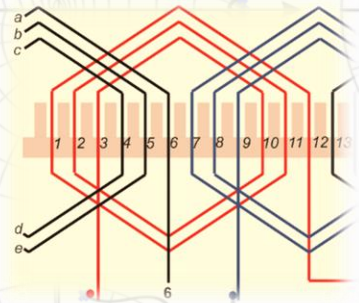
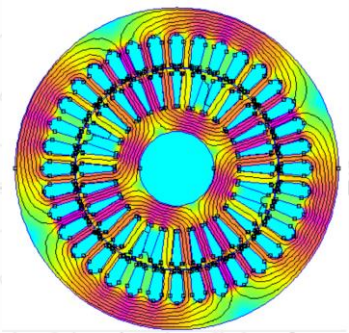
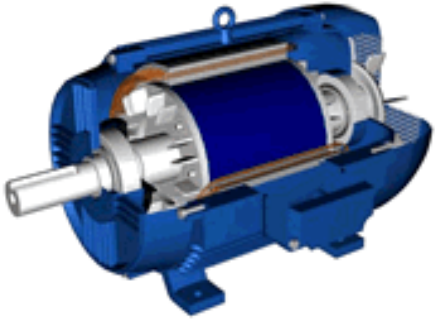


Aula 13: Teoria do campo girante

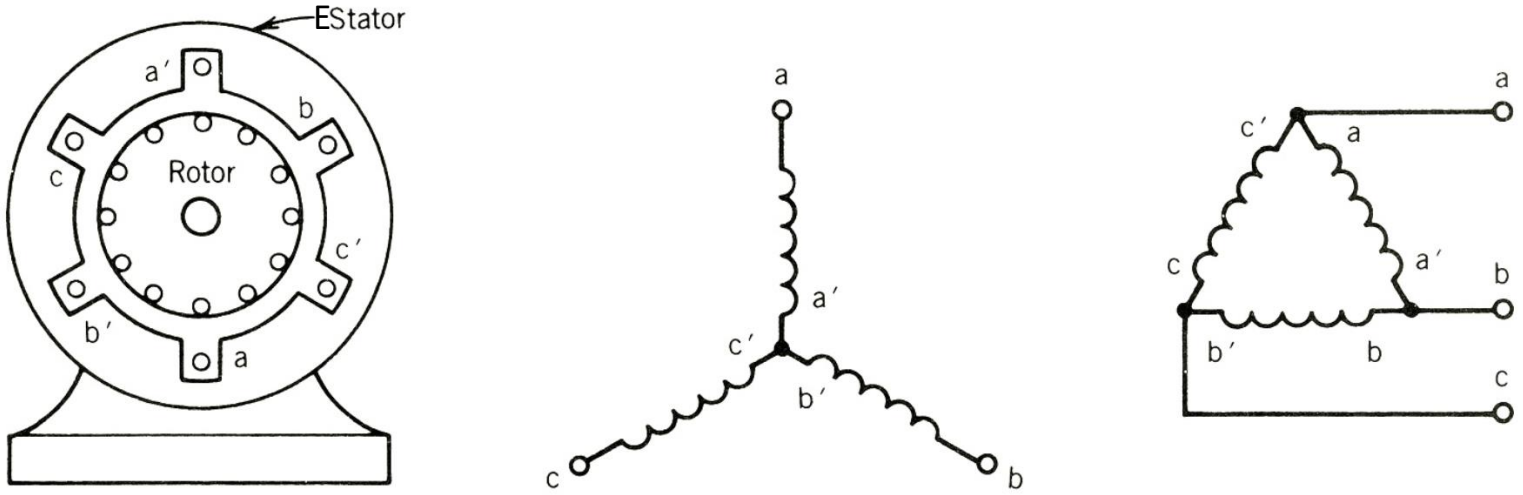
Prof. Allan Fagner Cupertino
afcupertino@ieee.org





http://www.semage.com.br/calternada.php

Estrutura do estator



- Estator com apenas uma bobina por fase (máquina de 2 pólos);
- As bobinas estão espacialmente defasadas de 120 graus (graus mecânicos);
- Correntes de estator eletricamente defasadas de 120 graus (graus elétricos).

Fonte: P. C. Sen. "Principles of Electrical Machines and Power Electronics".

Correntes de estator e força magnetomotriz

- Correntes de estator:

$$i_a = I_m \cos \omega t$$

$$i_b = I_m \cos\left(\omega t - \frac{2\pi}{3}\right)$$

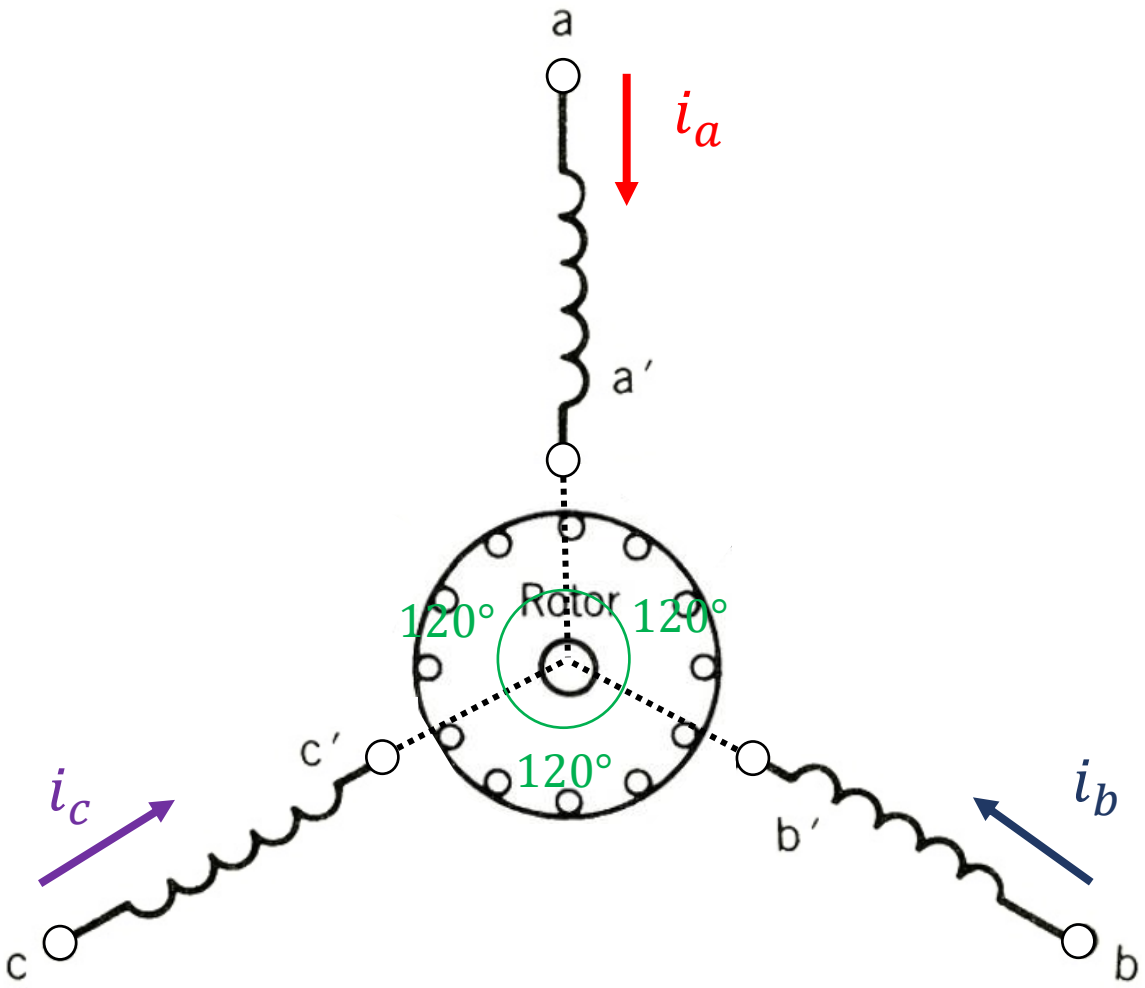
$$i_c = I_m \cos\left(\omega t + \frac{2\pi}{3}\right)$$

- Densidade de fluxo $B = \mu H$ e $H \propto i$;

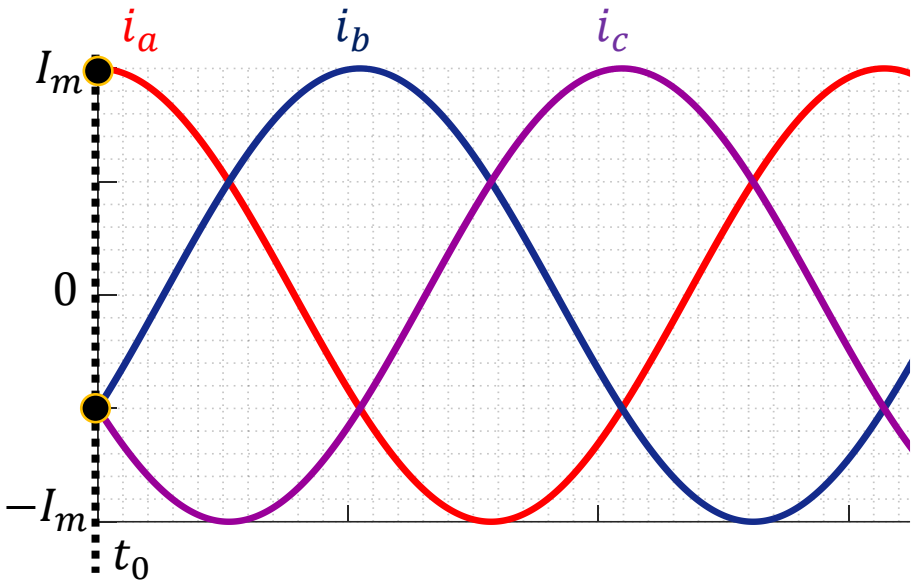
$$B_a = B_m \cos \omega t$$

$$B_b = B_m \cos\left(\omega t - \frac{2\pi}{3}\right)$$

$$B_c = B_m \cos\left(\omega t + \frac{2\pi}{3}\right)$$



Densidades de fluxo de cada fase: t = t_0

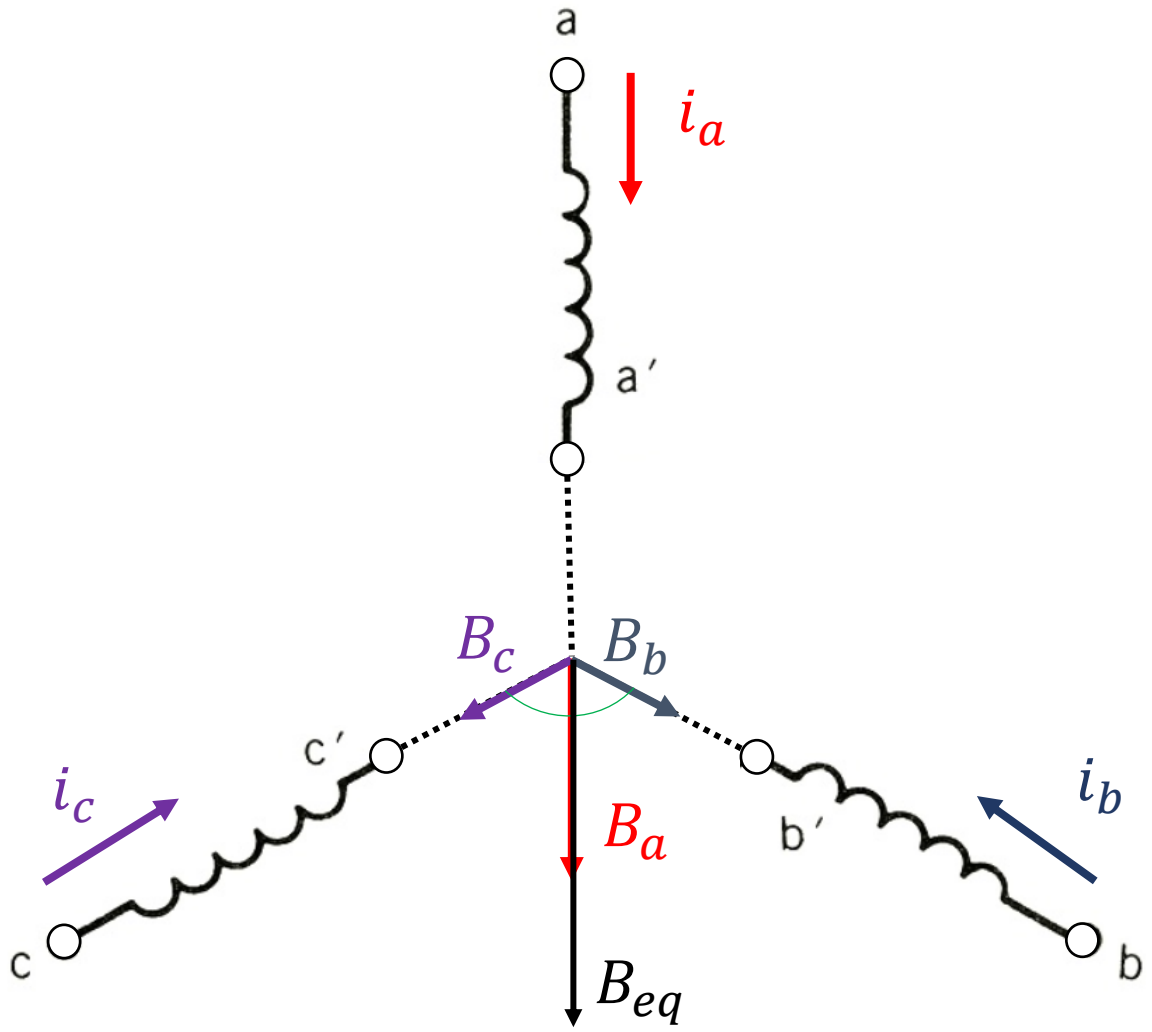


- $t = t_0 \rightarrow \omega t = 0$

$$B_a = B_m \cos 0 = B_m$$

$$B_b = B_m \cos\left(0 - \frac{2\pi}{3}\right) = -\frac{B_m}{2}$$

$$B_c = B_m \cos\left(0 + \frac{2\pi}{3}\right) = -\frac{B_m}{2}$$

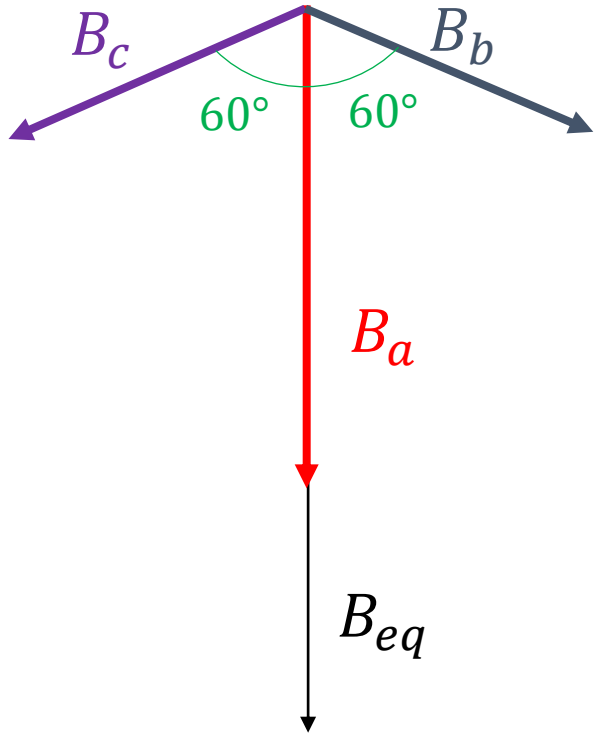


Cálculo da densidade de fluxo equivalente: $\mathbf{t = t_0}$

- $t = t_0 \rightarrow \omega t = 0$

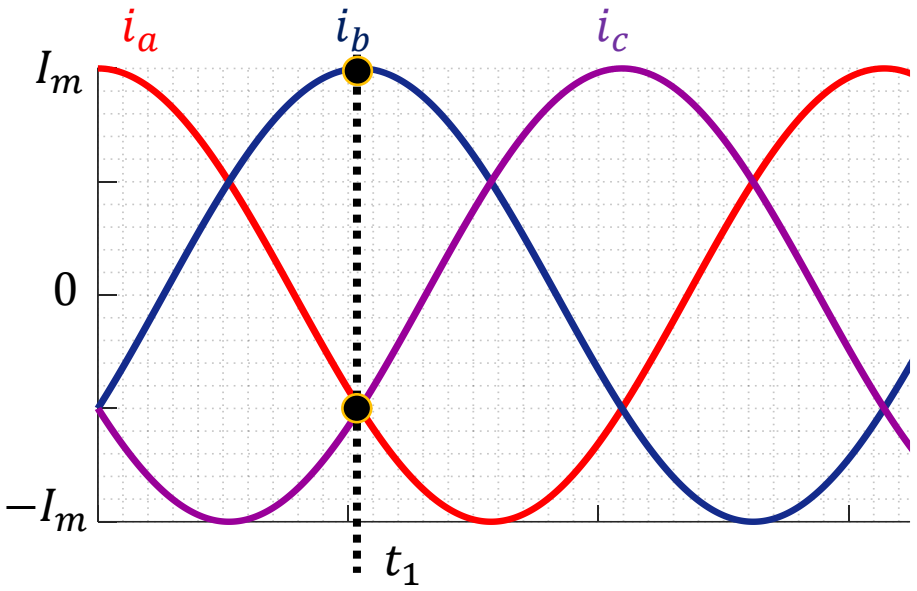
$$B_{eq} = B_m + \frac{B_m}{2}\cos 60° + \frac{B_m}{2}\cos 60°$$

$$\Leftrightarrow \boxed{B_{eq} = \frac{3}{2}B_m}$$



- B_{eq} está na direção da fase A;
- Amplitude 1,5 vezes maior que a amplitude de uma fase.

Densidades de fluxo de cada fase: t = t_1

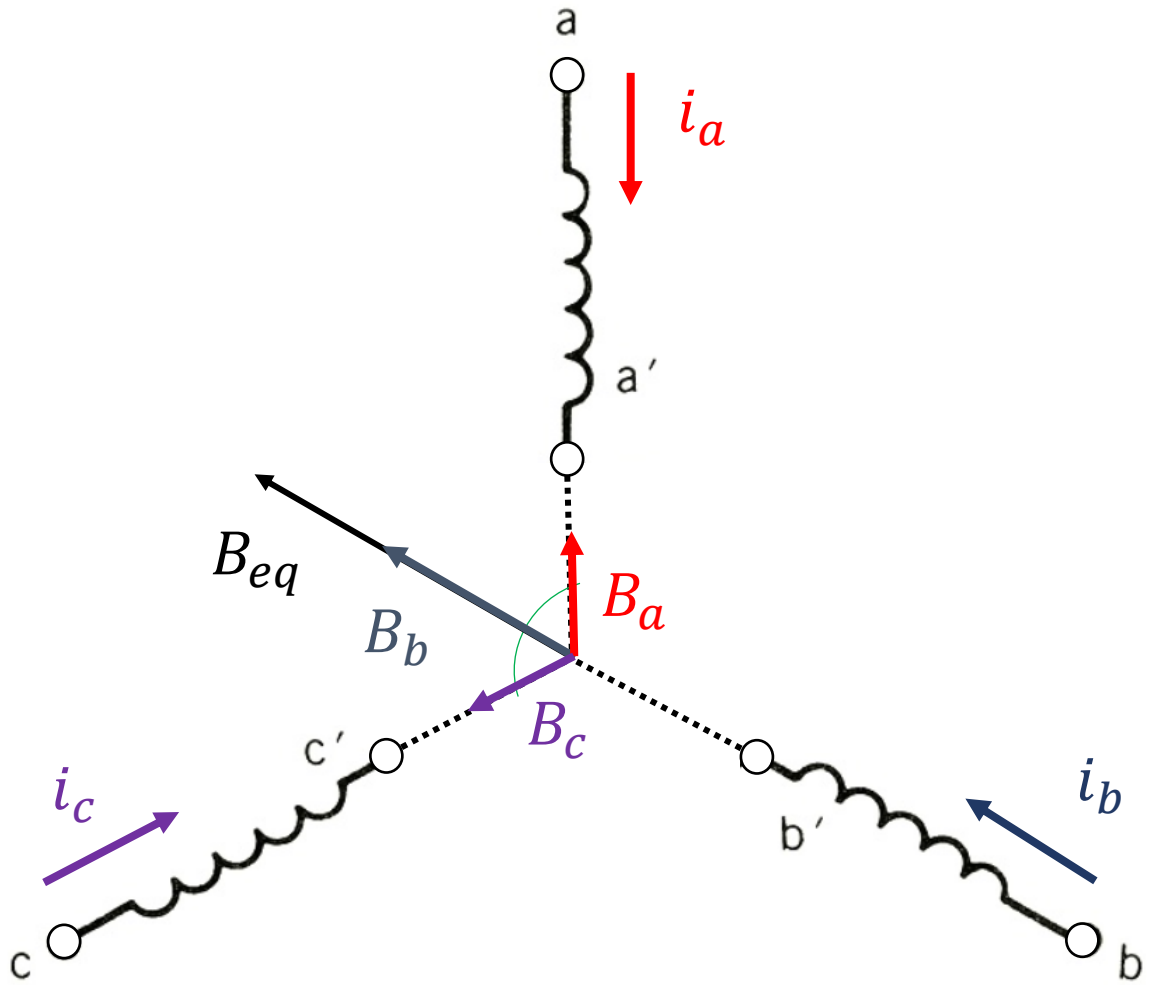


- $t = t_1 \rightarrow \omega t = \frac{2\pi}{3}$

$$B_a = B_m \cos 0 - \frac{2\pi}{3} = -\frac{B_m}{2}$$

$$B_b = B_m \cos(0) = B_m$$

$$B_c = B_m \cos\left(\frac{2\pi}{3} + \frac{2\pi}{3}\right) = -\frac{B_m}{2}$$

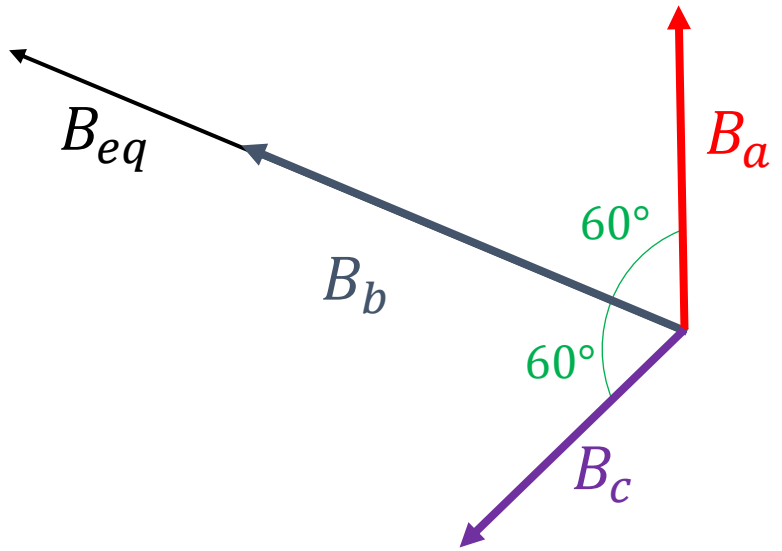


Cálculo da densidade de fluxo equivalente: $\mathbf{t = t_1}$

- $t = t_1 \rightarrow \omega t = \frac{2\pi}{3}$

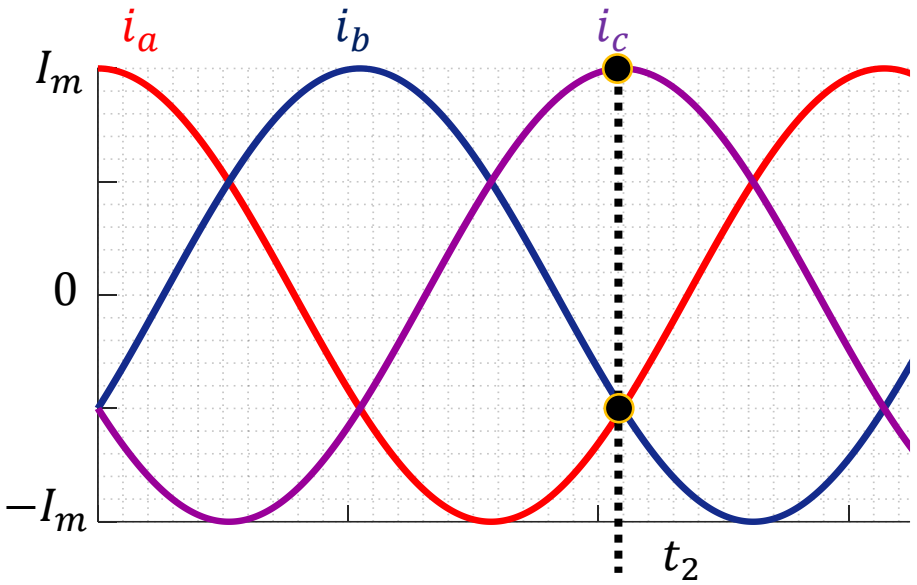
$$B_{eq} = \frac{B_m}{2}\cos 60° + B_m + \frac{B_m}{2}\cos 60°$$

$$\Leftrightarrow \boxed{B_{eq} = \frac{3}{2}B_m}$$



- B_{eq} está na direção da fase B;
- Amplitude 1,5 vezes maior que a amplitude de uma fase.

Densidades de fluxo de cada fase: t = t_2

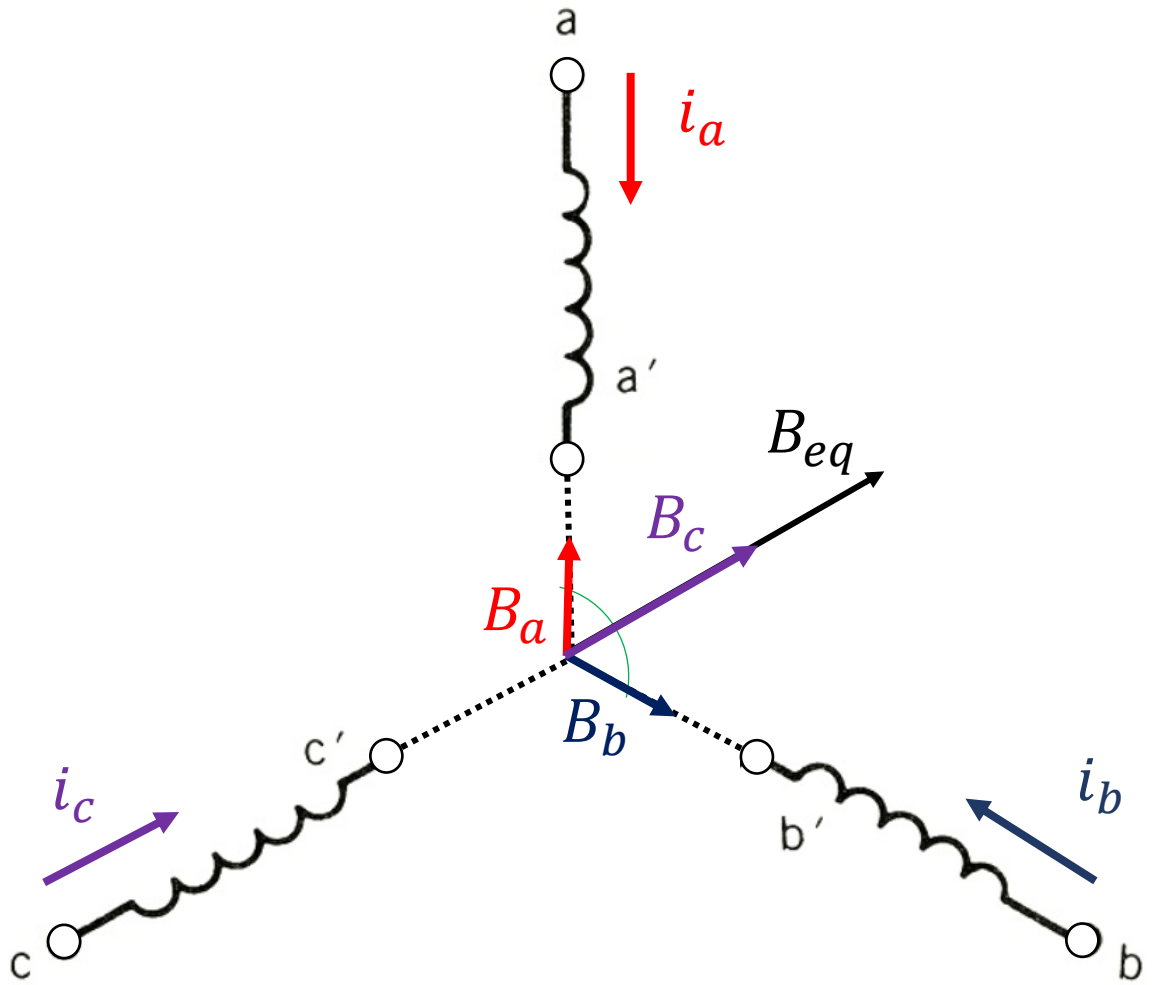


- $t = t_1 \rightarrow \omega t = \frac{4\pi}{3}$

$$B_a = B_m \cos 0 - \frac{4\pi}{3} = -\frac{B_m}{2}$$

$$B_b = B_m \cos\left(\frac{4\pi}{3} - \frac{2\pi}{3}\right) = -\frac{B_m}{2}$$

$$B_c = B_m \cos(2\pi) = B_m$$

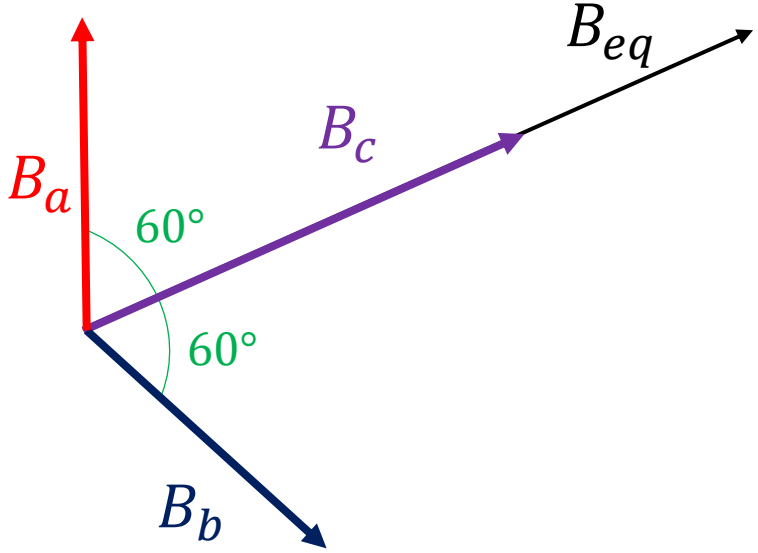


Cálculo da densidade de fluxo equivalente: $\mathbf{t = t_2}$

- $t = t_2 \rightarrow \omega t = \frac{4\pi}{3}$

$$B_{eq} = \frac{B_m}{2}\cos 60° + \frac{B_m}{2}\cos 60° + B_m$$

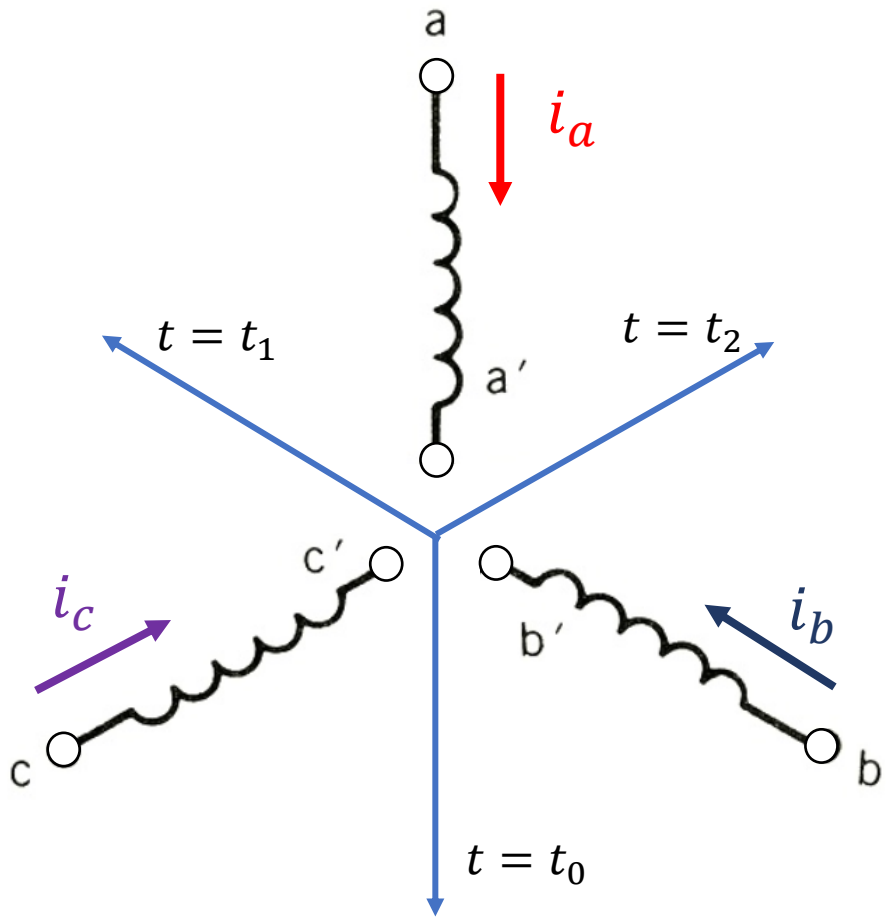
$$\Leftrightarrow \boxed{B_{eq} = \frac{3}{2}B_m}$$



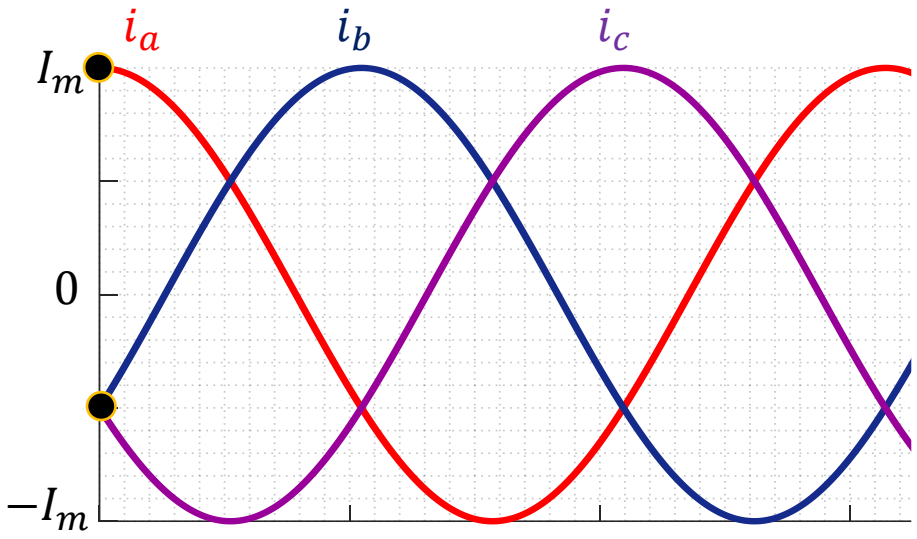
- B_{eq} está na direção da fase C;
- Amplitude 1,5 vezes maior que a amplitude de uma fase.

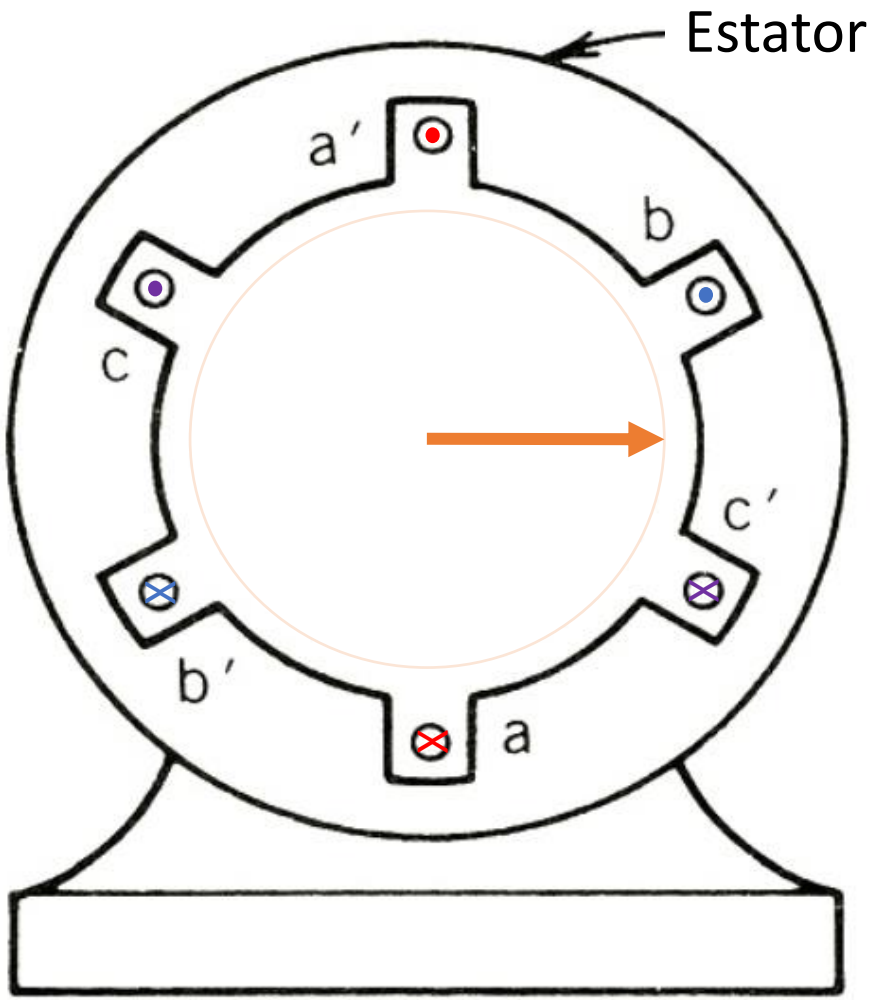
Teoria do campo girante

- Note que o campo magnético gerado por cada fase é pulsante;
- Contudo, o campo magnético resultante apresenta uma amplitude constante;
- Quando a corrente percorre 120 graus elétricos o fluxo percorre 120 graus mecânicos!
- Este campo é denominado campo girante!

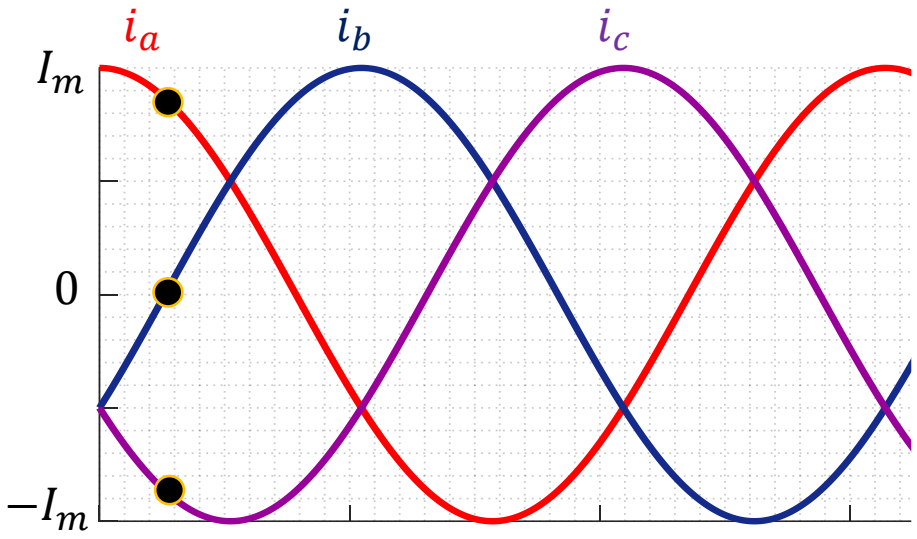


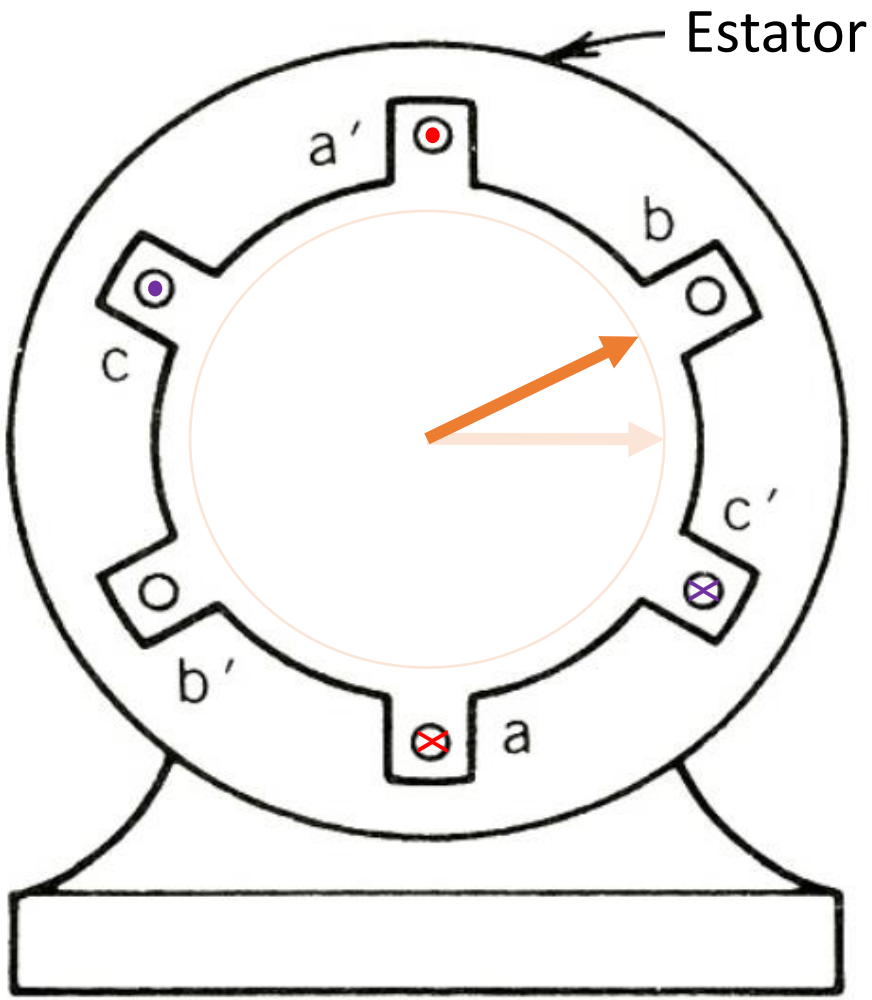
Campo girante – máquina de 2 pólos



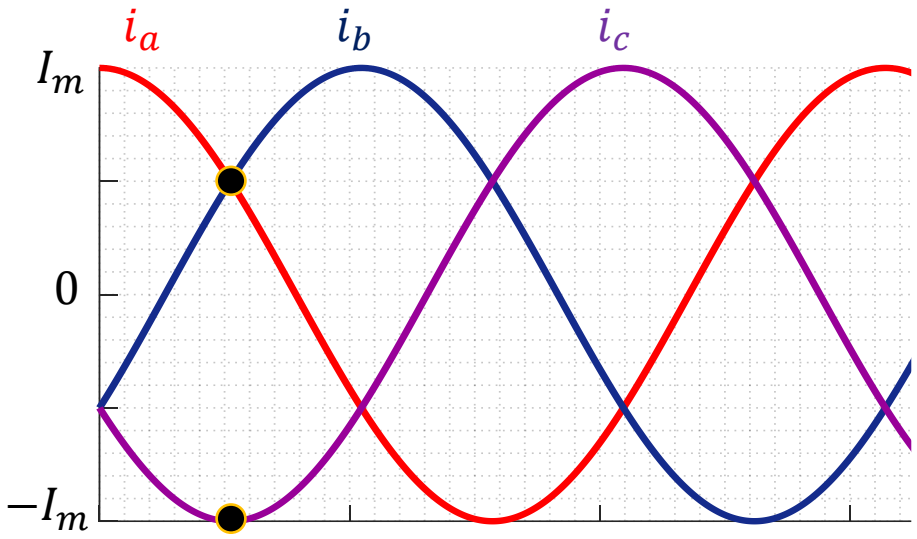


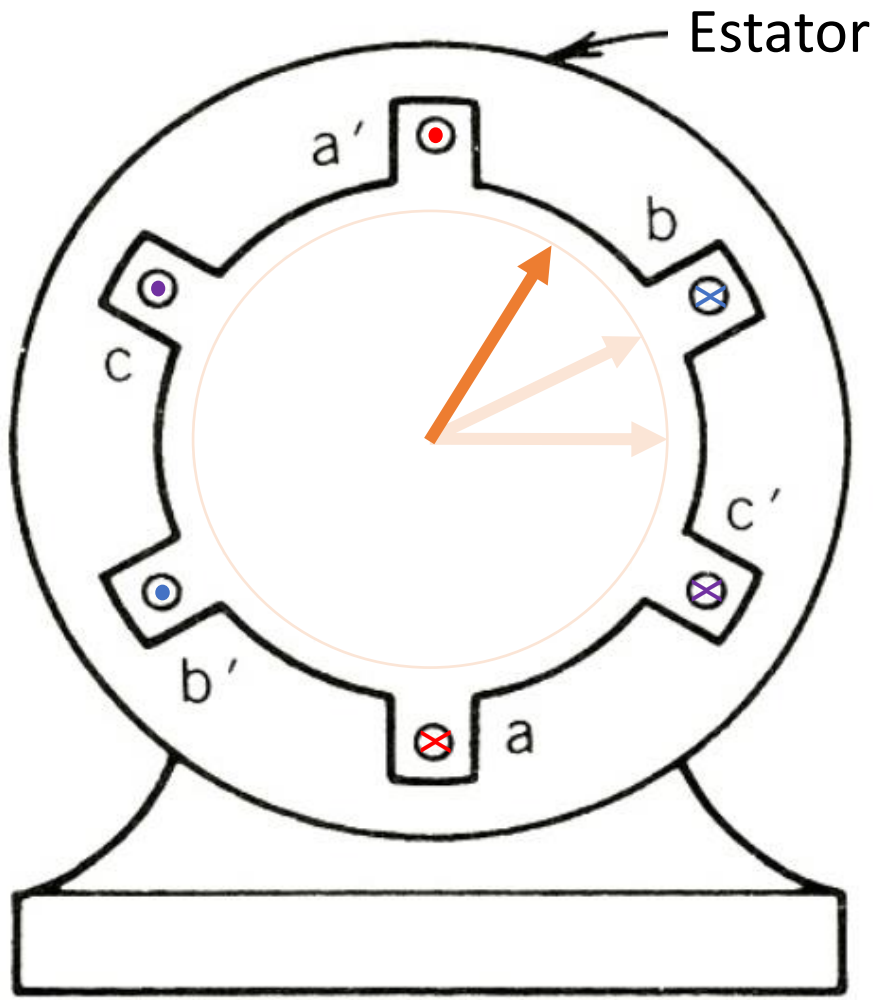
Campo girante – máquina de 2 pólos



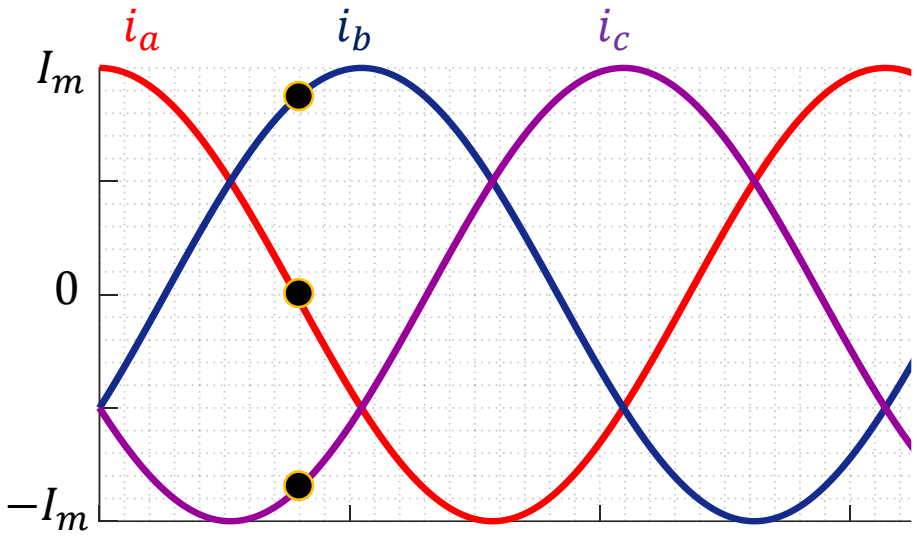


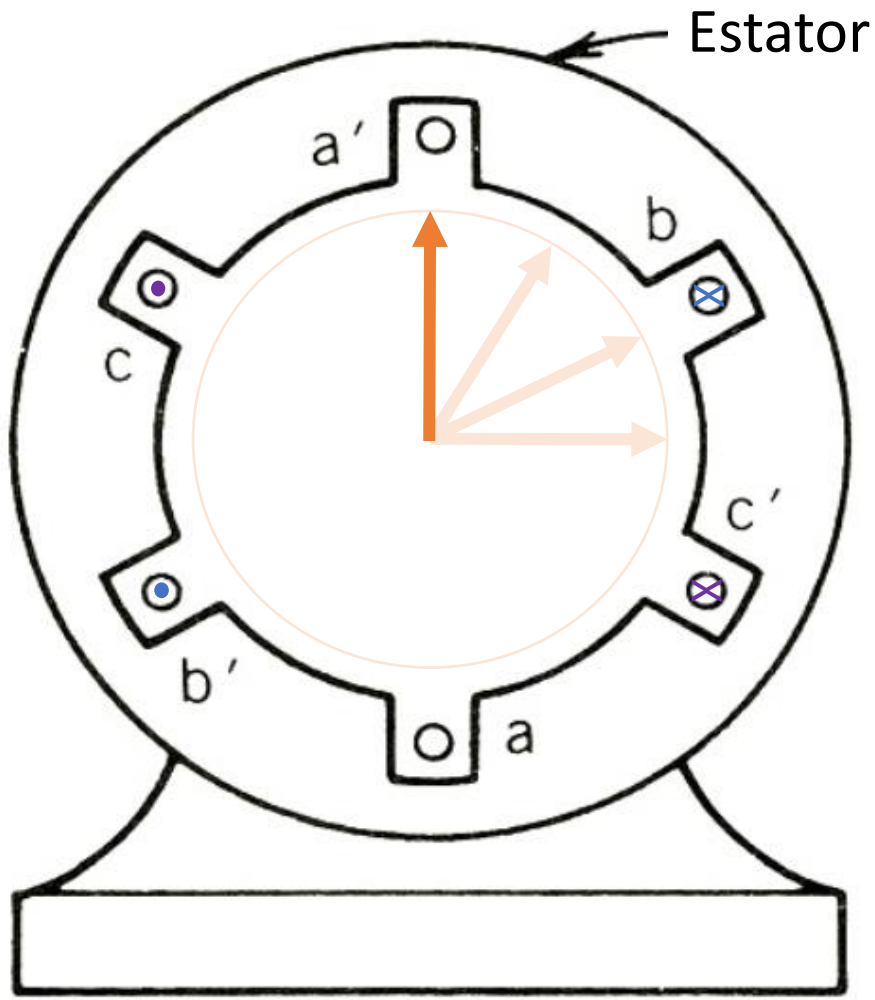
Campo girante – máquina de 2 pólos



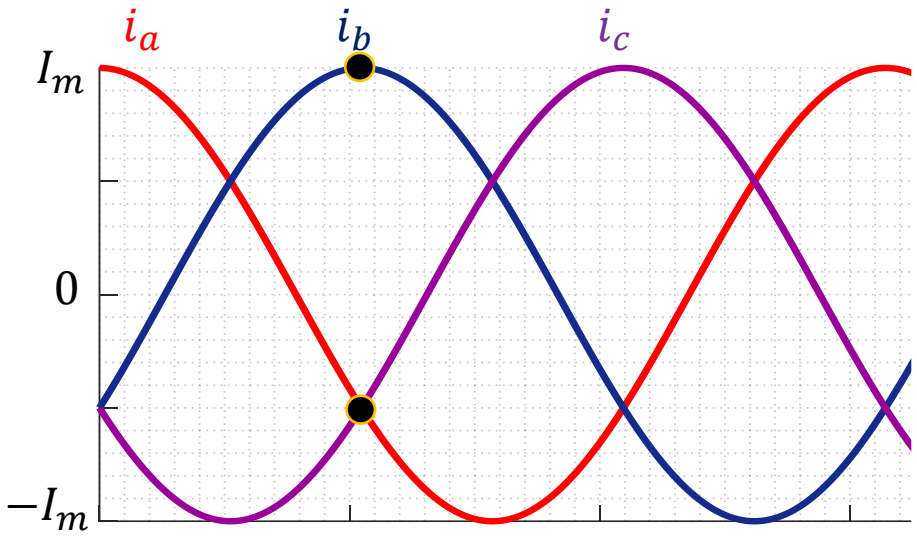


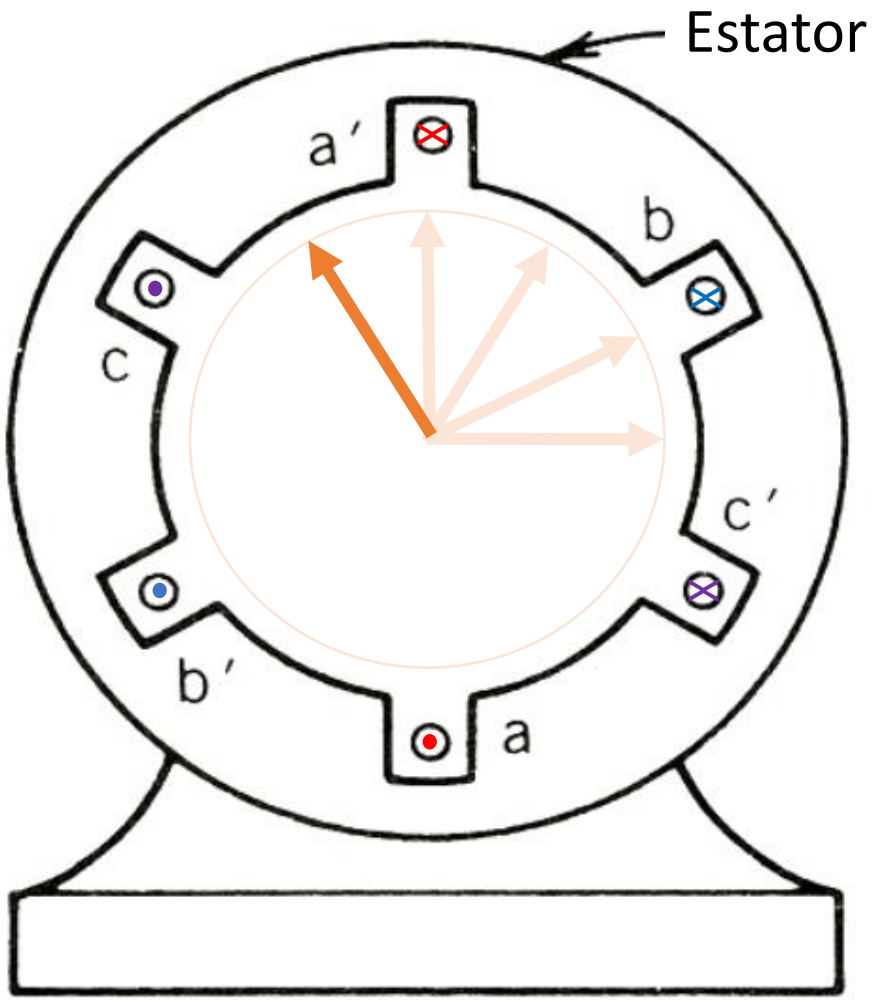
Campo girante – máquina de 2 pólos



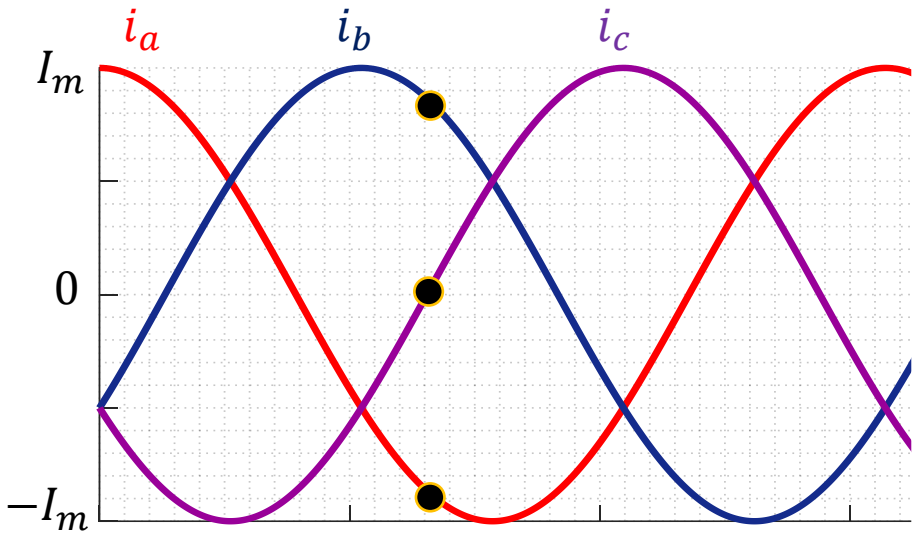


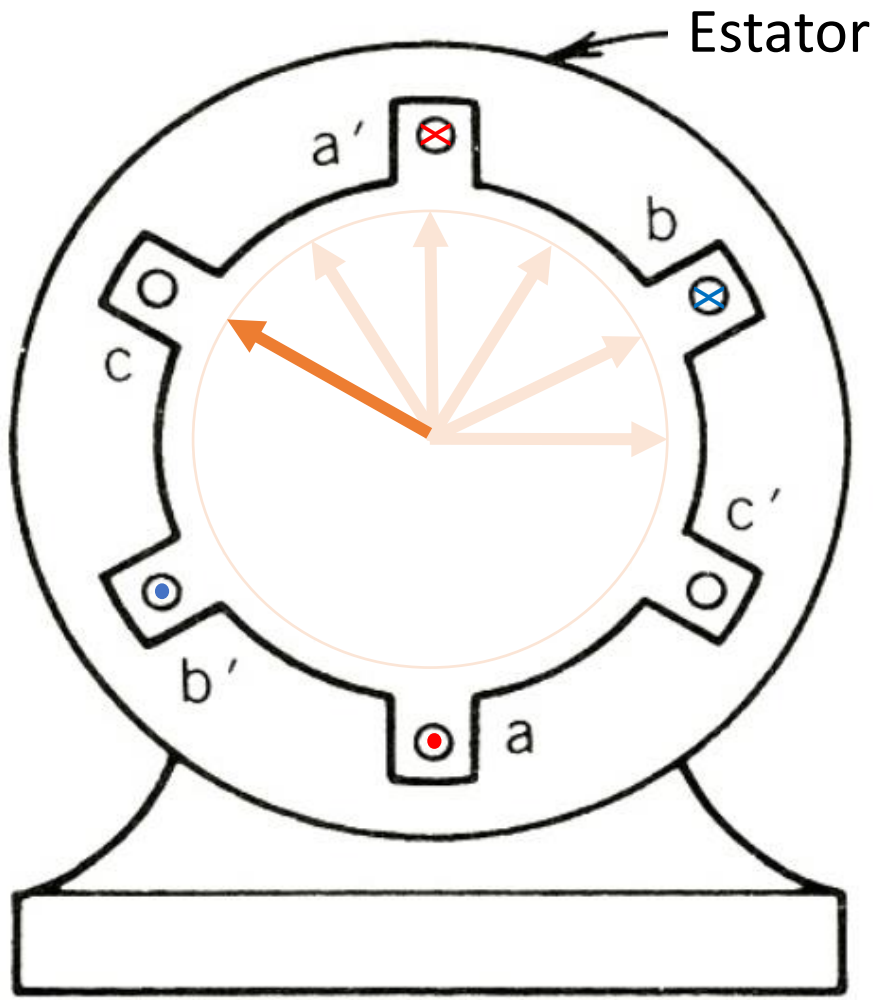
Campo girante – máquina de 2 pólos



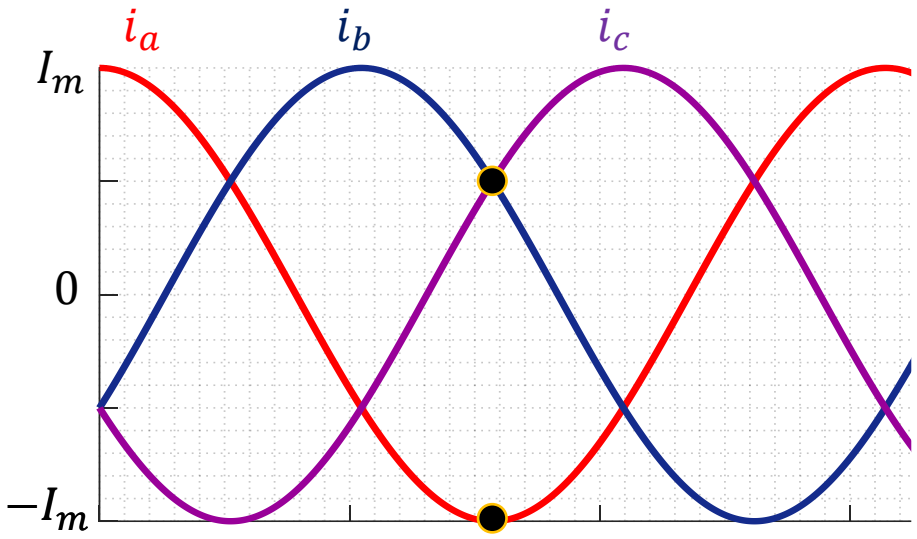


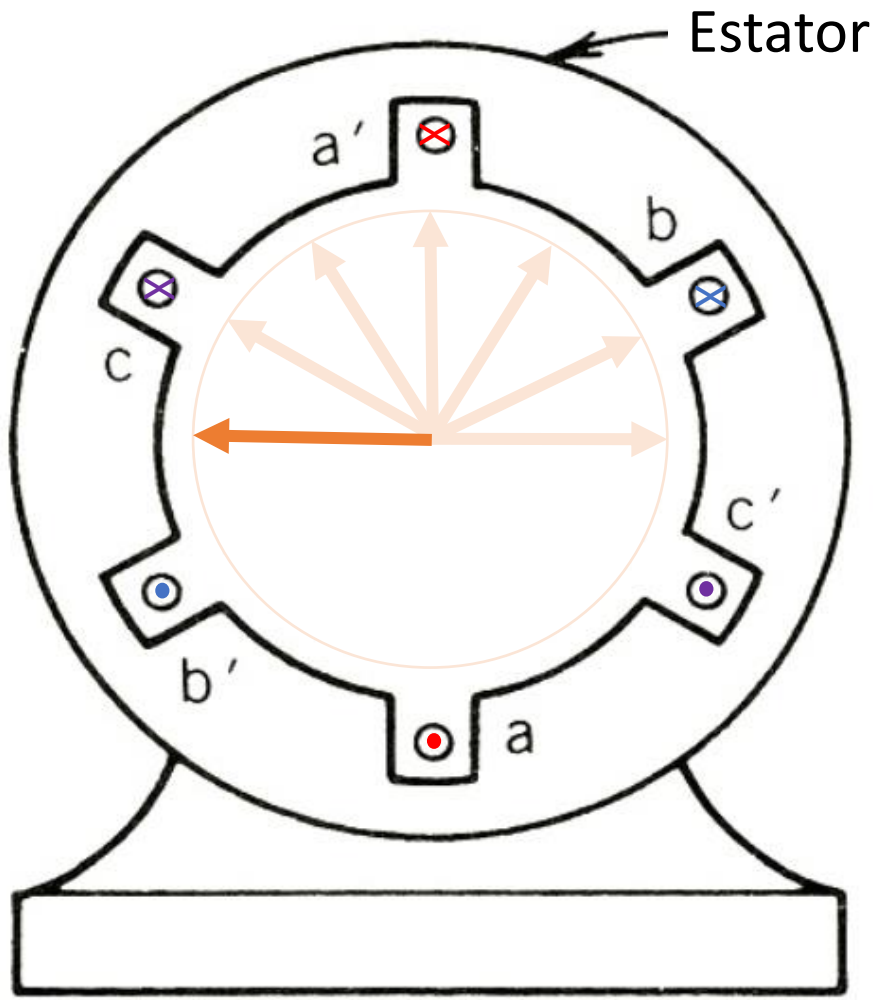
Campo girante – máquina de 2 pólos



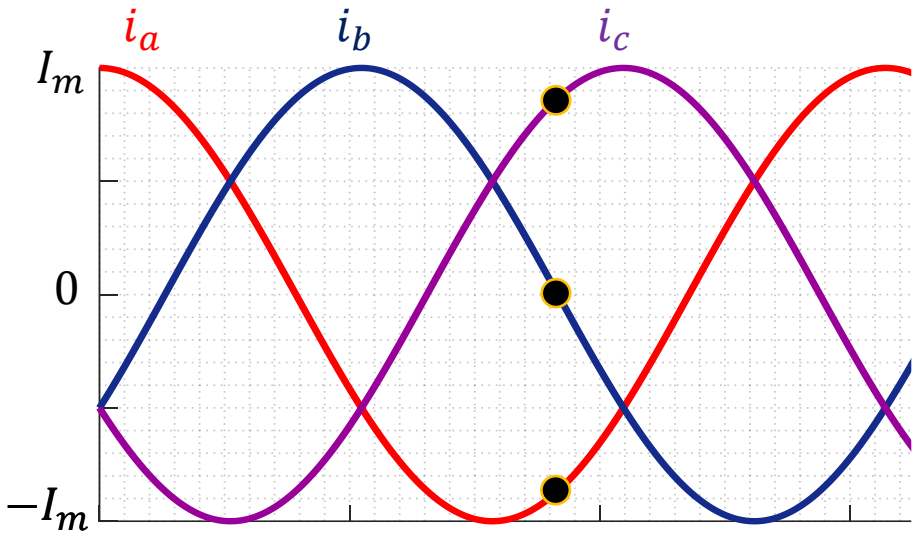


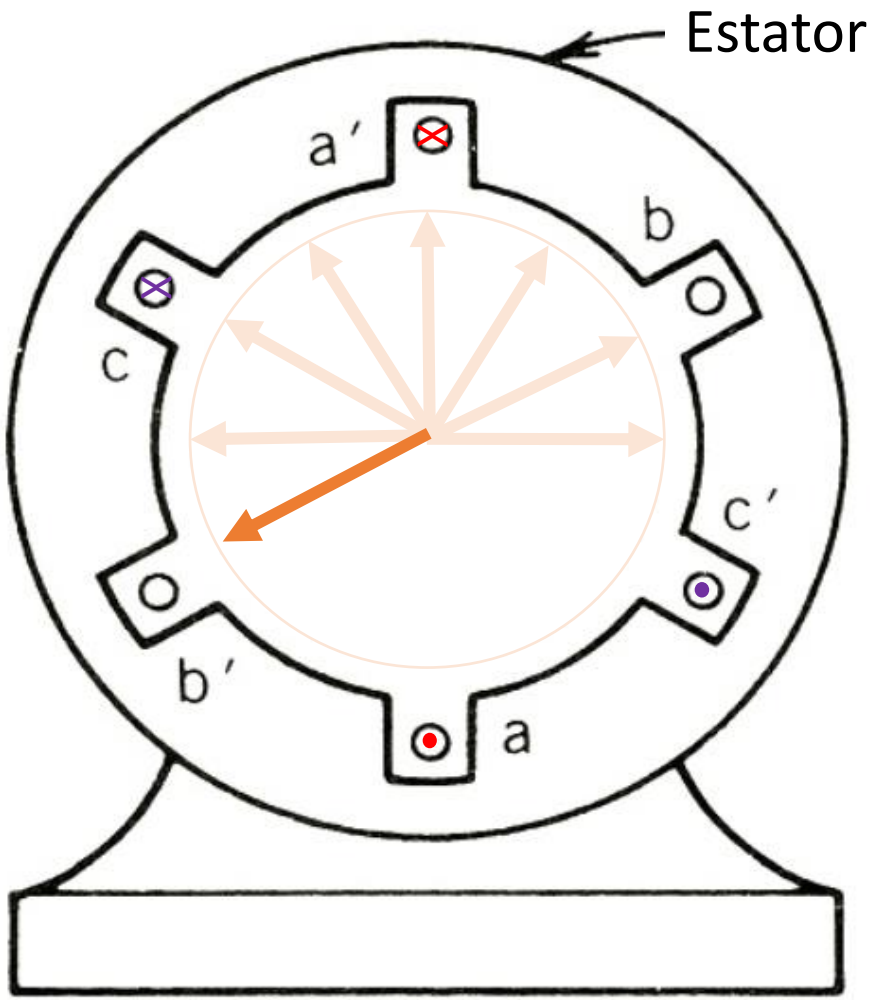
Campo girante – máquina de 2 pólos



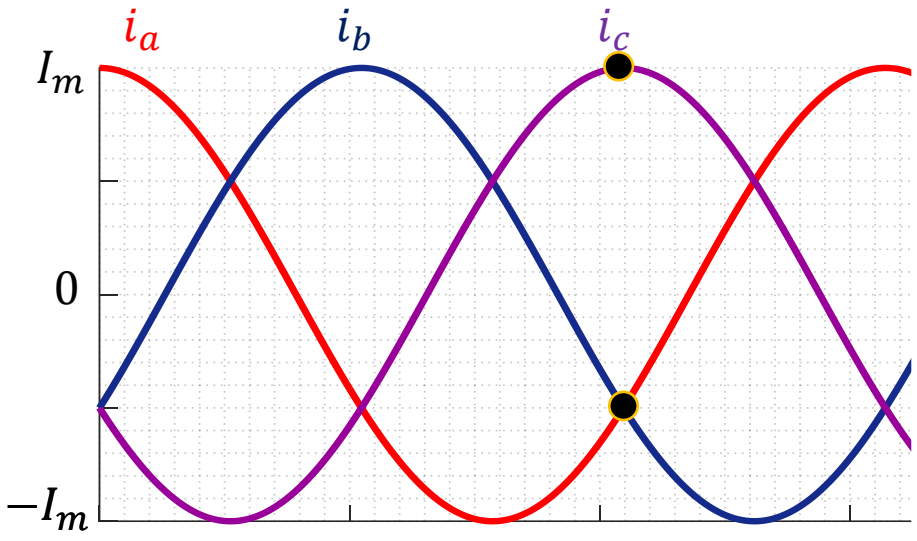


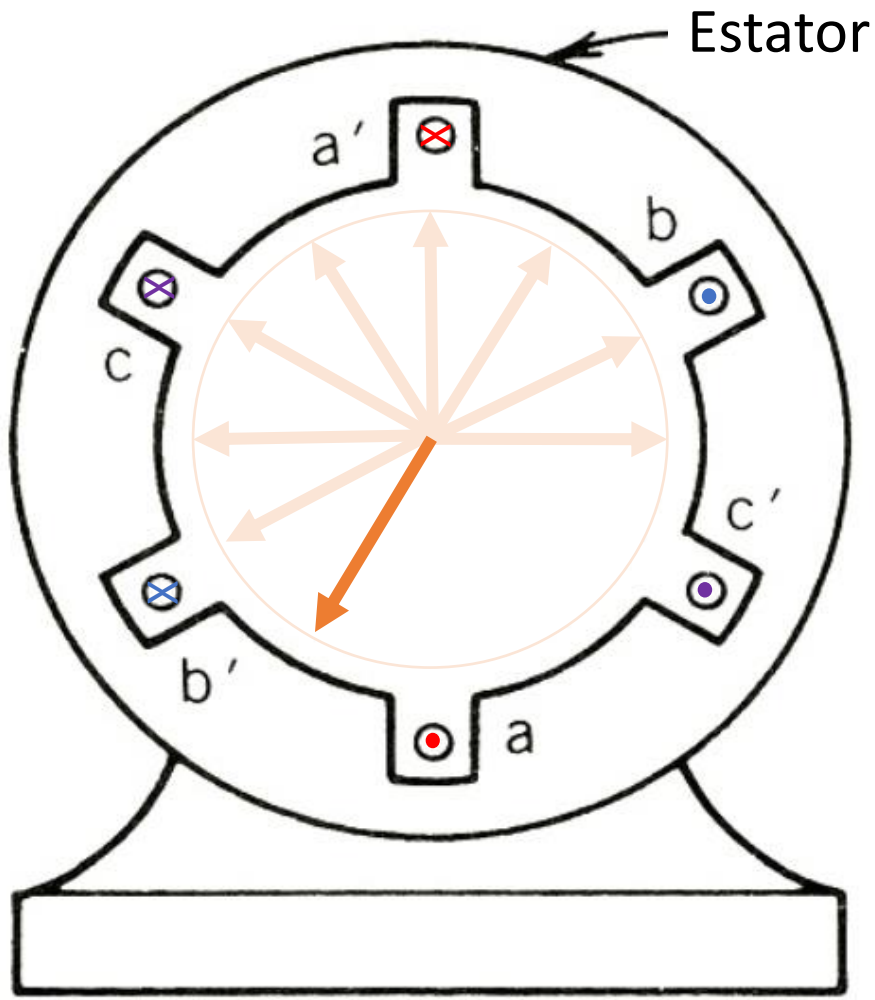
Campo girante – máquina de 2 pólos



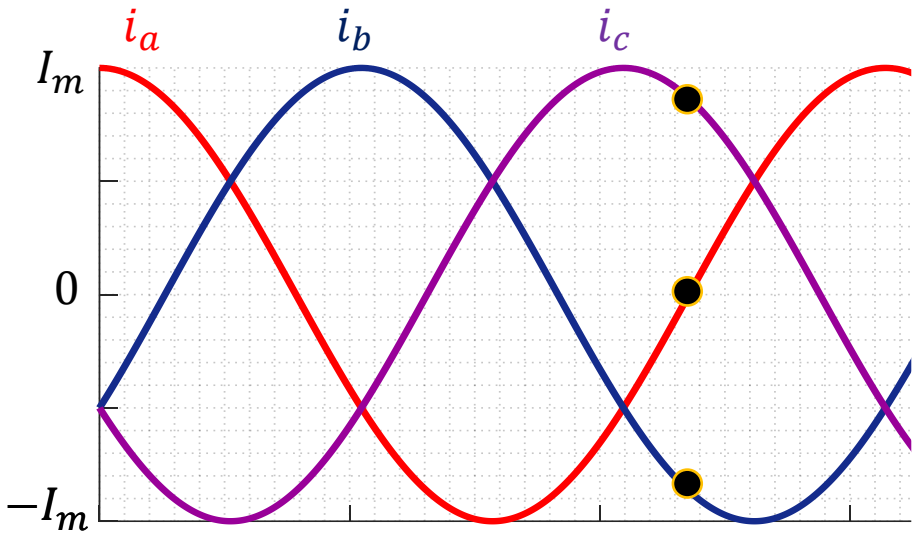


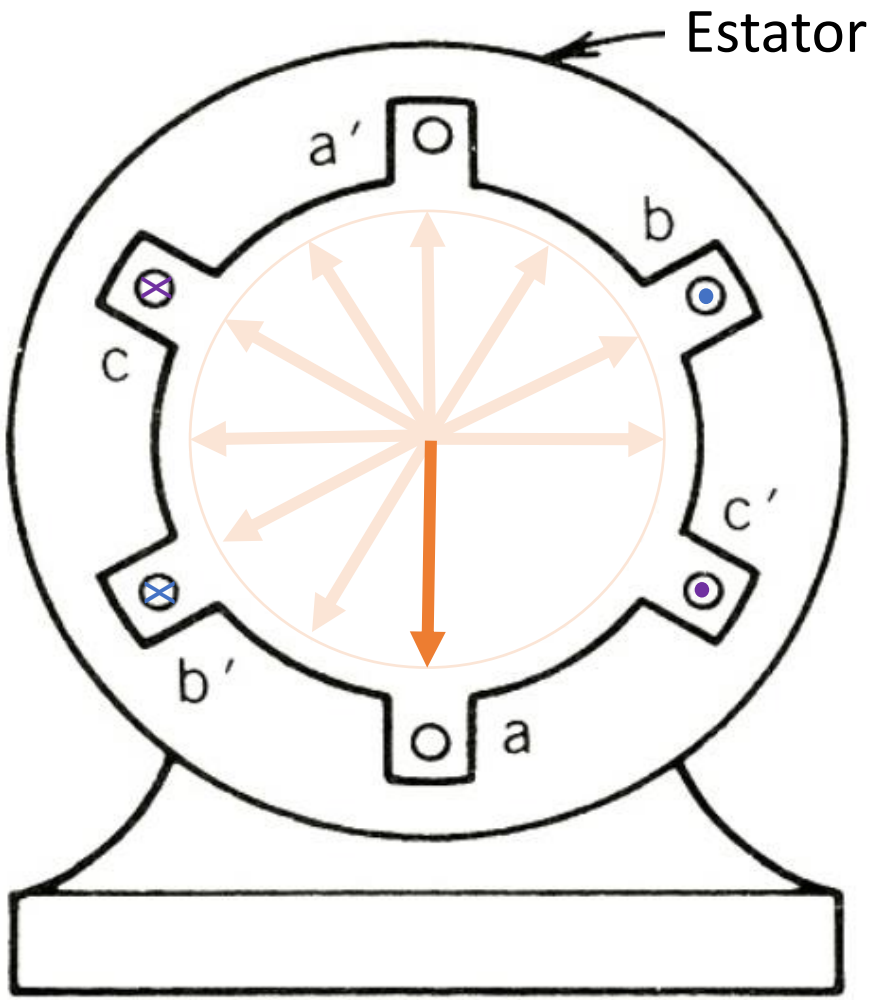
Campo girante – máquina de 2 pólos



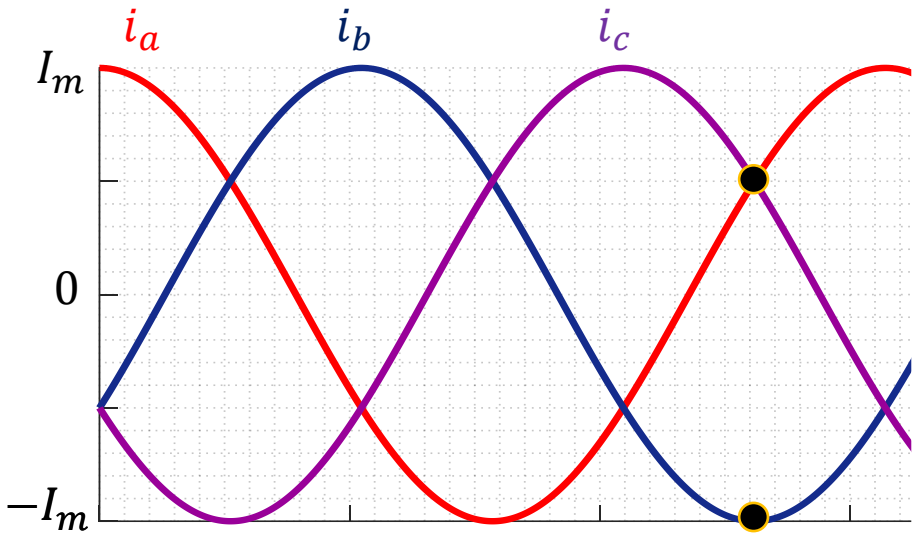


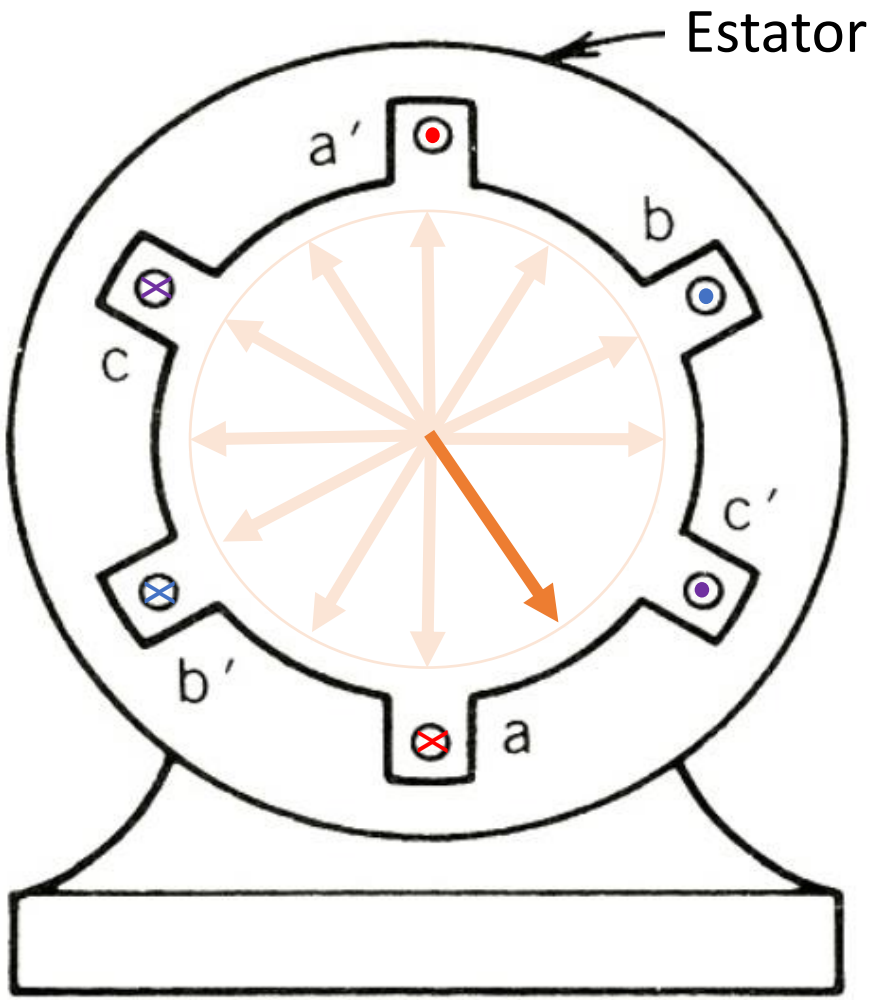
Campo girante – máquina de 2 pólos



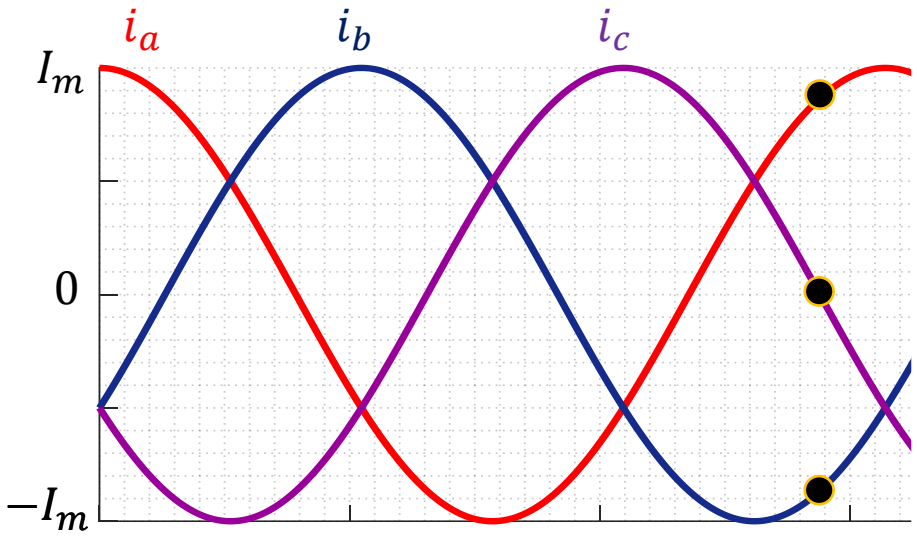


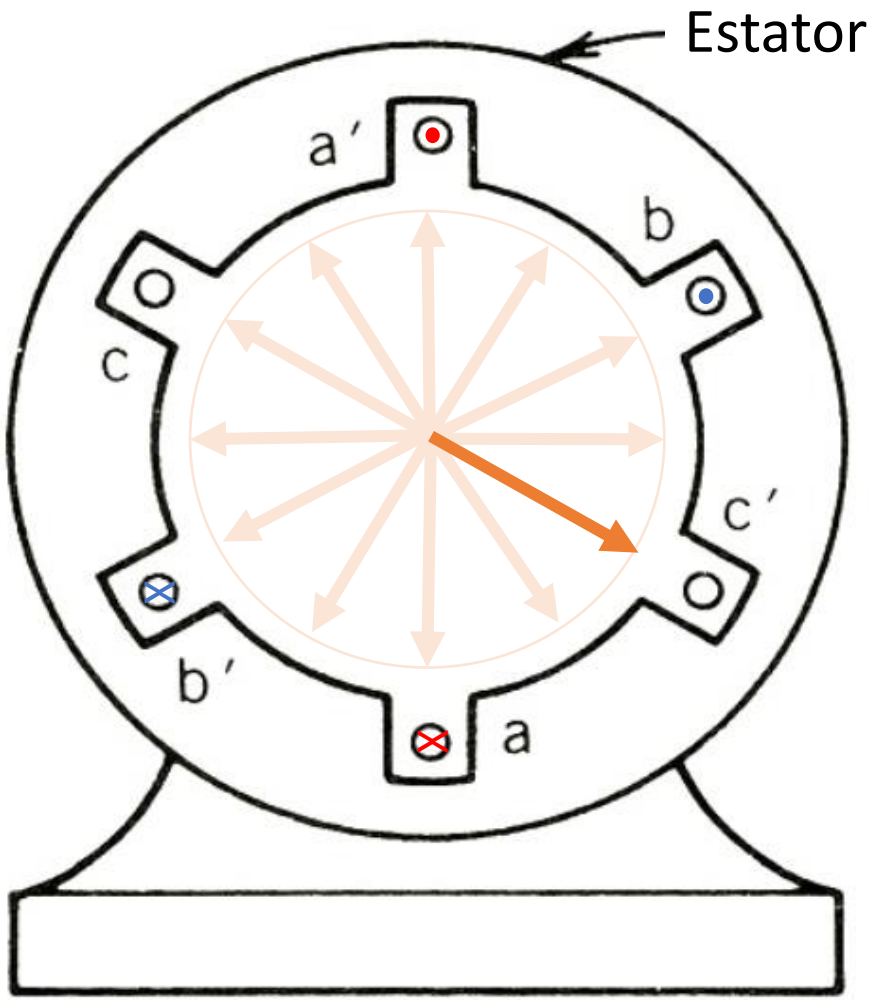
Campo girante – máquina de 2 pólos



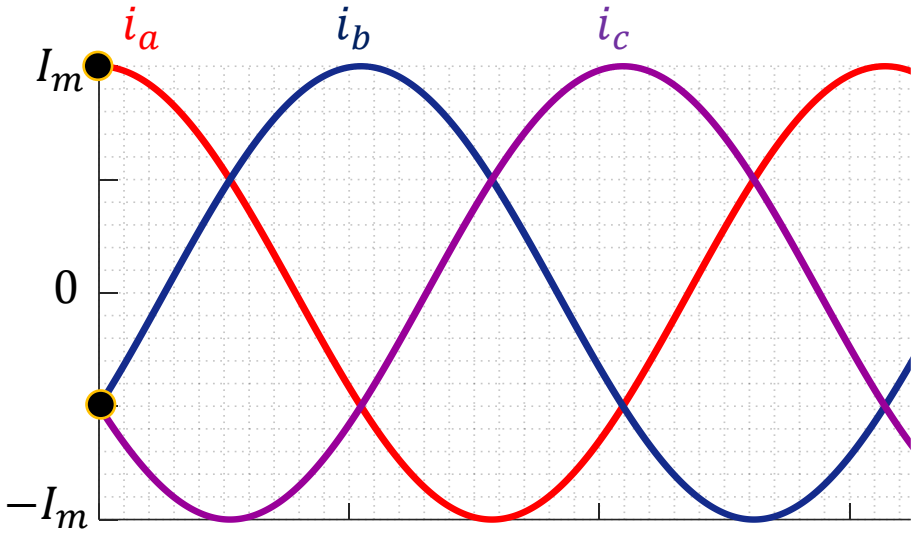


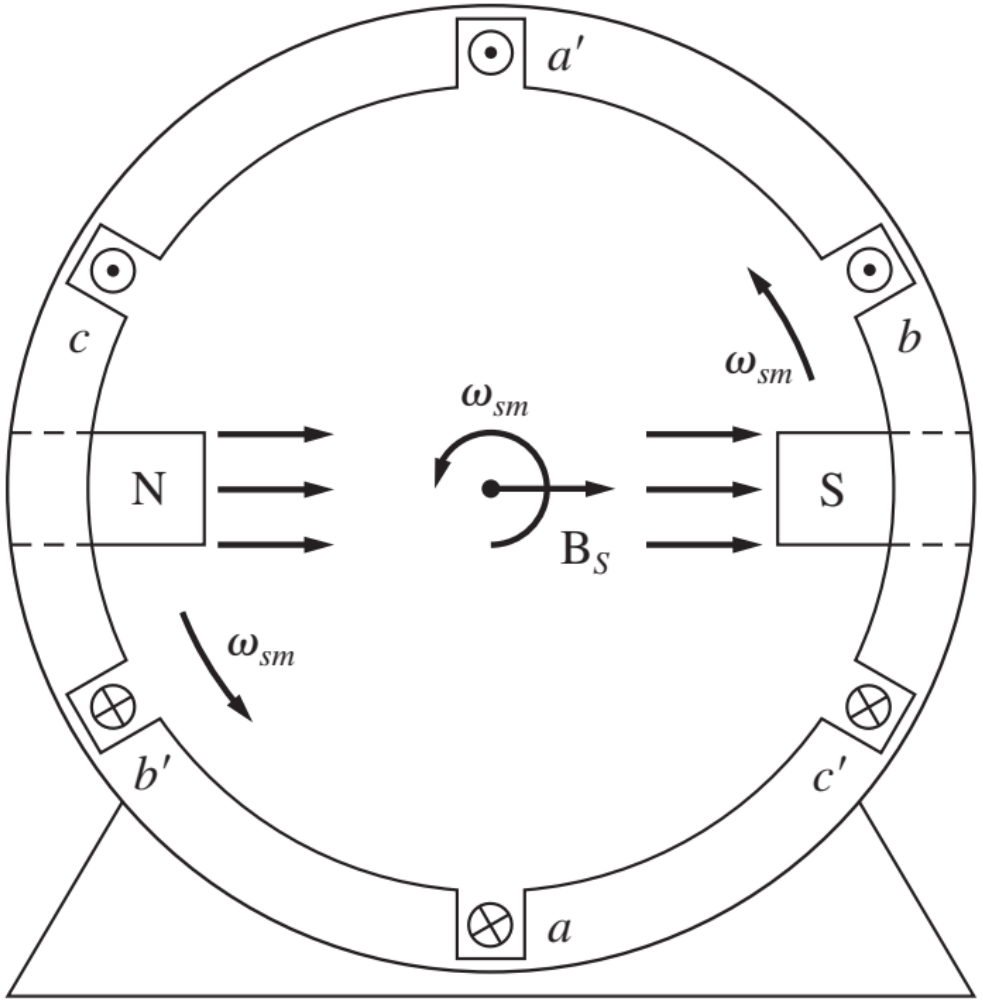
Campo girante – máquina de 2 pólos





Analogia a um ímã – máquina de 2 pólos

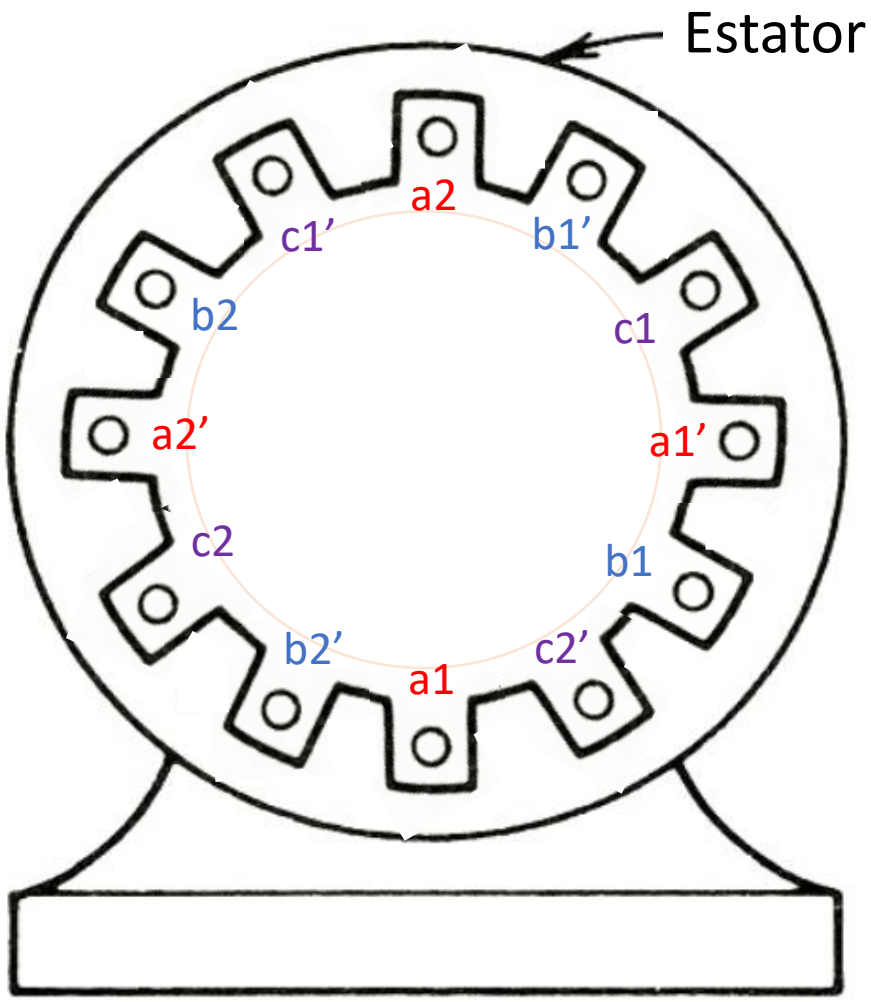


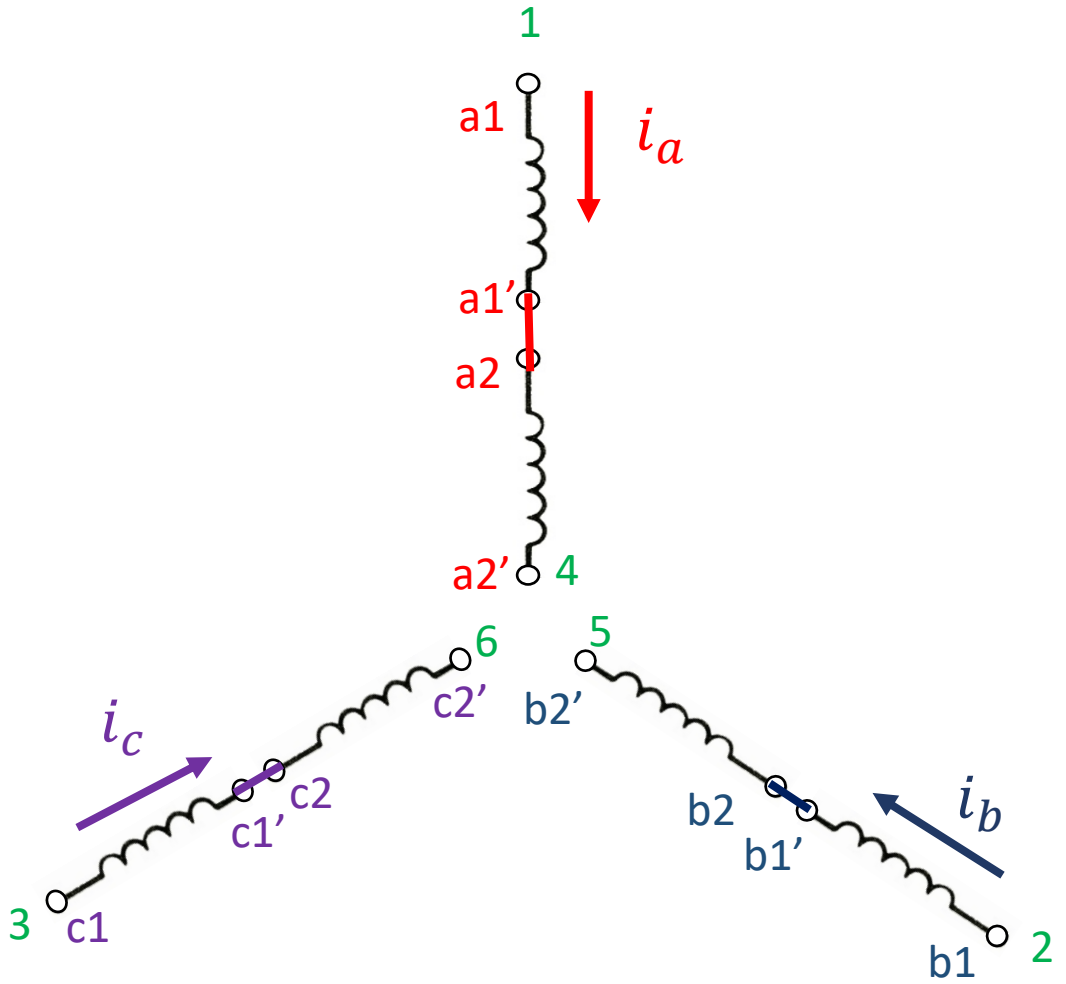


- Conclusão:

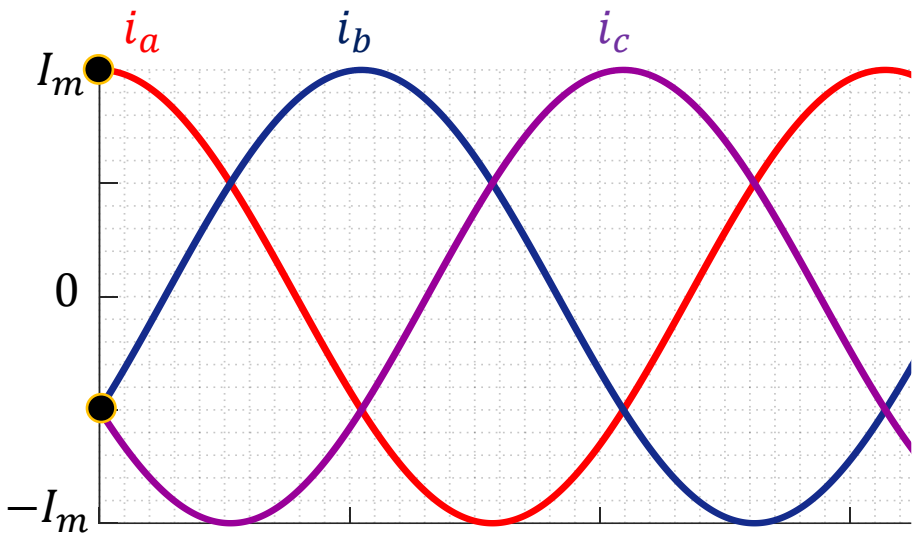
Para a máquina de dois polos, $\theta_m = \theta_e$.

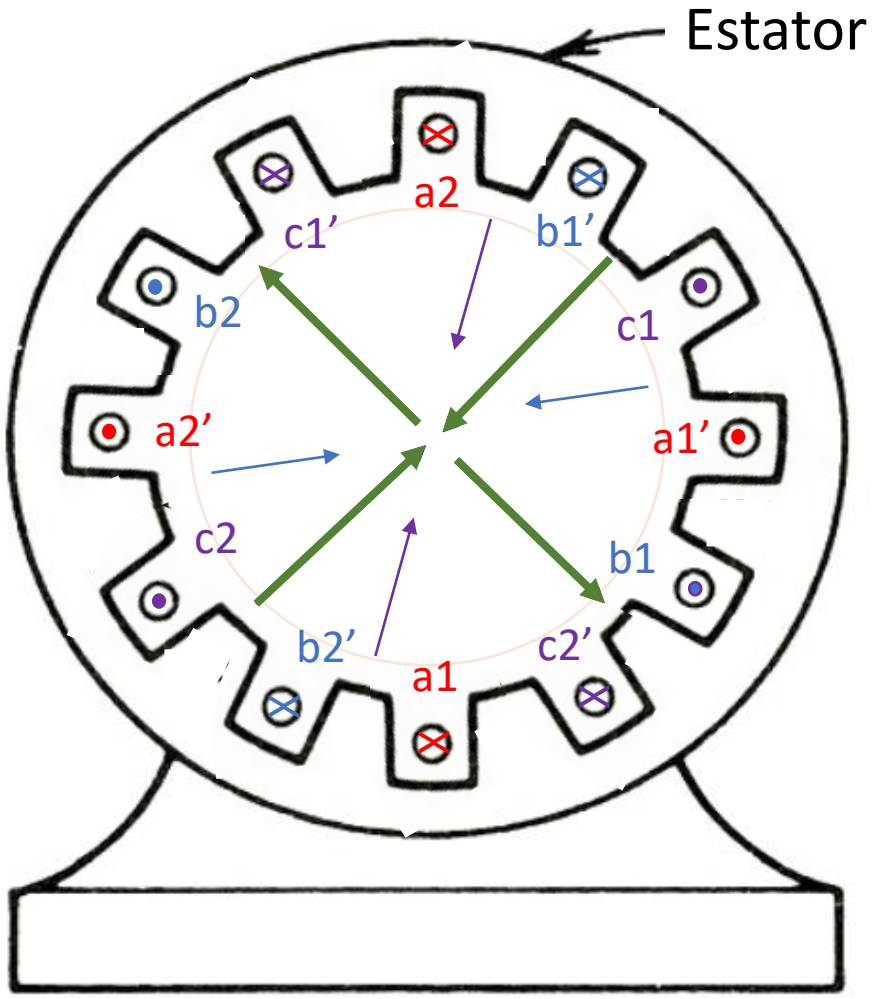
Campo girante – máquina de 4 pólos



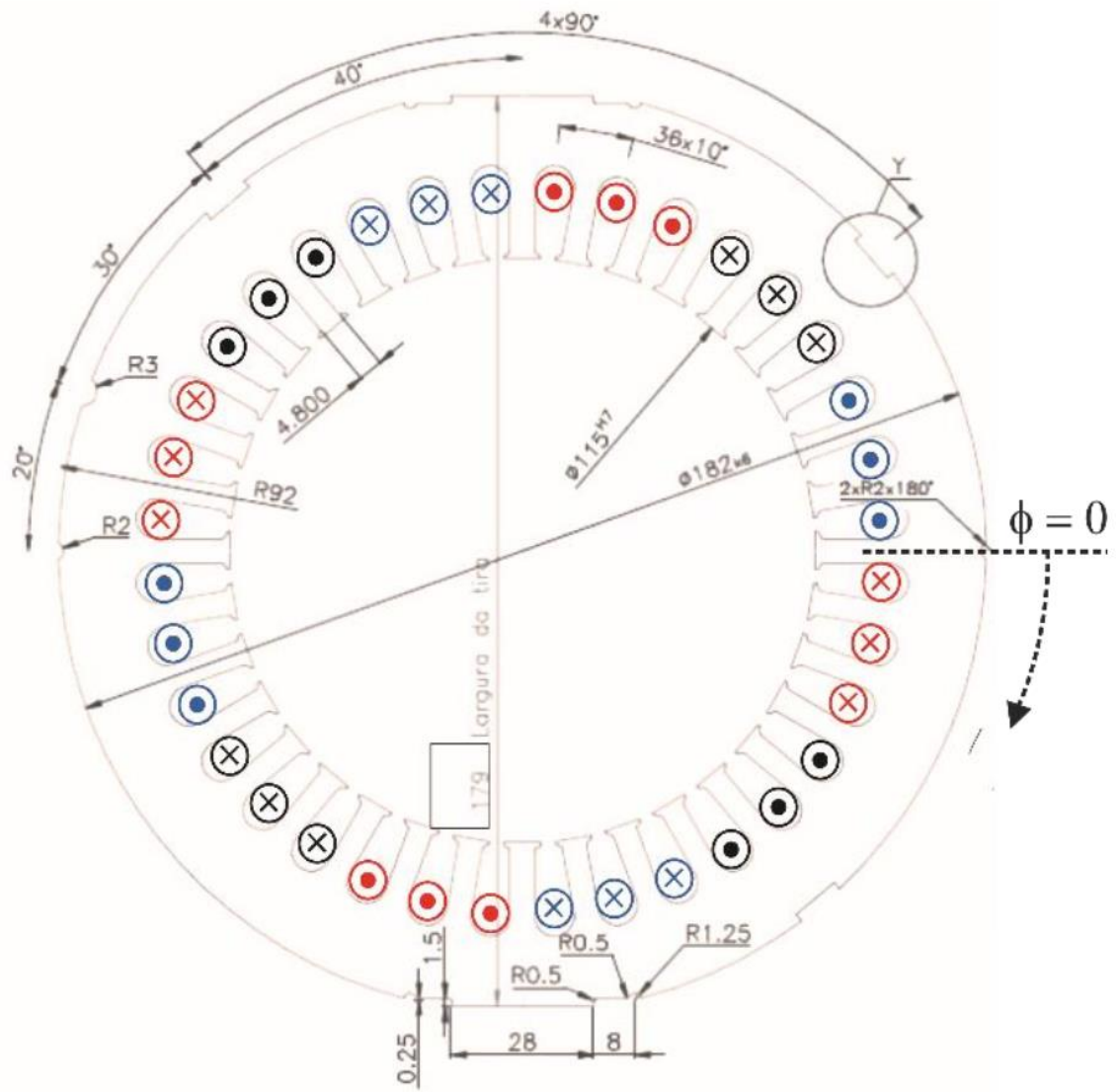


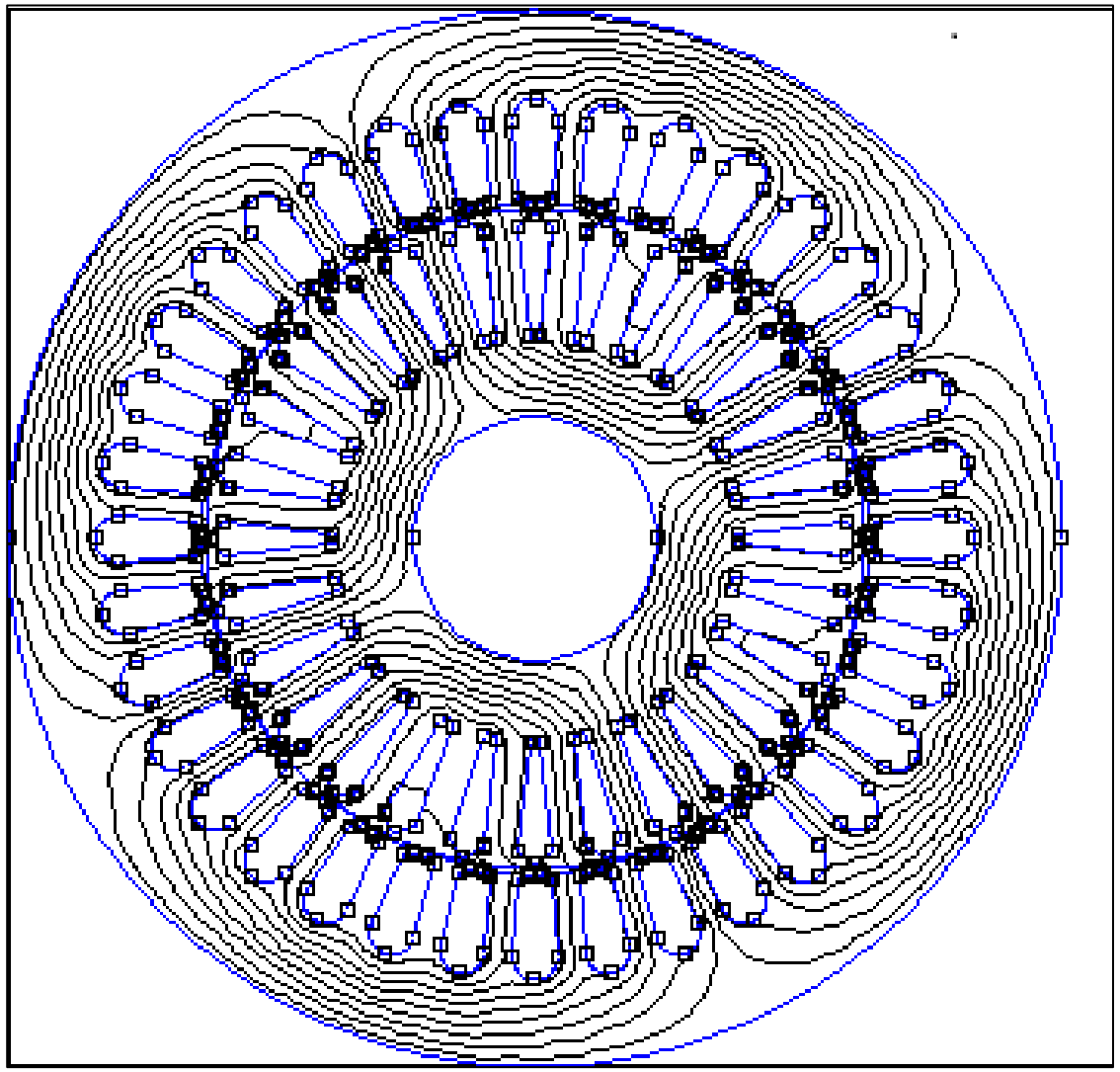
Campo girante – máquina de 4 pólos



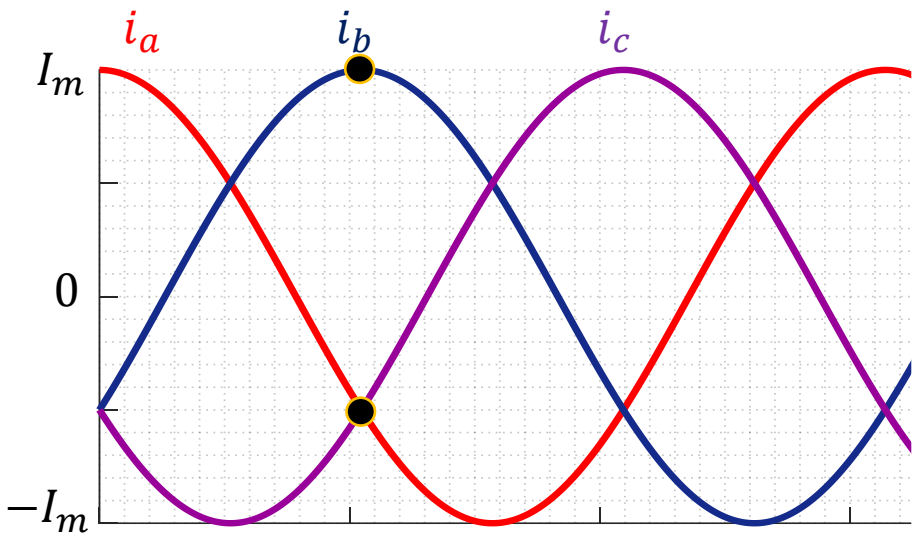


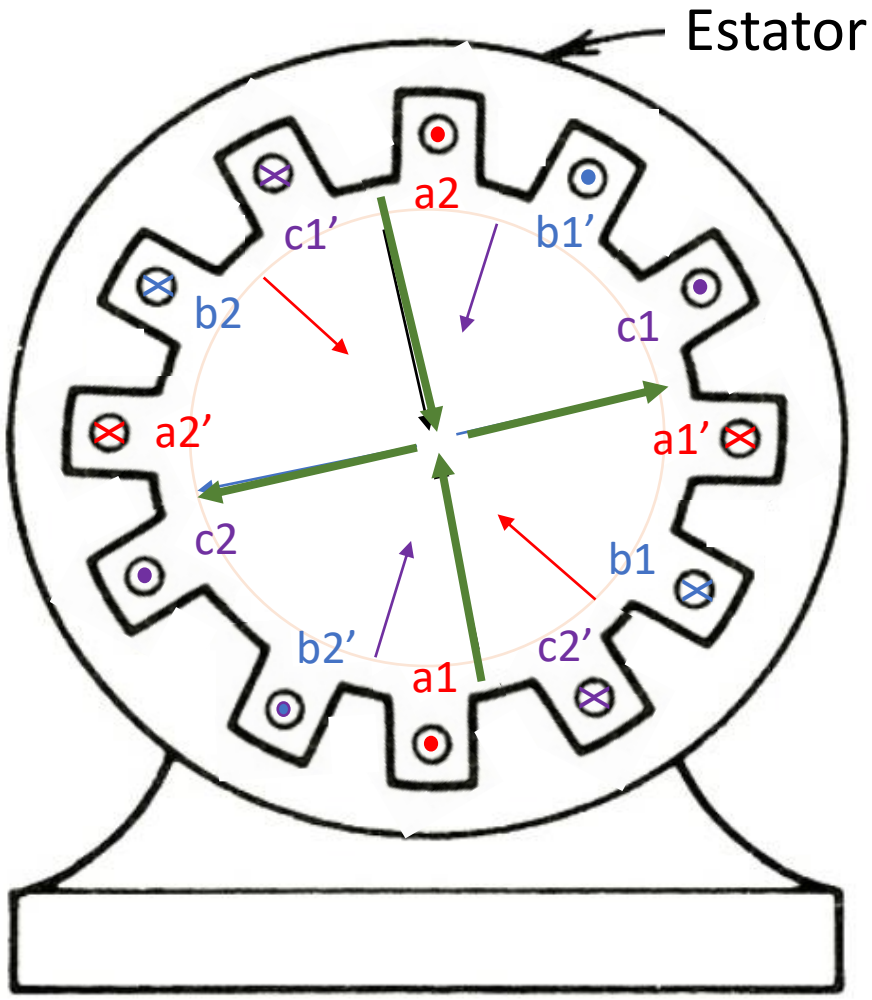
Campo girante – máquina de 4 pólos



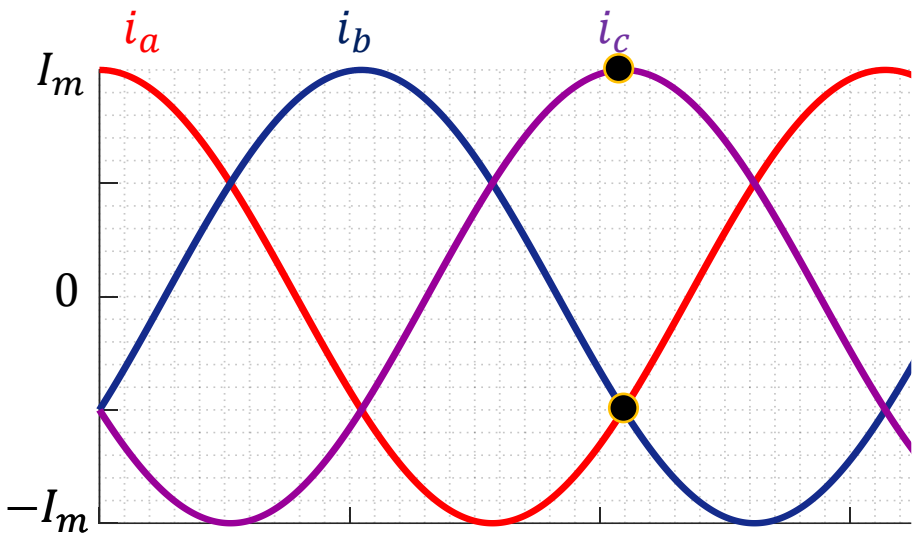


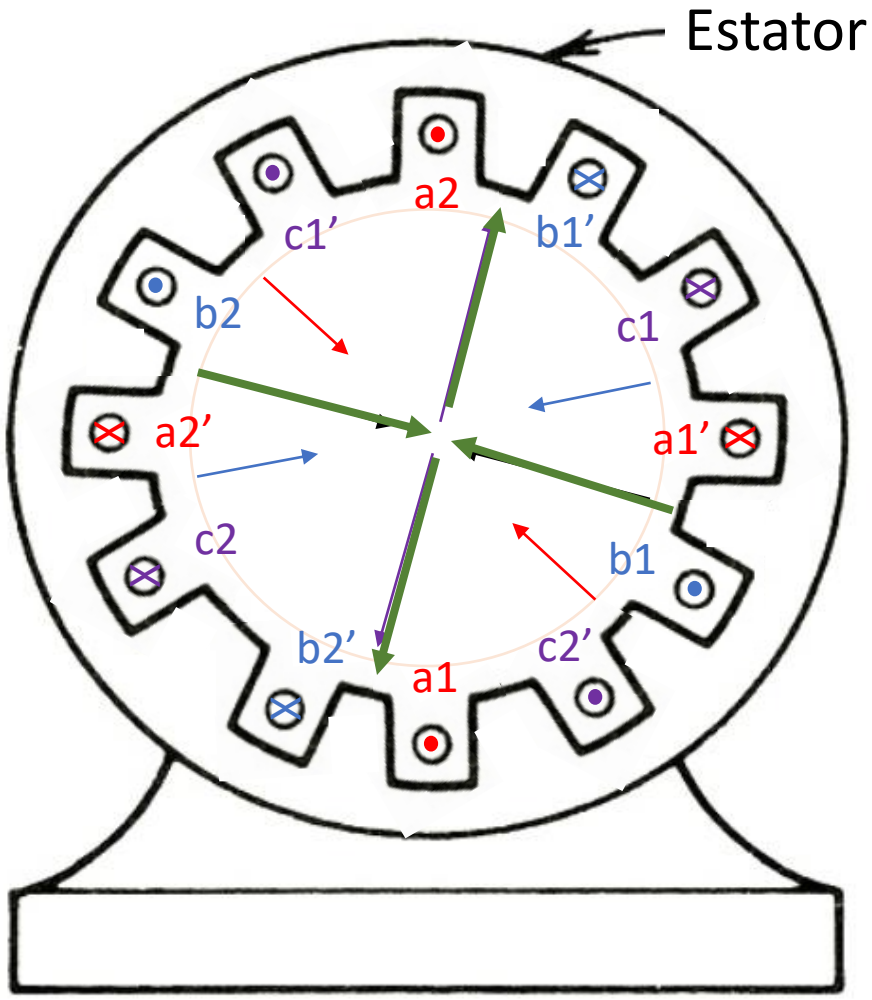
Campo girante – máquina de 4 pólos



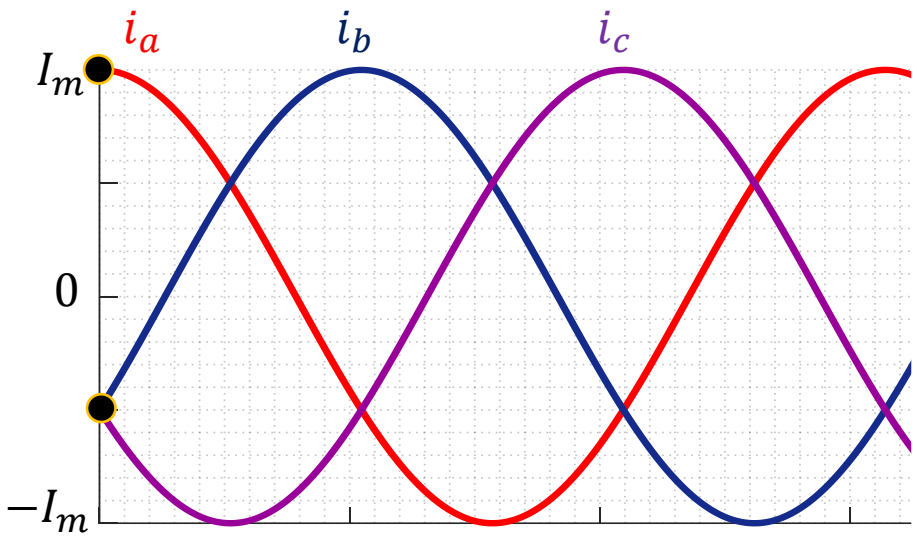


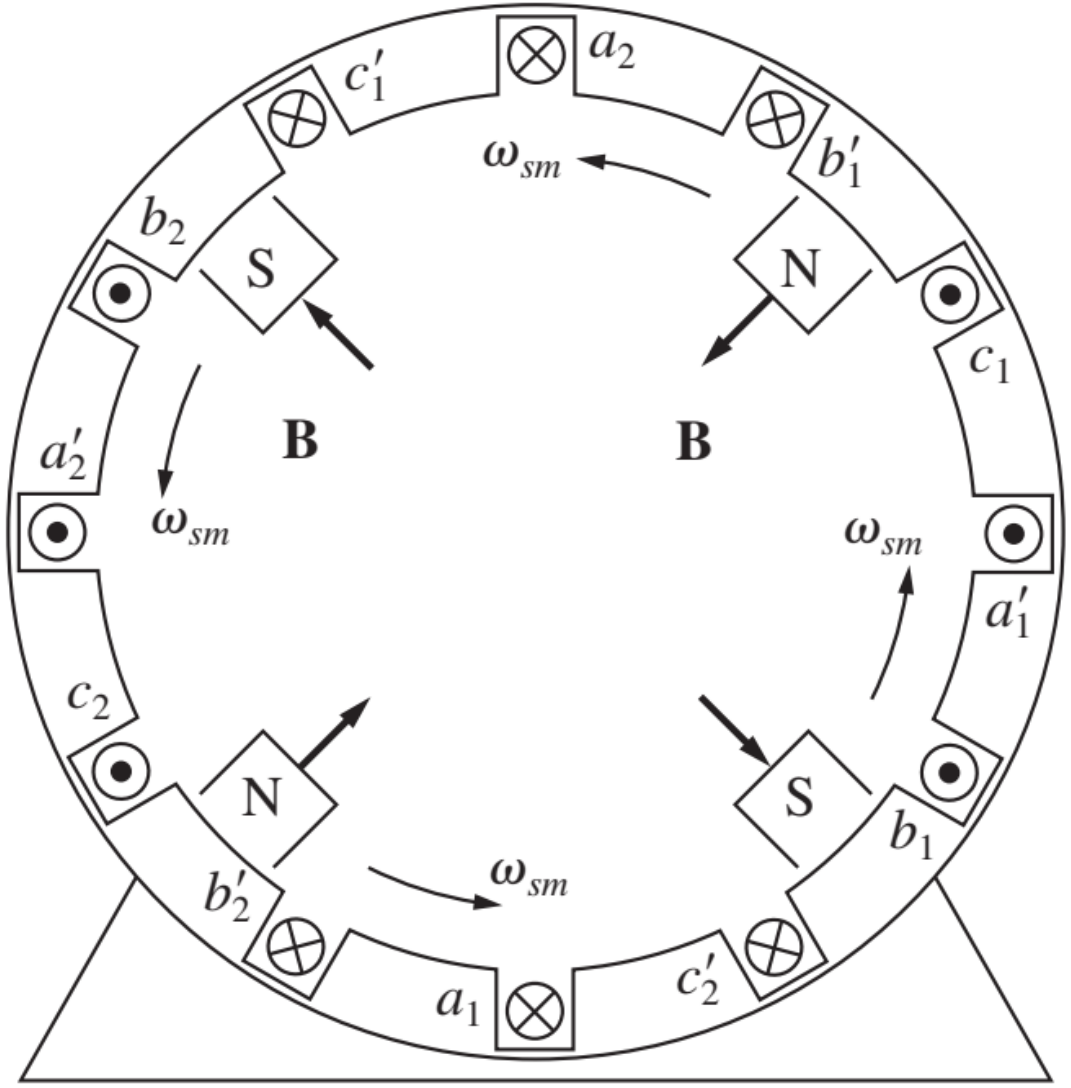
Campo girante – máquina de 4 pólos



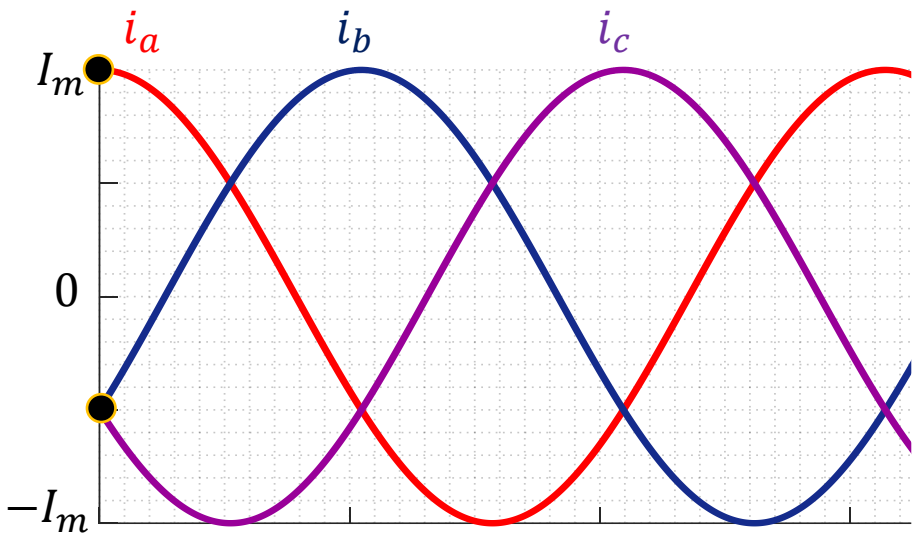


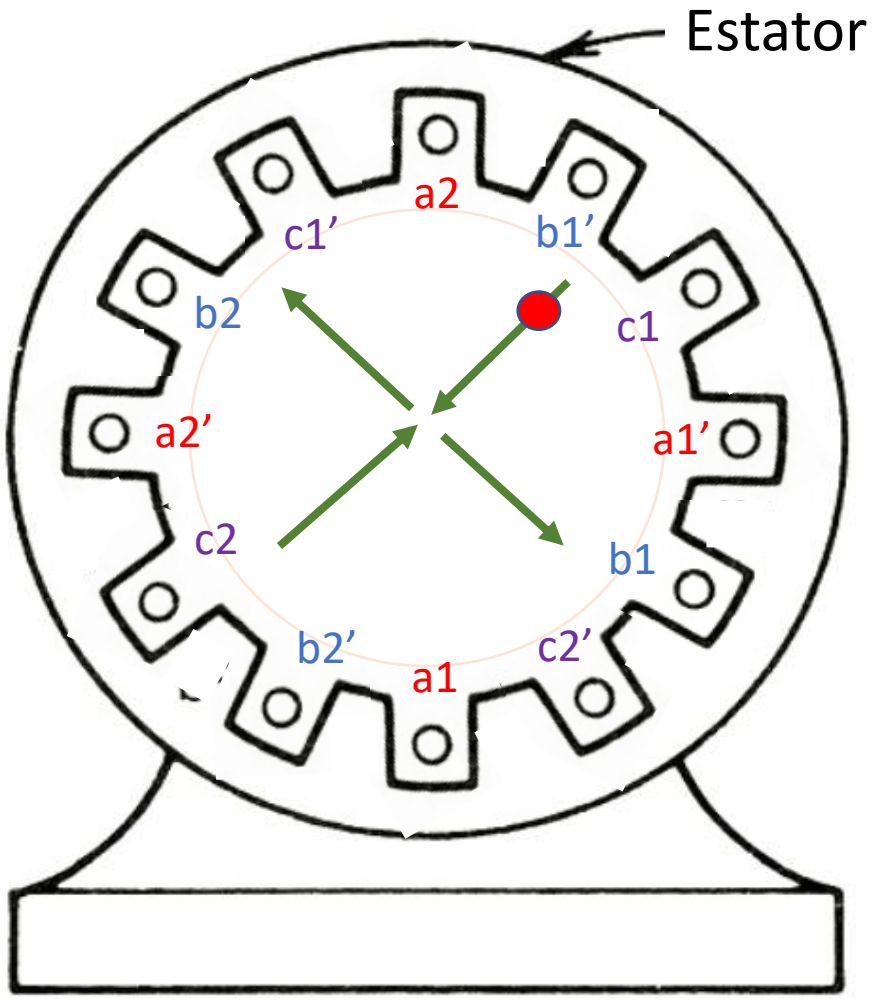
Analogia a um ímã – máquina de 4 pólos



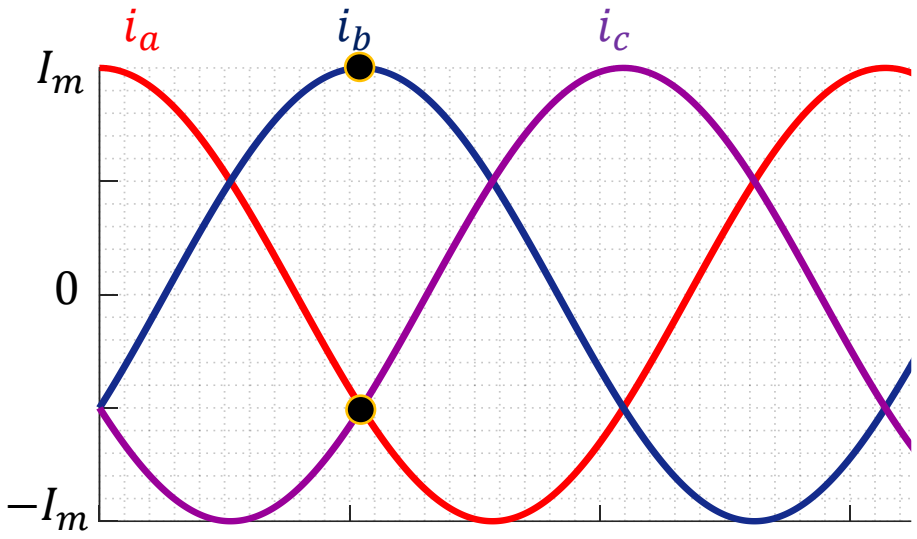


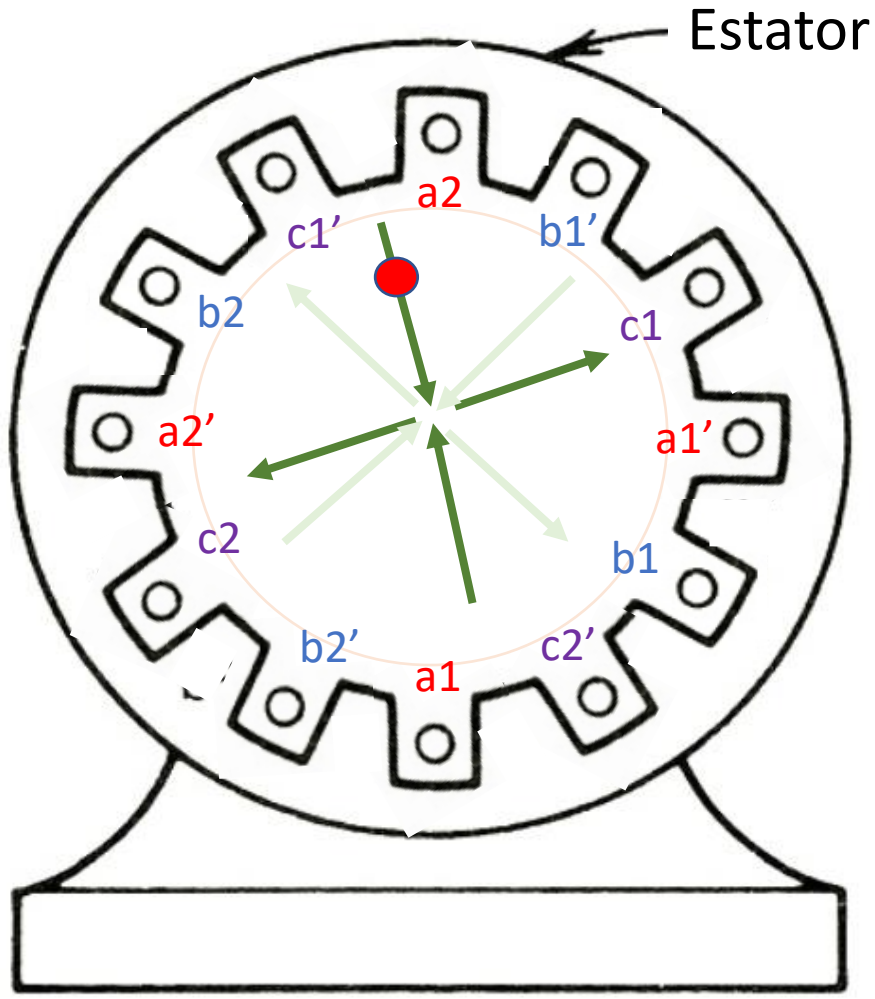
Movimentação do campo girante – máquina de 4 polos



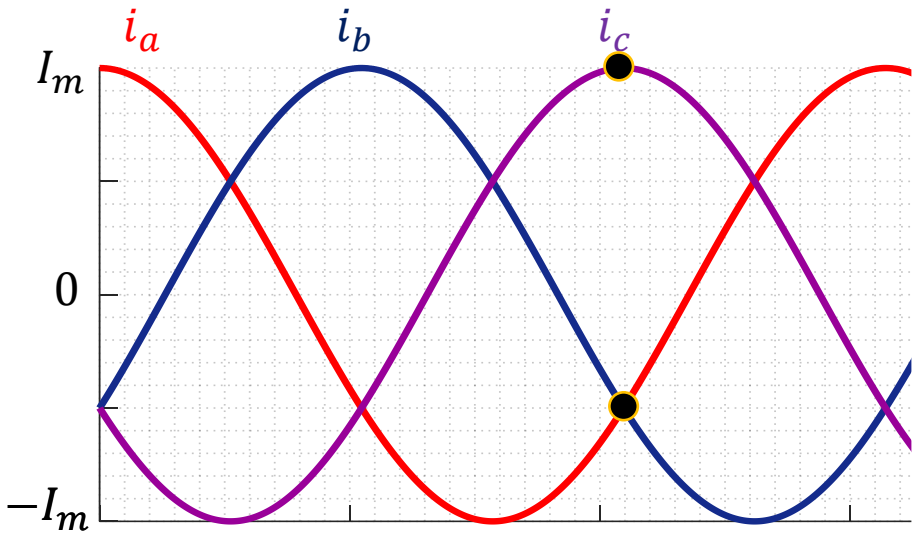


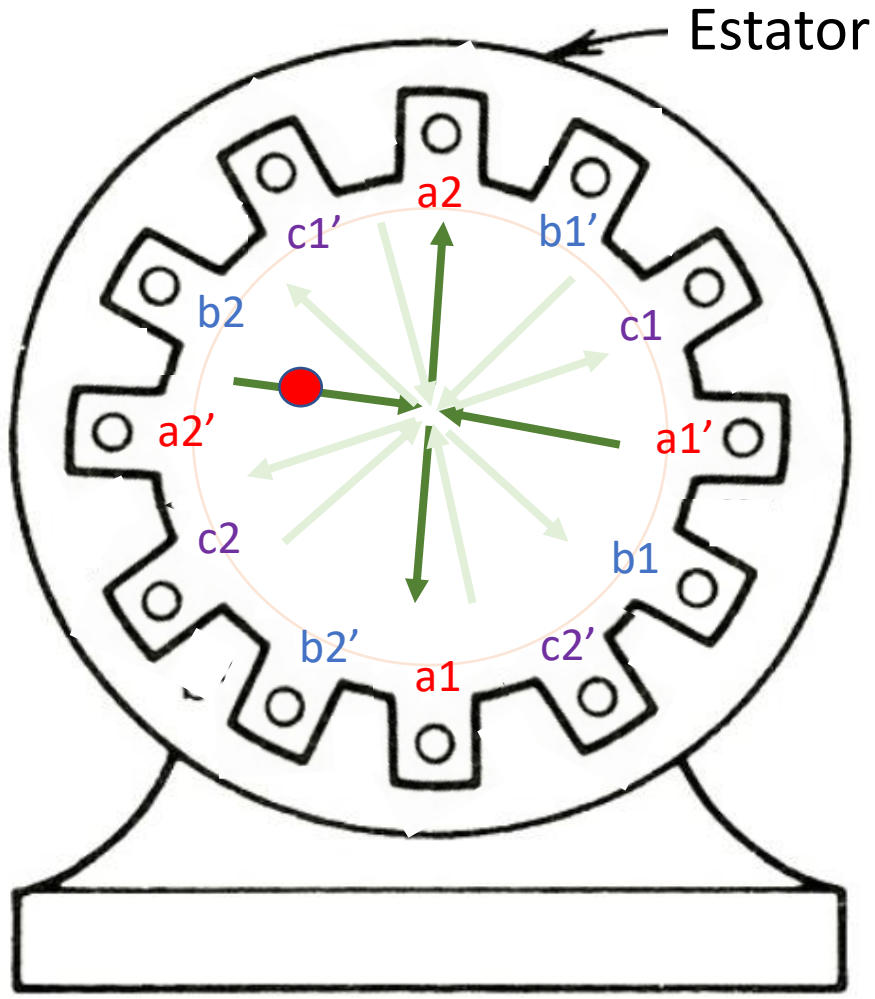
Movimentação do campo girante – máquina de 4 polos





Movimentação do campo girante – máquina de 4 polos





❑ Conclusão:

Para a máquina de quatro polos, $\theta_e = 2\theta_m$.

Velocidade do campo girante - caso geral

$$\theta_e = \frac{p}{2}\theta_m$$

onde p é o número de polos da máquina.

A velocidade angular do campo girante em rpm é dada por:

$$n_s = \frac{120\ f}{p}$$

onde f é a frequência das correntes de estator em Hz e p é o número de polos da máquina.

n_s é denominada **velocidade síncrona** da máquina.

- Máquina de 4 polos e 60 Hz $\rightarrow n_s = 1800$ rpm.

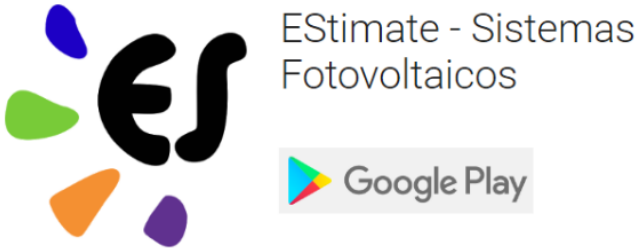
Obrigado pela Atenção

www.gesep.ufv.br

https://www.facebook.com/gesep

https://www.instagram.com/gesep_vicosa/

https://www.youtube.com/channel/UCe9KOSGORXh_hDBIcxMU2Nw



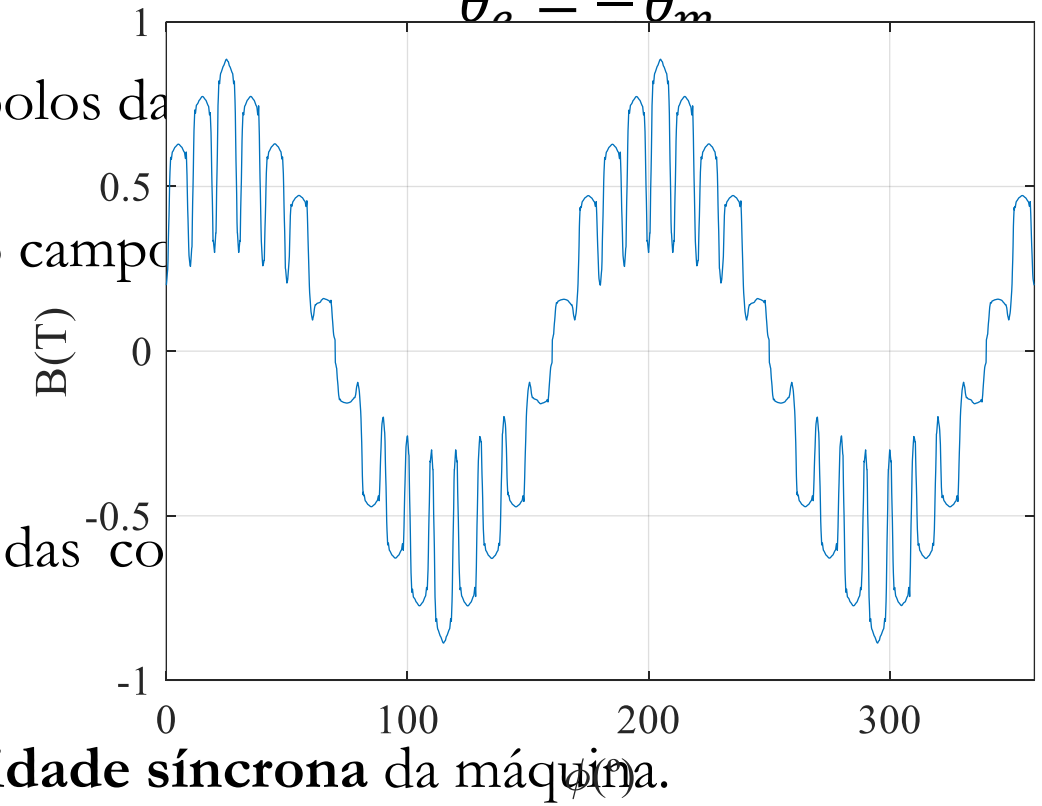
https://play.google.com/store/apps/details?id=br.developer.gesep.estimate

Velocidade do campo girante - caso geral

$$\theta_e = \frac{p}{2}\theta_m$$

onde p é o número de polos da

A velocidade angular do campo



onde f é a frequência das co número de par de polos da máquina.

n_s é denominada **velocidade síncrona** da máquina.

- Máquina de 4 polos e 60 Hz → $n_s = 1800$ rpm.