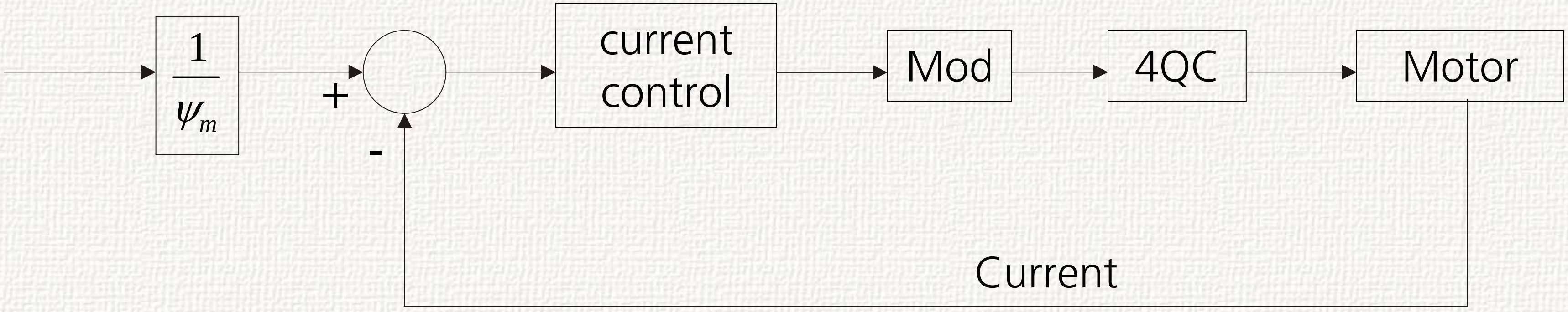
Detailed picture of the rotor



Current control of DC-motor



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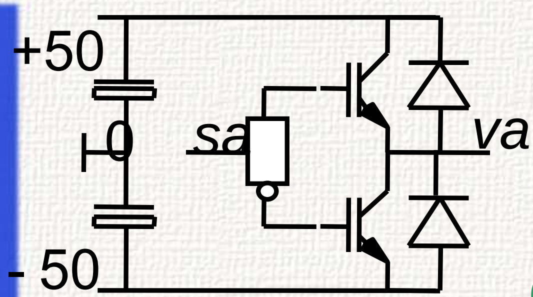
Current control of DC-motor, cont'd

$$u_a = R_a \cdot i_a + L_a \cdot \frac{di_a}{dt} + e_a = \{R_a = 0\} = L_a \cdot \frac{di_a}{dt} + \omega_r \cdot \psi_m$$

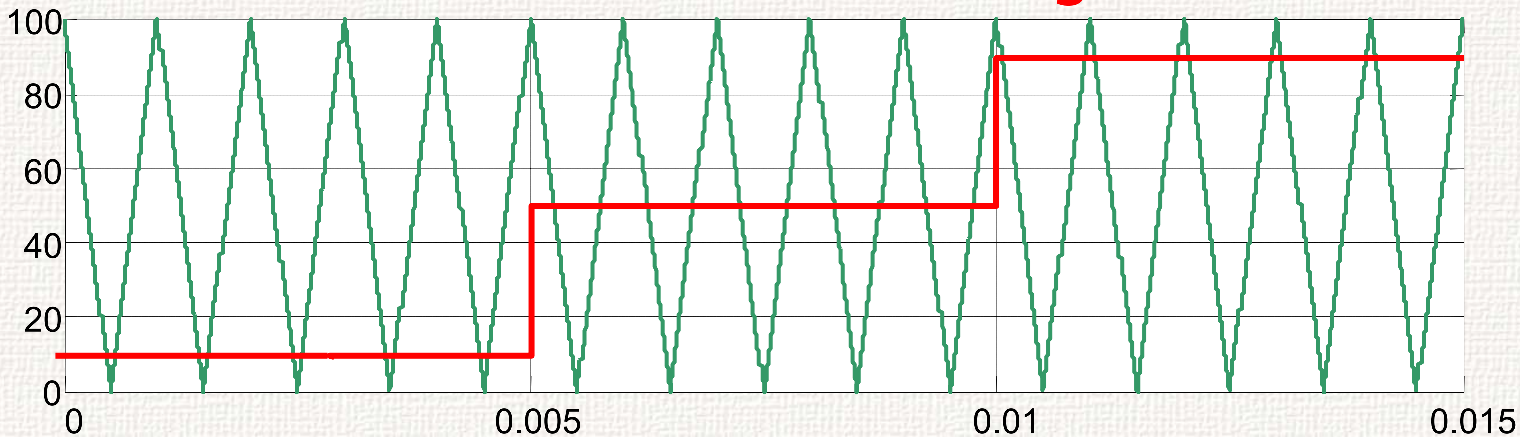
$$u_a^*(k) = L_a \cdot \frac{i_a(k+1) - i_a(k)}{T_s} + \omega_r(k) \cdot \psi_m$$

$$u_a^*(k) = k_i \cdot \left(i_a^*(k) - i_a(k)\right) + \omega_r(k) \cdot \psi_m$$

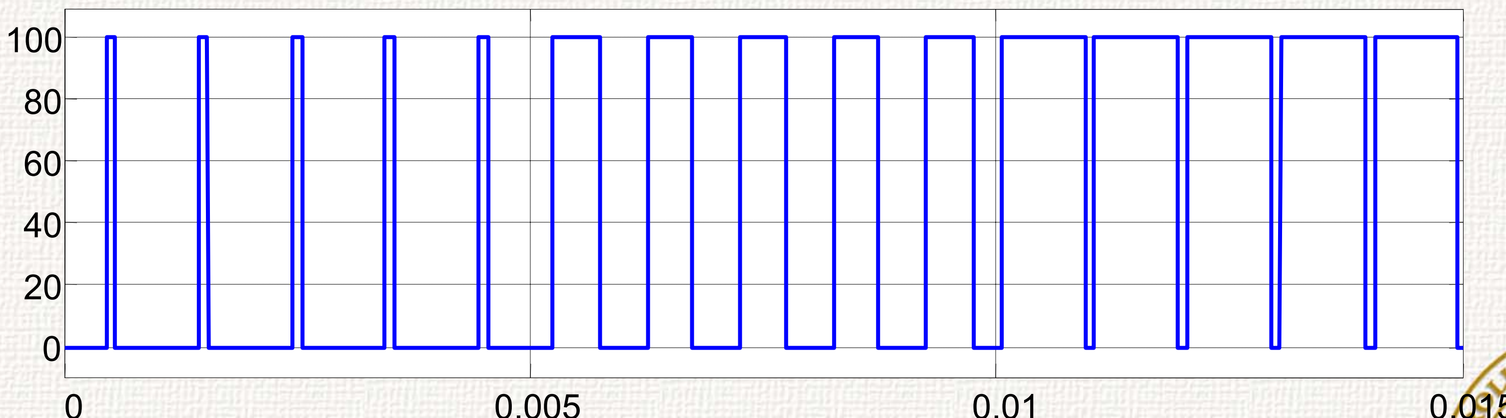


Puls width modulation

Carrier wave voltage reference

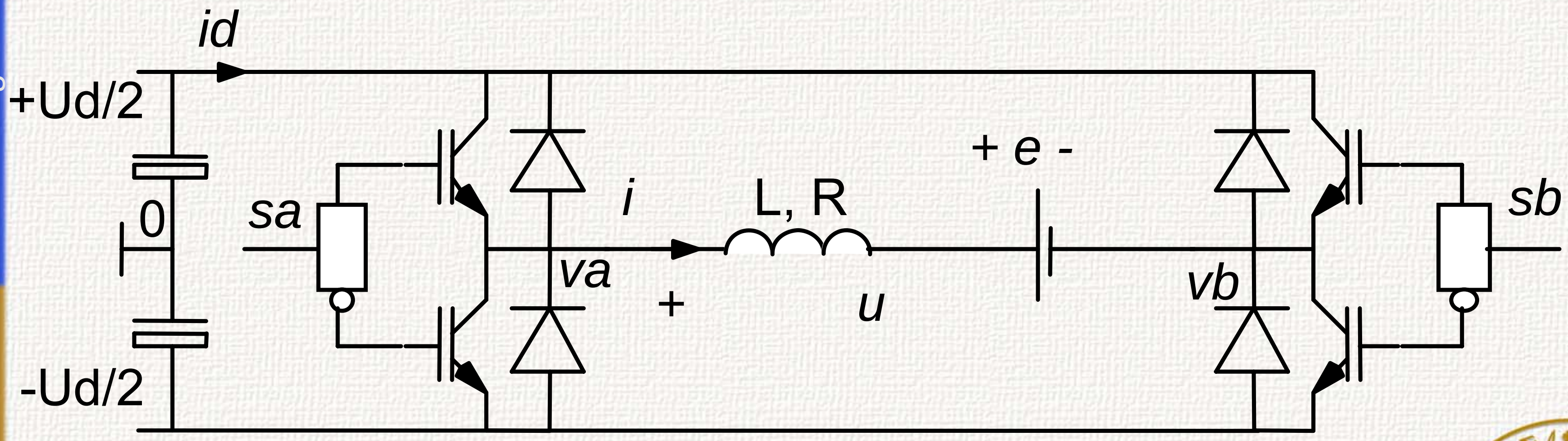


Output voltage



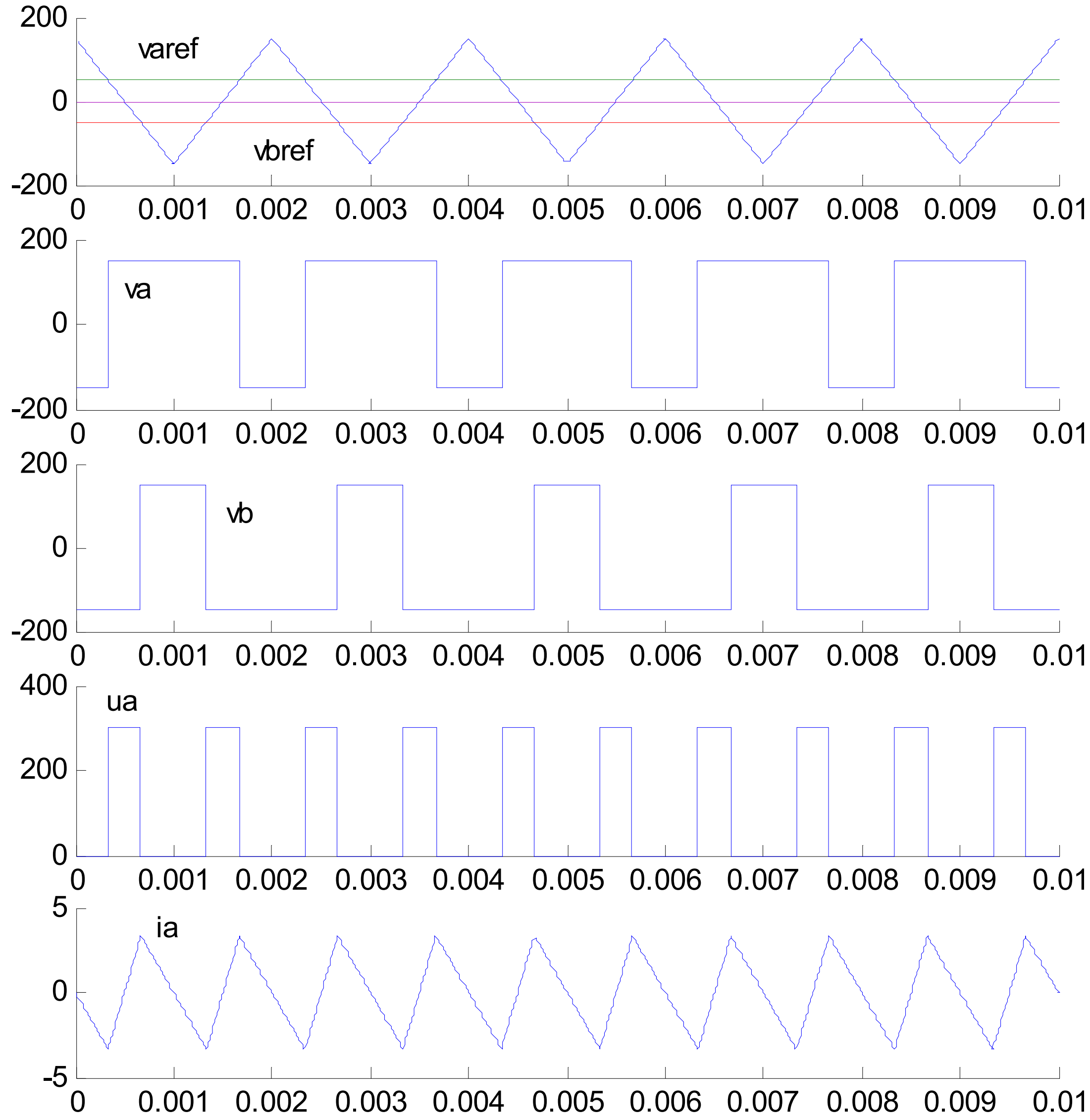
4Q PWM

- 1 voltage, 2 potentials
- infinite number of combainations of va* and vb* for u=va-vb.
- Set va*=u*/2 och vb*=-u*/2



Control of a 4-kv. DC conv:

- v_a*=u*/2
- v_b*=-u*/2
- Example:
  - Udc=300 V
  - u*=100 V



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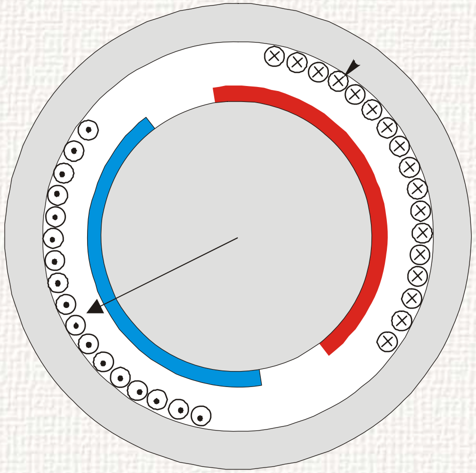
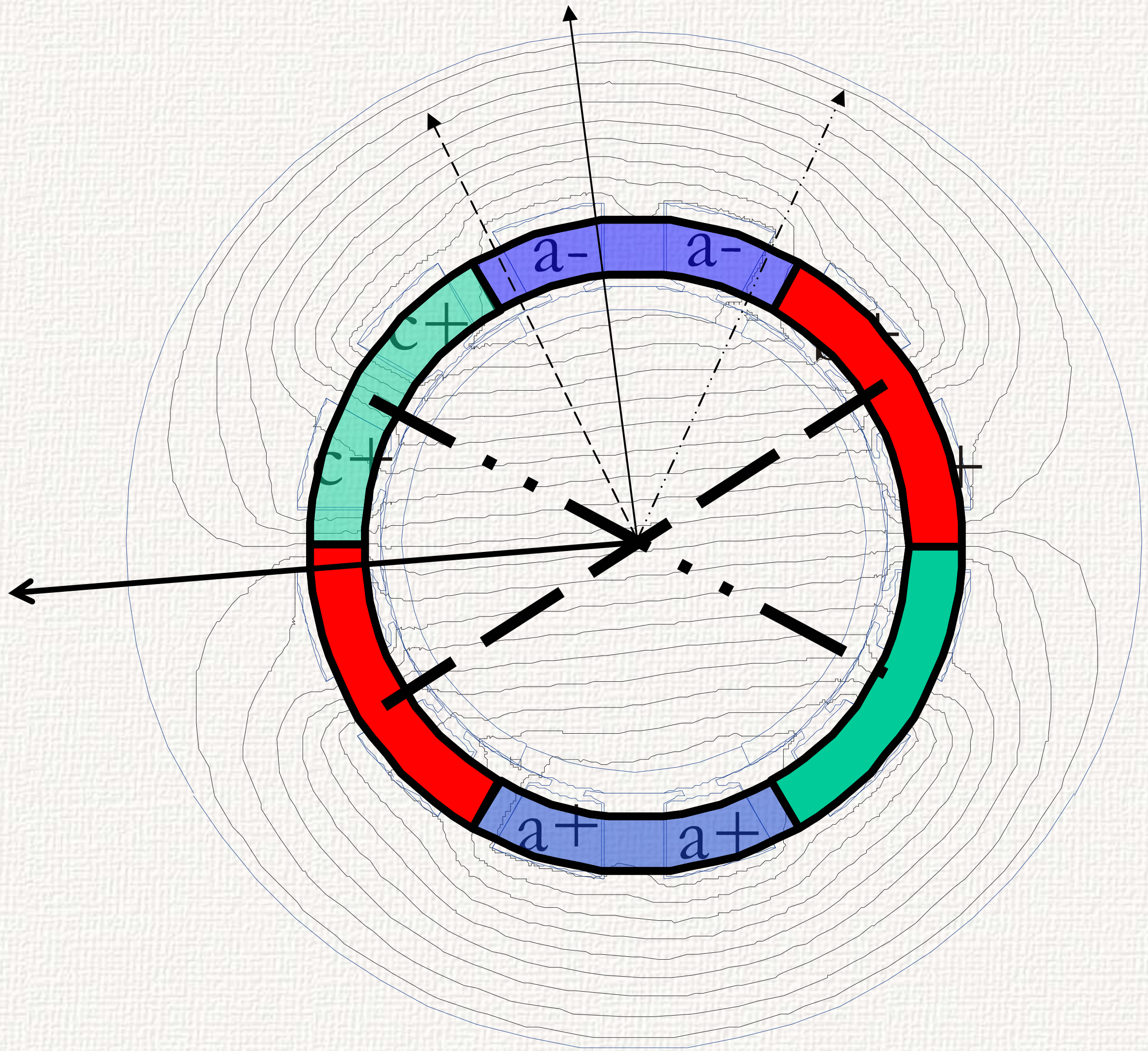
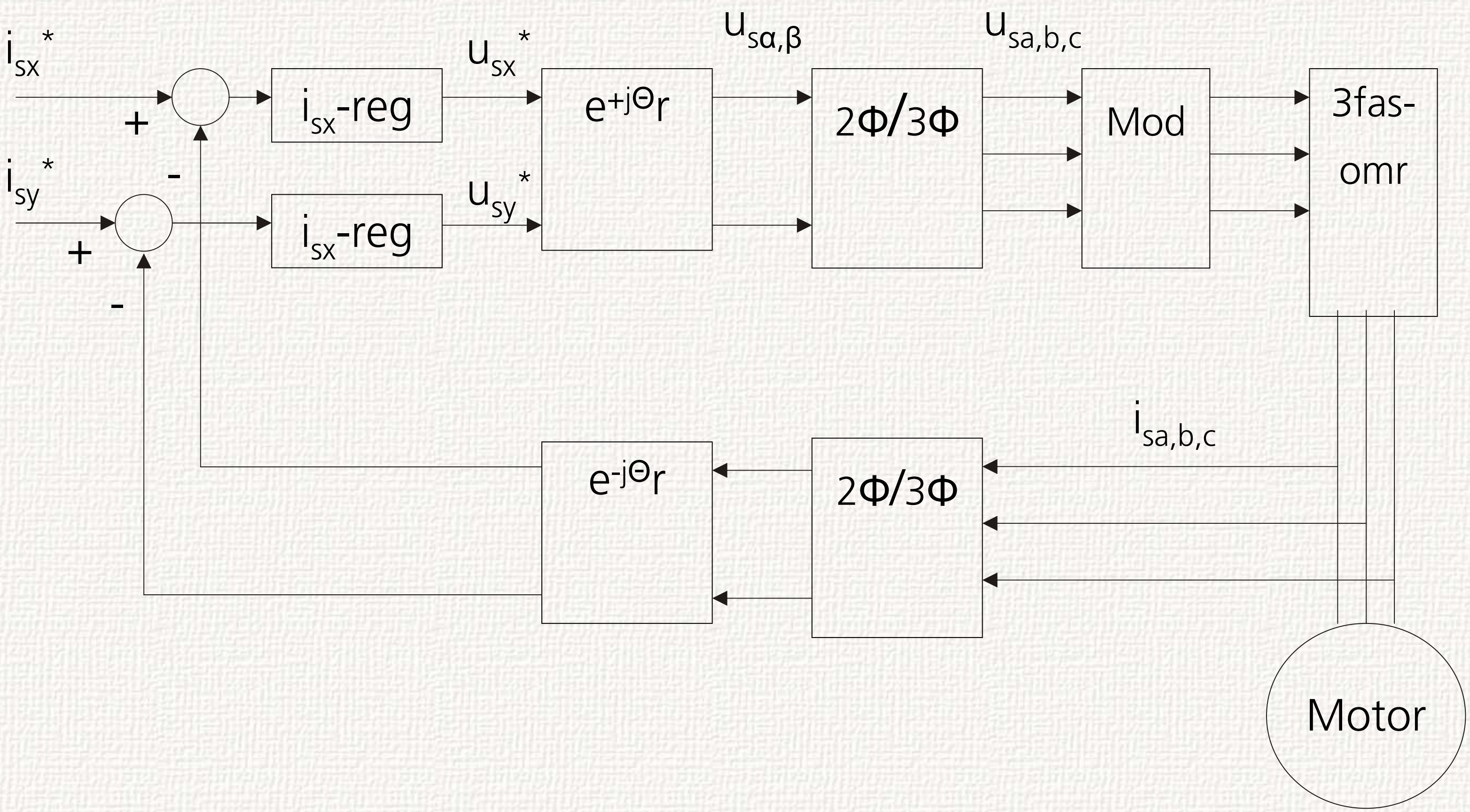
Permanent magnetized synchrounous motor, PMSM



3-phase PMSM



Vektor control of a PMSM-motor



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Convertion of current from stator to rotor coordinates

$$\vec{i}_s^{\,xy} = \vec{i}_s^{\,\alpha\beta} \cdot e^{-j\theta_r} = \vec{i}_s^{\,\alpha\beta} \cdot e^{-j\omega_r t} =$$

$$= \left(i_{s\alpha} \cdot \cos(\omega t) + i_{s\beta} \cdot \sin(\omega t)\right) + j \cdot \left(i_{s\beta} \cdot \cos(\omega t) - i_{s\alpha} \cdot \sin(\omega t)\right)$$

$$\begin{cases} i_{sx} = i_{s\alpha} \cdot \cos(\omega t) + i_{s\beta} \cdot \sin(\omega t) \\ i_{sy} = i_{s\beta} \cdot \cos(\omega t) - i_{s\alpha} \cdot \sin(\omega t) \end{cases}$$

Current control PMSM

$$\vec{u}_s^* = R_s \cdot \vec{i}_s^* + L_s \cdot \frac{\left(\vec{i}_s^* - \vec{i}_s\right)}{T_s} + j\omega \cdot L_s \cdot \vec{i}_s^* + j\omega \cdot \vec{\psi}_m$$

$$\vec{i}_s^* = \frac{T^*}{\psi_m}$$

$$\begin{cases} u_{sx}^* = R_s \cdot i_{sx} + L_s \cdot \frac{\left(i_{sx}^* - i_{sx}\right)}{T_s} - \omega \cdot L_s \cdot i_{sy} \\ u_{sy}^* = R_s \cdot i_{sy} + L_s \cdot \frac{\left(i_{sy}^* - i_{sy}\right)}{T_s} + \omega \cdot L_s \cdot i_{sx} + \omega \cdot \psi_m \end{cases}$$

where

$$i_{sx}^* = 0$$

and

$$i_{sy}^* = \frac{T^*}{\psi_m}$$

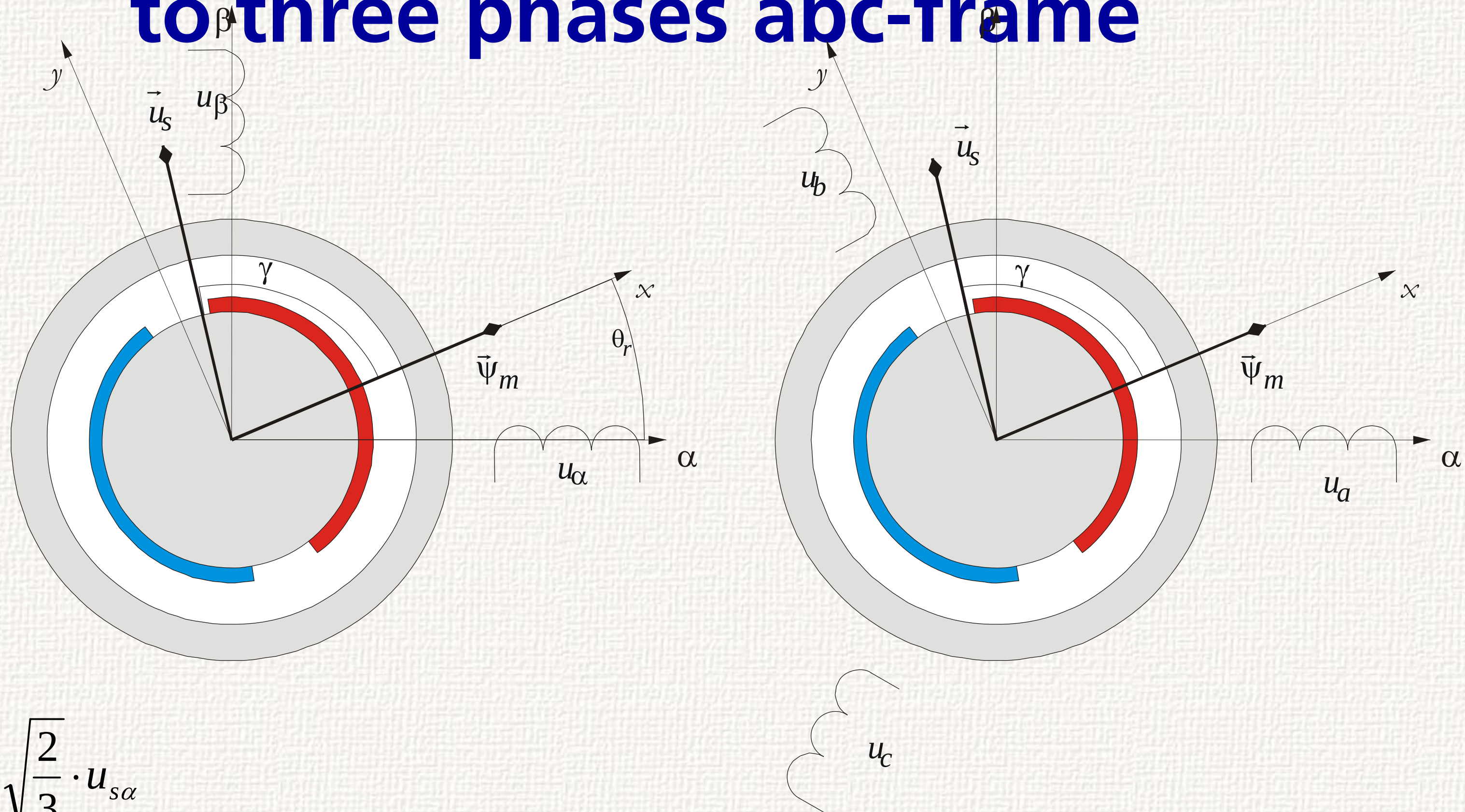
Convertion of stator voltage from rotor to stator coordinates

$$\vec{u}_s^{\alpha\beta} = \vec{u}_s^{xy} \cdot e^{j\theta_r} = \vec{u}_s^{xy} \cdot e^{j\omega_r t} =$$

$$= \left(u_{sx} \cdot \cos(\omega t) - u_{sy} \cdot \sin(\omega t)\right) + j \cdot \left(u_{sy} \cdot \cos(\omega t) + u_{sx} \cdot \sin(\omega t)\right)$$

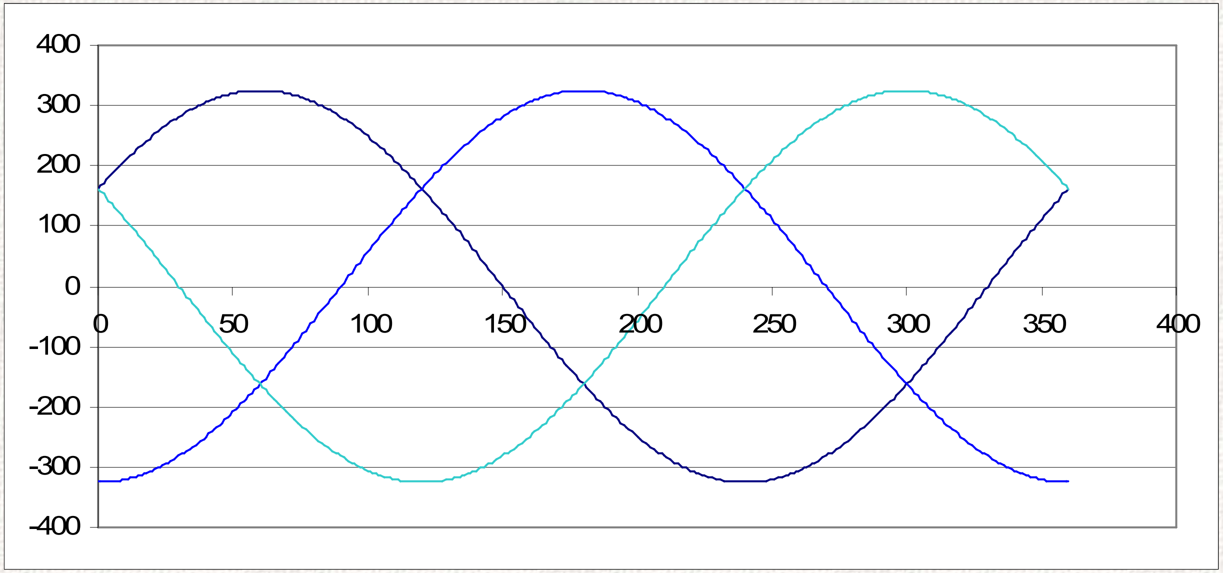
$$\begin{cases} u_{s\alpha} = u_{sx} \cdot \cos(\omega t) - u_{sy} \cdot \sin(\omega t) \\ u_{s\beta} = u_{sy} \cdot \cos(\omega t) + u_{sx} \cdot \sin(\omega t) \end{cases}$$

Conversion from two phases αβ-frame to three phases abc-frame



$$
\begin{cases}
u_a = \sqrt{\dfrac{2}{3}} \cdot u_{s\alpha} \\
u_b = \sqrt{\dfrac{2}{3}} \cdot \left(-\dfrac{1}{2} u_{s\alpha} + \dfrac{\sqrt{3}}{2} u_{s\beta} \right) \\
u_c = \sqrt{\dfrac{2}{3}} \cdot \left(-\dfrac{1}{2} u_{s\alpha} - \dfrac{\sqrt{3}}{2} u_{s\beta} \right)
\end{cases}
$$

The 3-phase voltage



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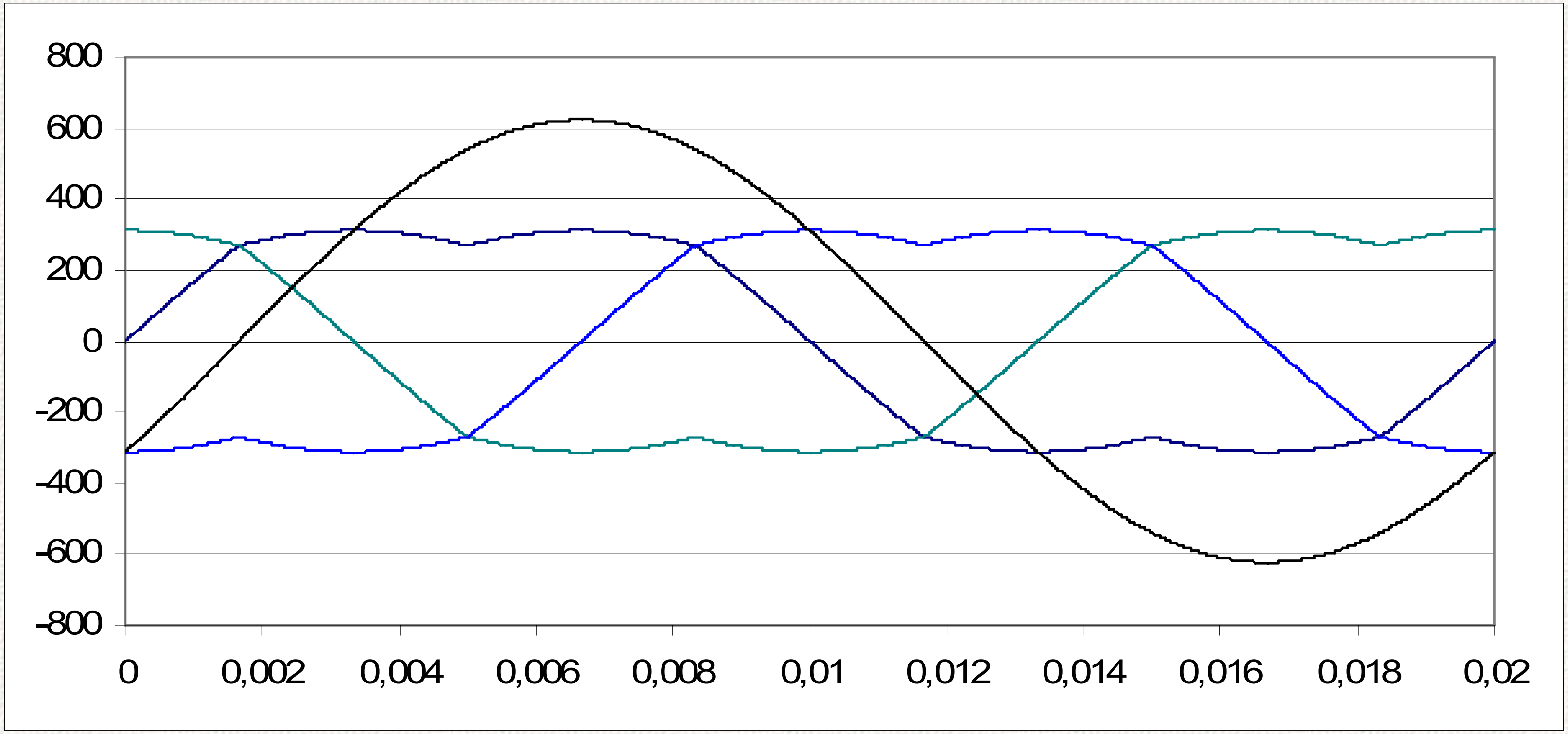
Symmetrized motor voltage



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Control of 3-phase converter

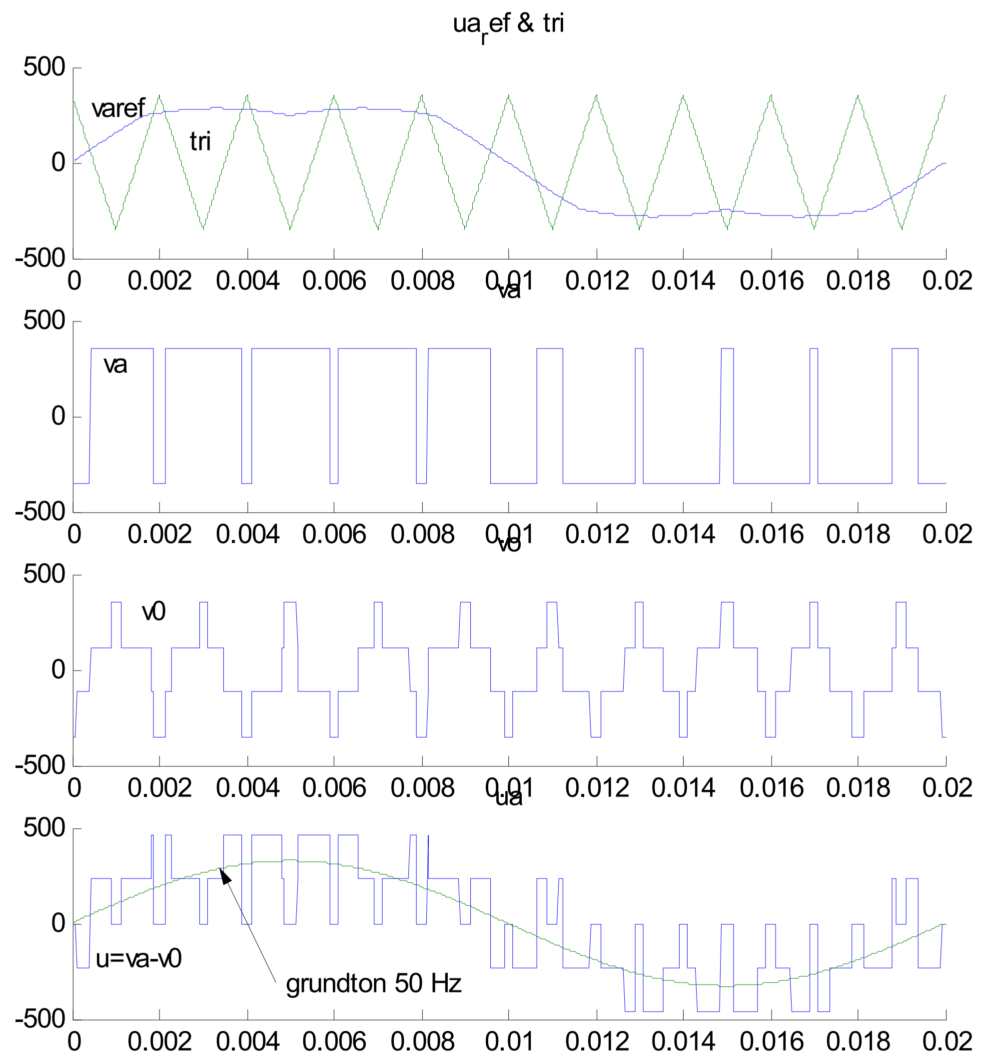
- **Symmetration of references**

$$v_a^* = u_a^* - u_z$$

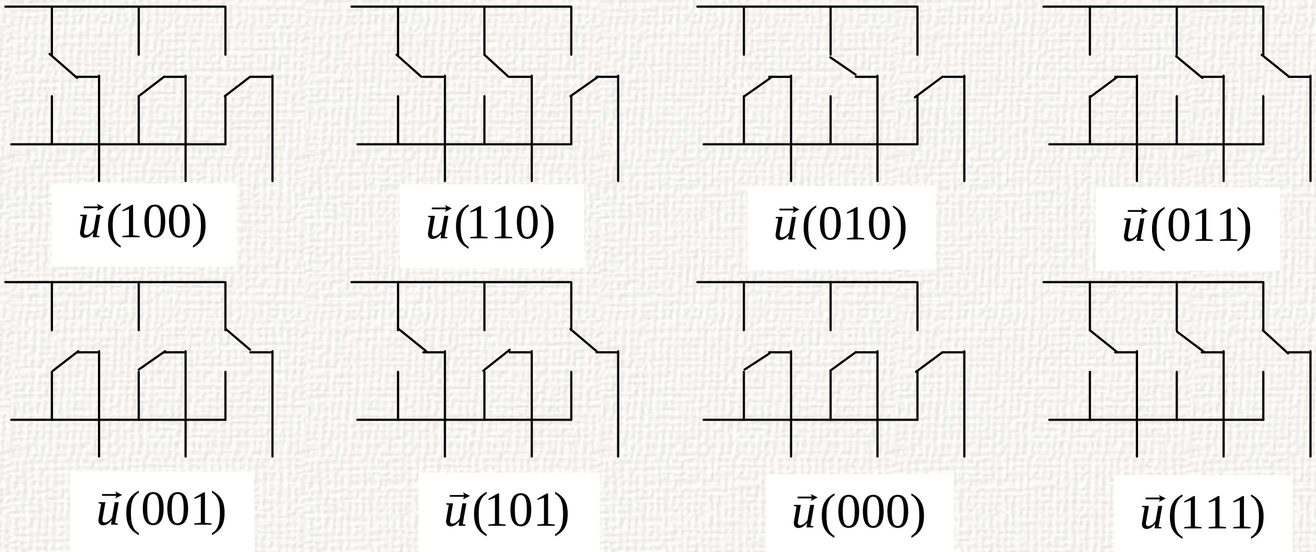
$$v_b^* = u_b^* - u_z$$

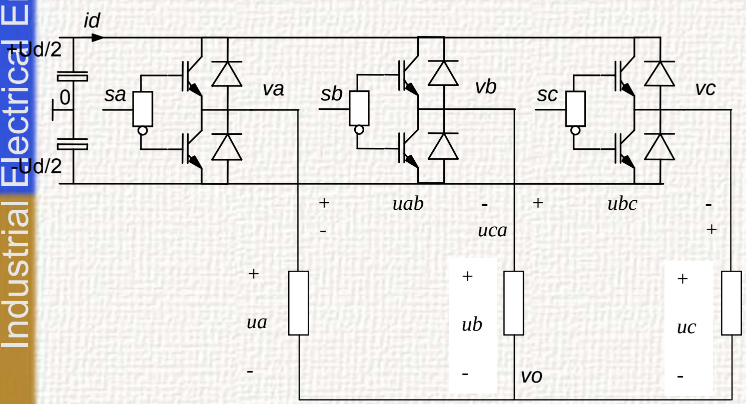
$$v_c^* = u_c^* - u_z$$

$$u_z = \frac{\max + \min}{2}$$



3-phase output voltage as vector





$$\vec{u} = u_\alpha + j u_\beta = \sqrt{\frac{2}{3}}\left[u_a + u_b e^{j\frac{2\pi}{3}} + u_c e^{j\frac{4\pi}{3}}\right] =$$

$$= \sqrt{\frac{3}{2}}u_a + j\frac{1}{\sqrt{2}}(u_b - u_c)$$