ELEKTRIČNI STROJEVI

• strojevi – asinkroni, sinkroni, istosmjerni

• svaki od njih može raditi kao generator ili motor

•Asinkroni se pretežito koriste kao motori, sinkroni kao generatori (ima i sinkronih motora)

ASINKRONI STROJEVI

• slaba prilagodljivost brzine vrtnje (bez frekvencijskih pretvornika)

• uz frekvencijske pretvarače mogu se dobiti svojstva kao kod istosmjernih motora (može se dobiti određeni moment pri određenoj brzini vrtnje)

• no upotreba frekvencijskih pretvornika uzrokuje ležajne struje (posebni izolirani ležajevi) i potencijalno zagrijavanje nekih dijelova stroja (temperatura nekog dijela stroja može premašiti temperaturni razred)

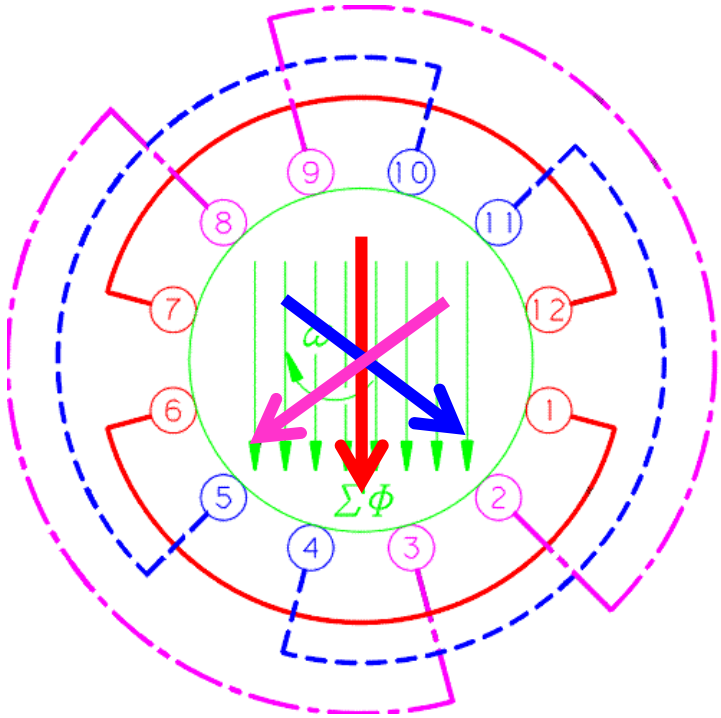
• velika struja pokretanja, obično u rasponu od (6-10) od nazivne vrijednosti

•upuštač – smanjenje napona prije pokretanja
– nedostatak – manji moment stroja (možda se neće pokrenuti)

ASINKRONI MOTORI

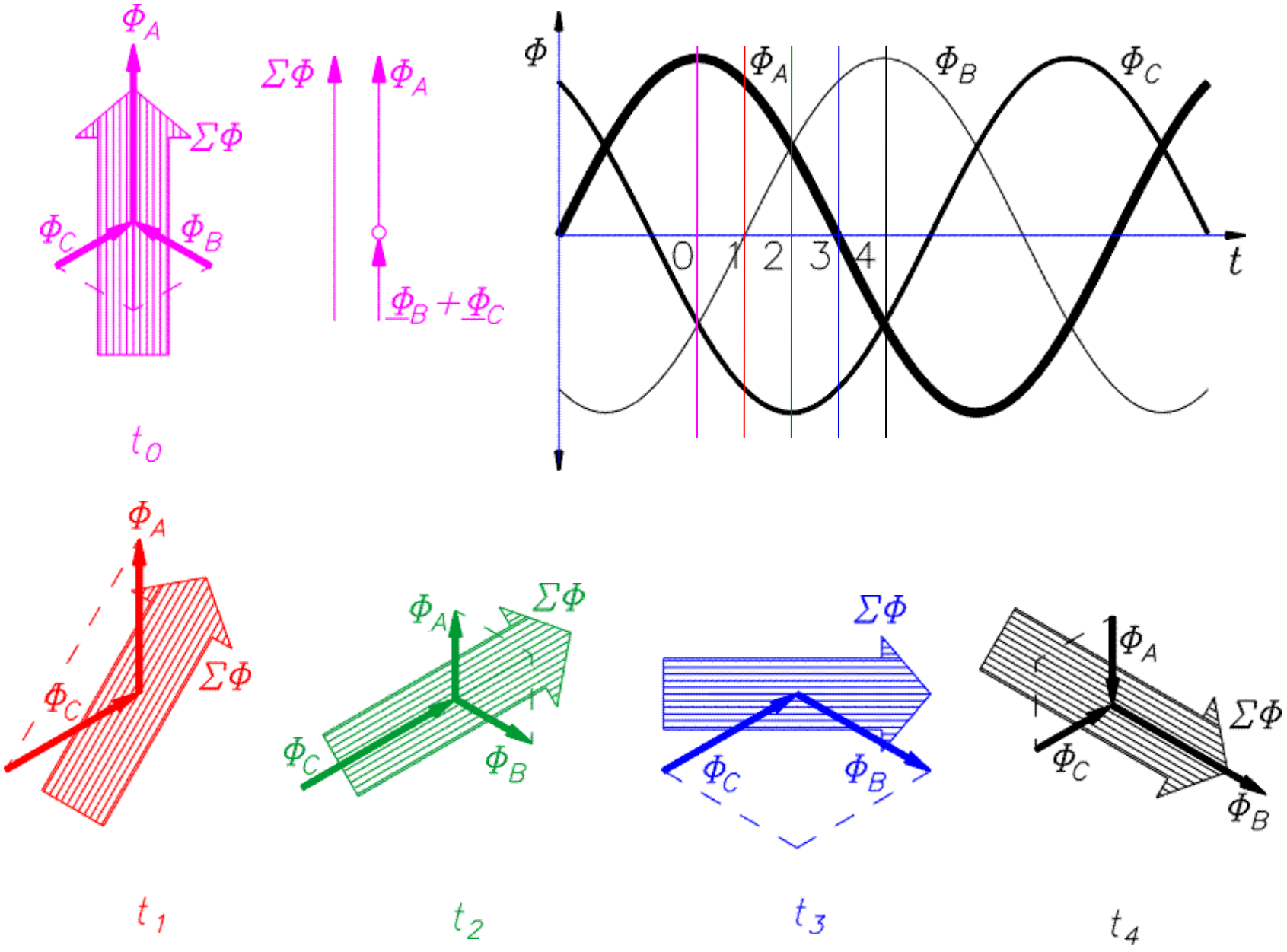
- rotirajuće magnetno polje (stator)
- rotor bez kontakata
- jednostavno održavanje
- pogodni za eksplozivnu atmosferu
- najrašireniji pogoni
- broj okretaja vezan uz broj pari polova motora i frekvenciju mreže

ROTIRAJUĆE MAGNETNO POLJE (TROFAZNOG STATORA)



- namoti međusobno pomaknuti za 120°
- limovi - gubici (kao transformator)
- namoti statora umetnuti u utore
- broj namotaja namota određen s *U* a presjek sa *I*

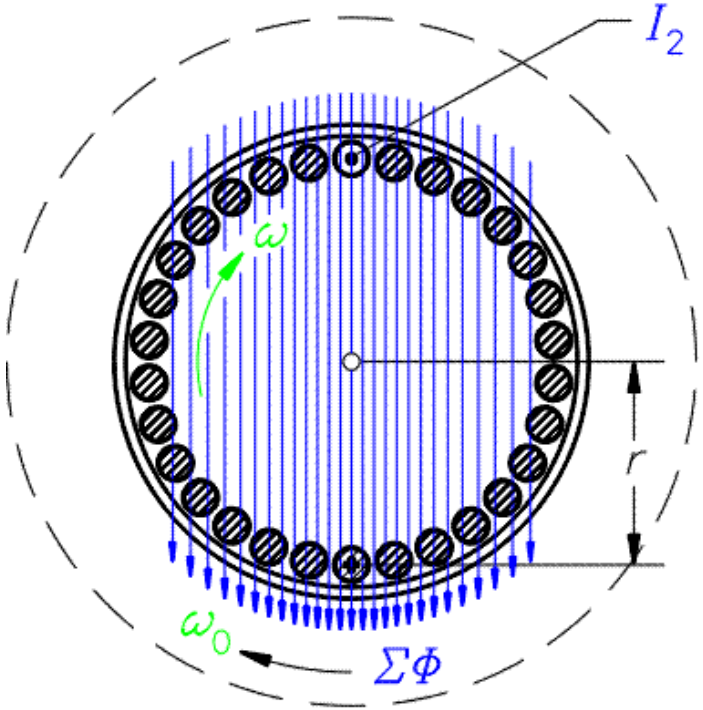
rotirajuće magnetno polje satora za trofazni sustav



MOMENT VRTNJE I KLIZANJE (ROTORA)

• rotor od limova - gubici (kao transformator) • po obodu namoti (vodiči) umetnuti u utore

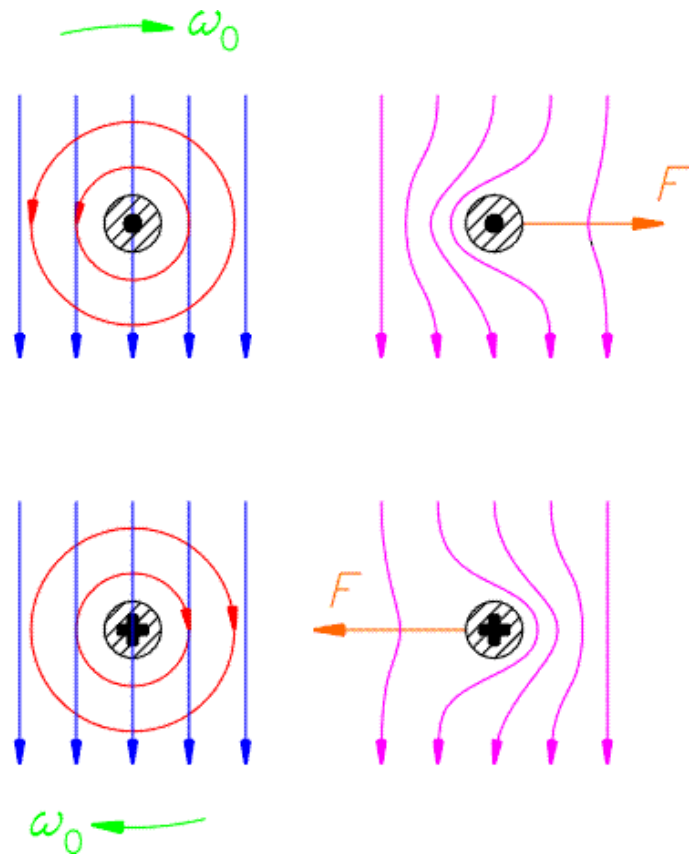
motor kao transformator ⇒ • stator kao primar • rotor kao sekundar



$$I_{20} = \frac{E_{20}}{Z_{20}}$$

$$I_2 = \frac{E_2}{Z_2}$$

$$E_2 = f(\omega_0 - \omega)$$
$$I_2 = f(\omega_0 - \omega)$$
$$F = f(I_2)$$
$$F = f(\omega_0 - \omega)$$
$$M = 2F \cdot r$$
$$M = f(\omega_0 - \omega)$$



brzina vrtnje magnetnog polja $n_s = \frac{60 \cdot f}{p}$ ***p* – broj pari polova**
za dvopolni stroj i 50 Hz *n*=3000 min^{-1}

u trenutku priključenja teče I_{20} **uz** $Z_{20} = \sqrt{R_2^2 + X_{20}^2}$ **i** R **= konst. a** $X_{20} = \omega_0 L_2 = 2\pi f_0 \cdot L_2$

$$U = 4{,}44 \cdot N \cdot \phi \cdot f$$

zbog I_{20} i $\Phi \Rightarrow F \Rightarrow M \Rightarrow$ vrtnja rotora $\Rightarrow \downarrow f$ induciranog U u rotoru

za $n = n_s \Rightarrow$ nema induciranog $U \Rightarrow$ nema $I_2 \Rightarrow$ nema $F \Rightarrow M \Rightarrow$ zaustavljanje rotora

zato se rotor uvjek vrti sporije od sinkrone brzine - klizi $s = \dfrac{n_s - n}{n_s}$

$$I_2 = \frac{E_2}{Z_2}$$

$$E_2 = f(\omega_0 - \omega) = E_{20} \cdot s \quad \text{— klizanje}$$

$$Z_2 = \sqrt{R_2^2 + X_2^2}$$

$$X_2 = \omega_2 L_2 = 2\pi f_2 \cdot L_2 = 2\pi \cdot s \, f \cdot L_2$$

- f_2 - f induciranog napona u rotoru
- f - mrežna f
- E_{20} - inducirani napon pri uključenju

klizanje u pokretanju $s = \dfrac{n_s - 0}{n_s} = 1$

klizanje pri sinkronoj brzini vrtnje $s = \dfrac{n_s - n_s}{n_s} = 0$

***U* rotora pri pokretanju (zakočeni rotor)** $E_{20} = \dfrac{N_2}{N_1} \cdot E_1$

***U* rotora uz klizanje** $E_2 = s \cdot \dfrac{N_2}{N_1} \cdot E_1$

***Z* rotora uz klizanje** $Z_2 = \sqrt{R_2^{\,2} + (s \cdot X_{20})^2}$

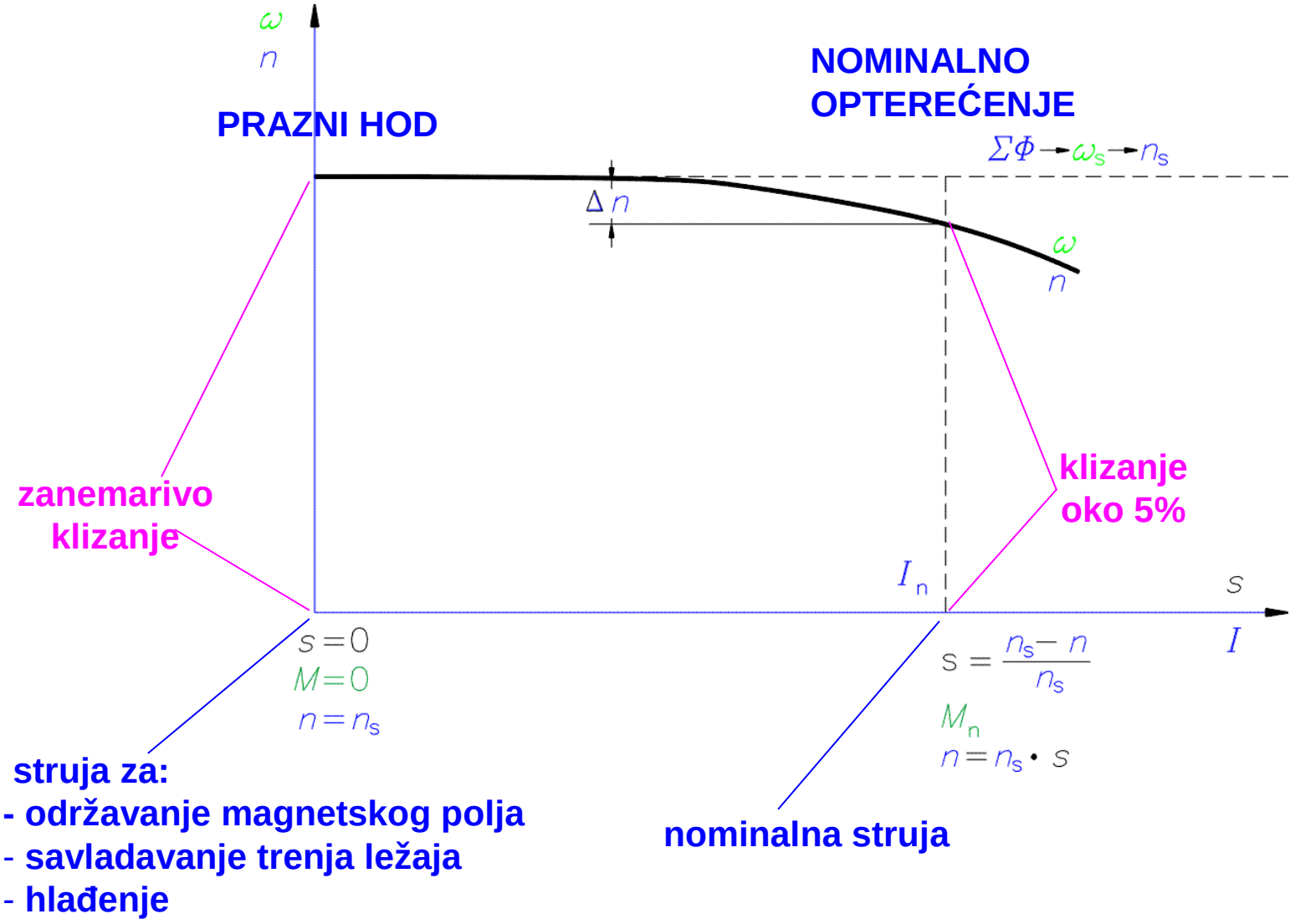
***I* rotora uz klizanje** $I_2 = \dfrac{s \cdot E_{20}}{\sqrt{R_2^{\,2} + (s \cdot \omega_0 \cdot L_2)^2}}$

pri pokretanju rotora je $\operatorname{tg} \varphi_2 = \dfrac{s \cdot X_{20}}{R_2}$

odnosno $\sin \varphi_2 = \dfrac{s \cdot X_2}{\sqrt{R_2^{\,2} + (s \cdot \omega_0 \cdot L_2)^2}}$

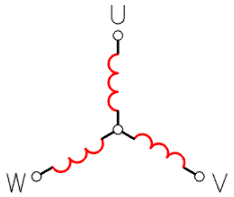
i $I_2 = \dfrac{E_{20}}{X_{20}} \cdot \sin \varphi_2$

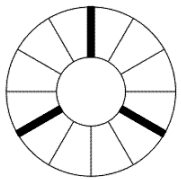
klizanje rotora



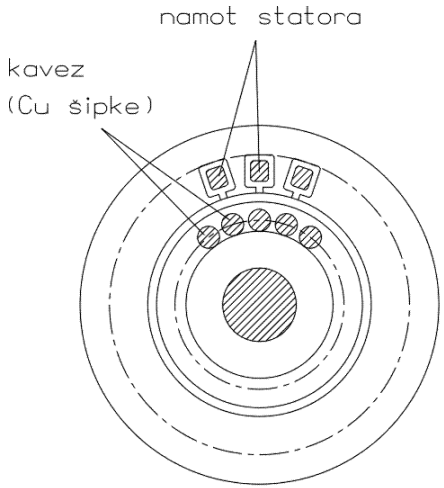
IZVEDBE MOTORA

kavezni



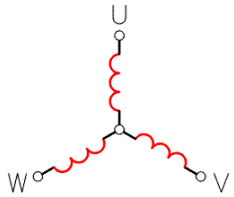


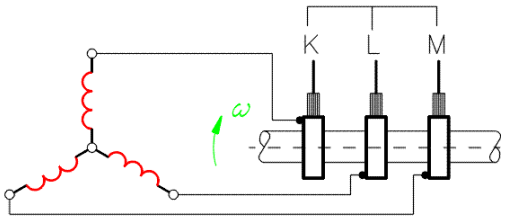
kratkospojni motor
rotor s kavezom



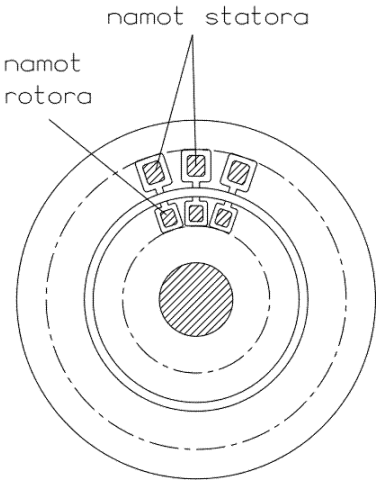
namot kaveznog motora

kolutni



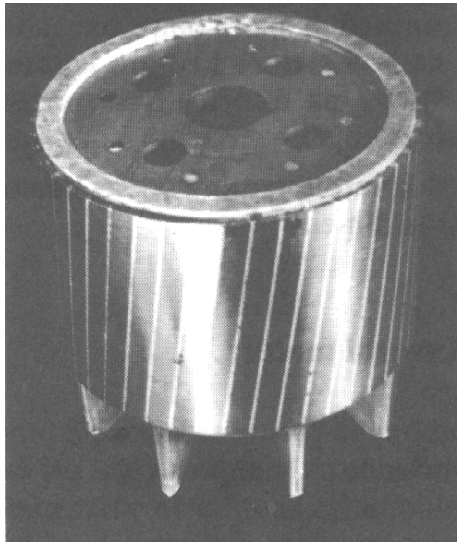


kolutni motor
rotor s namotom

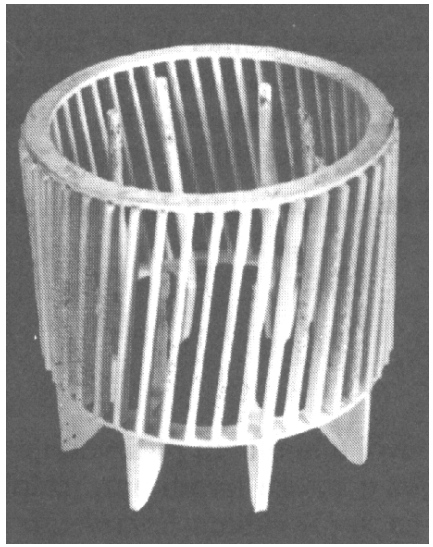


namot kolutnog motora

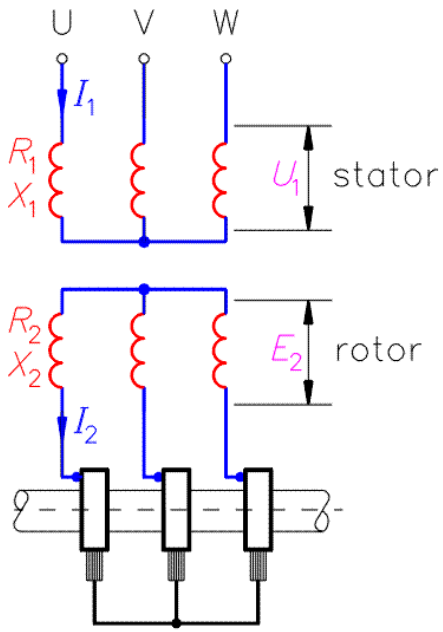
kavezni rotor

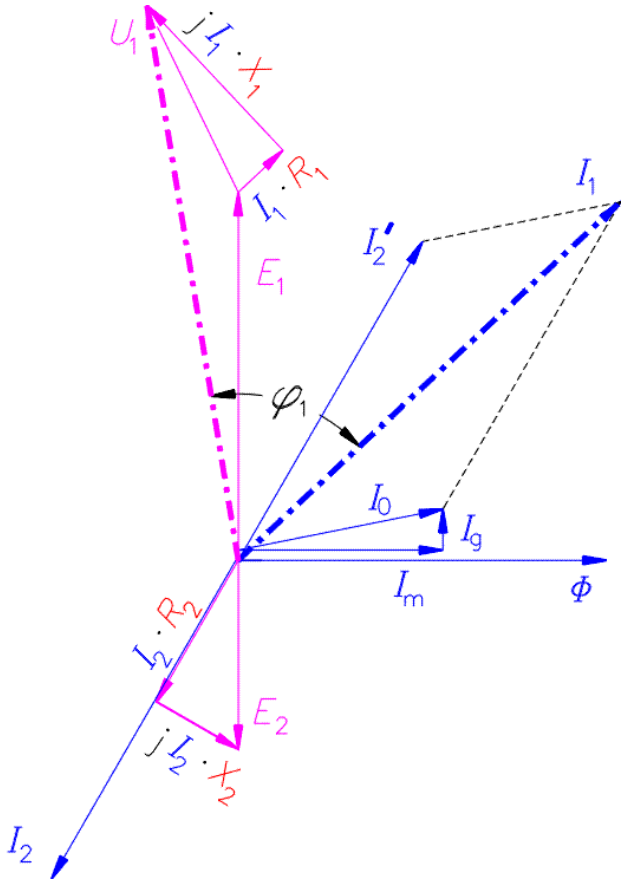


kavez rotora

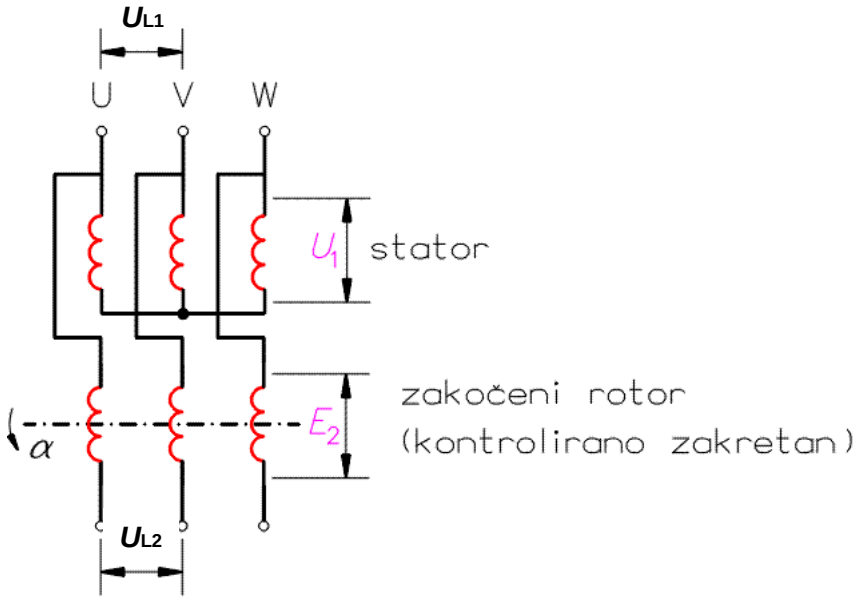


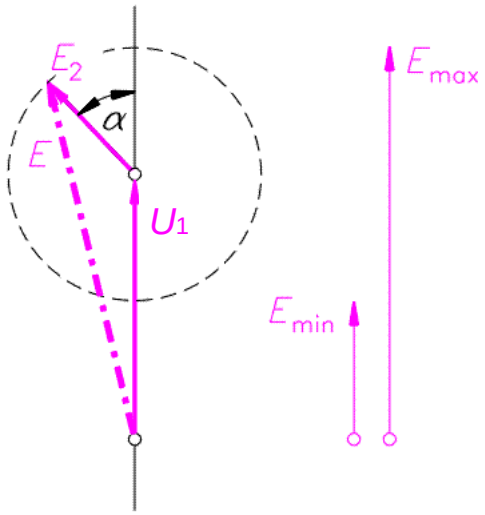
kolutni motor - kao transformator u kratkom spoju





Kolutni motor kao zakretni transformator



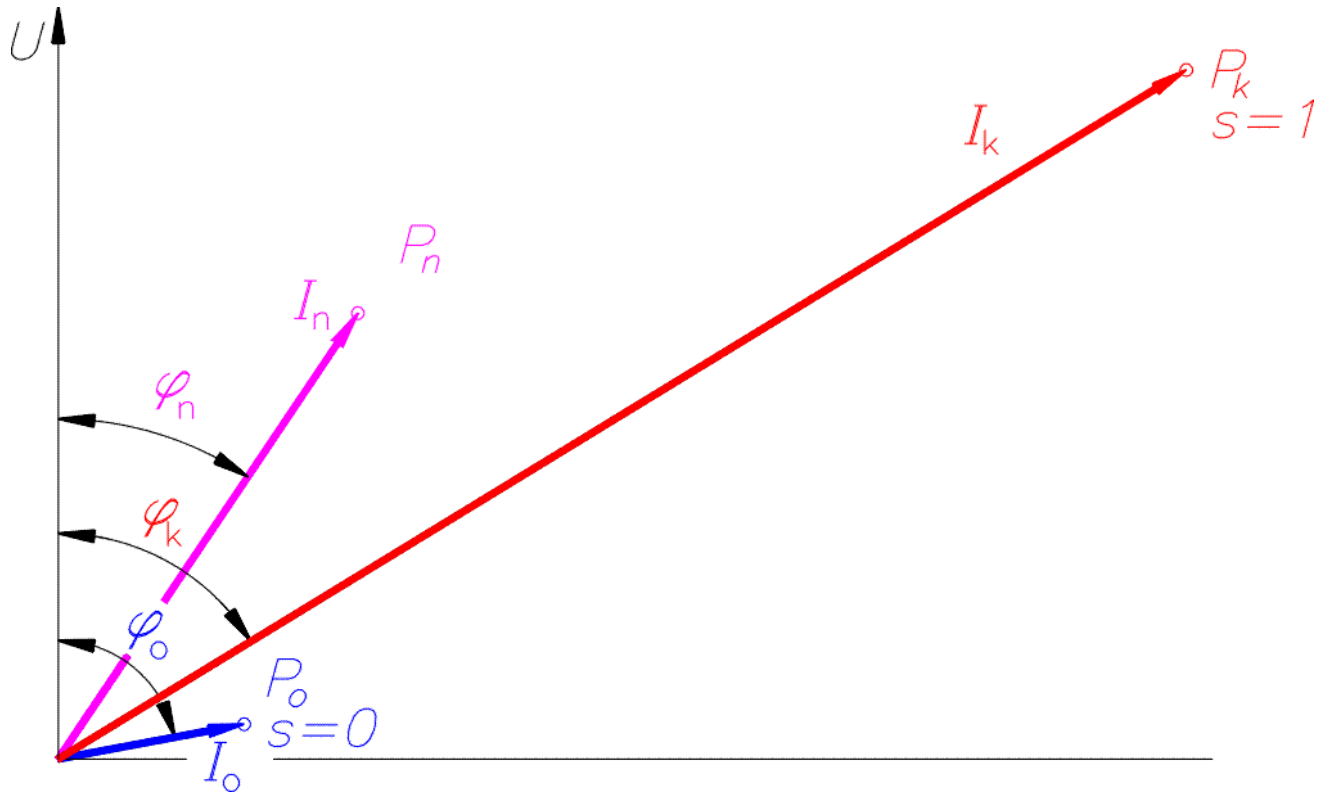


$$E_{min} = E_1 - E_2$$

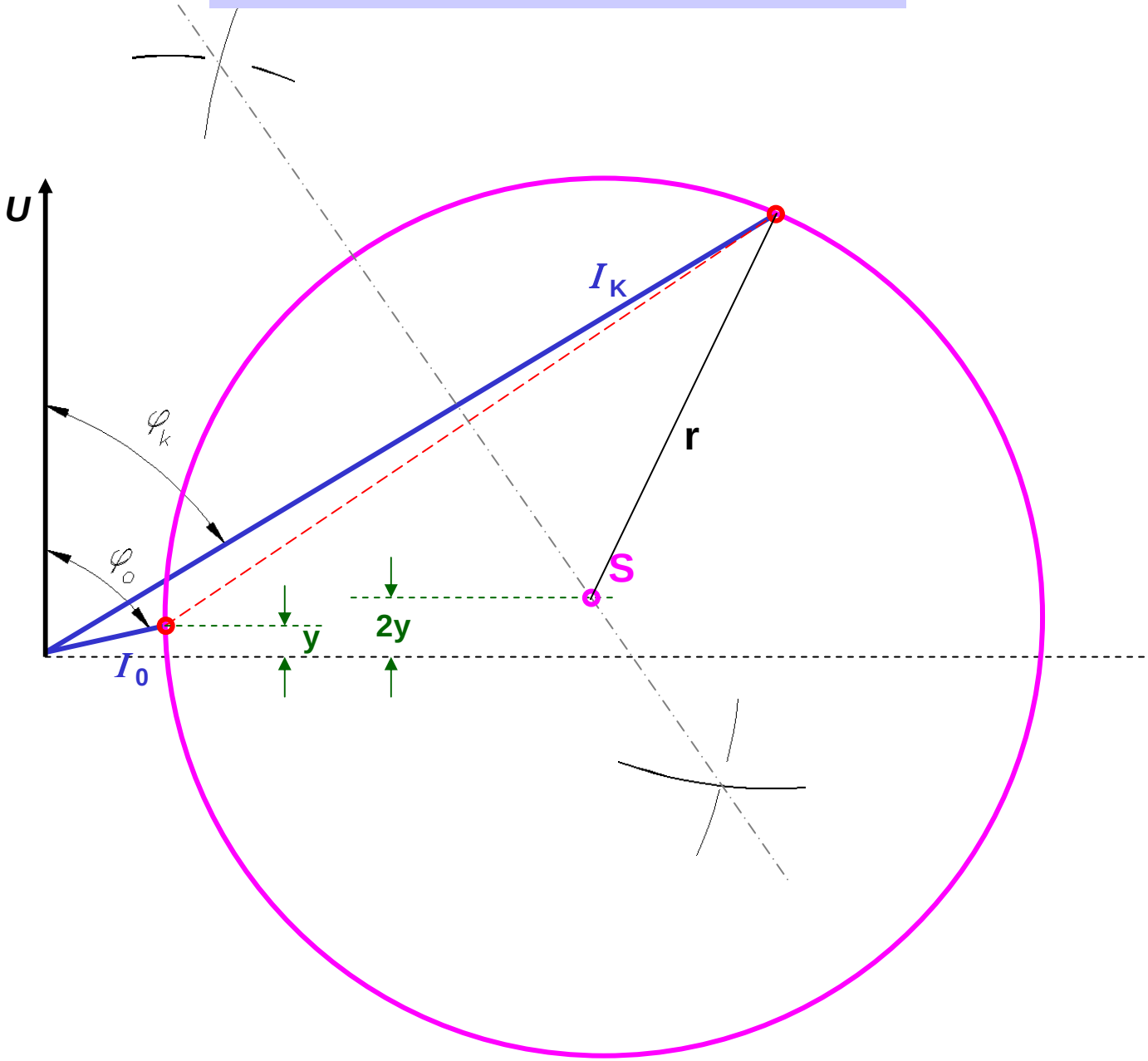
$$E_{max} = E_1 + E_2$$

KAZALIČNI PRIKAZ PARAMETARA MOTORA (kružni dijagram)

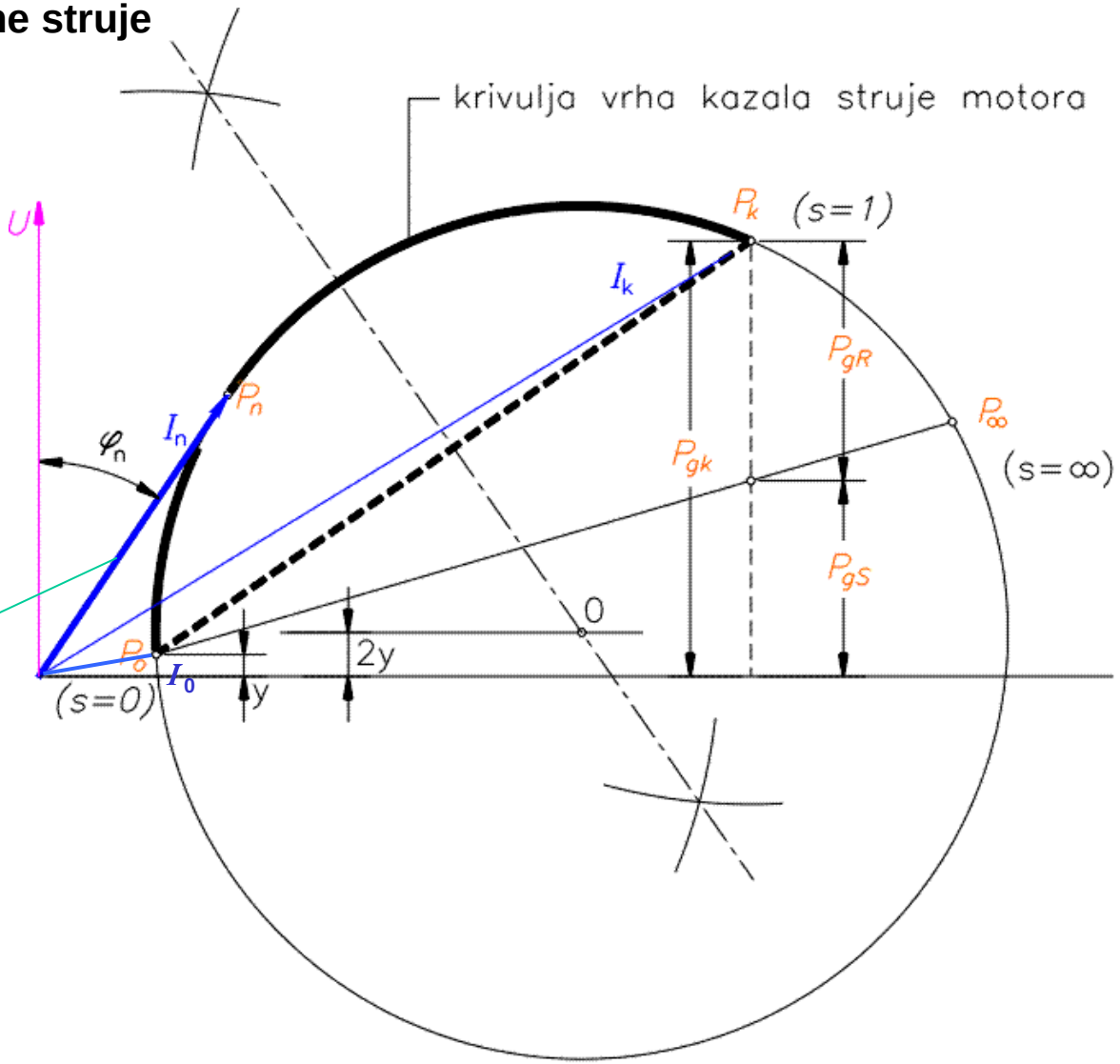
Struje motora



CRTANJE KRUŽNOG DIJAGRAMA



određivanje nominalne struje

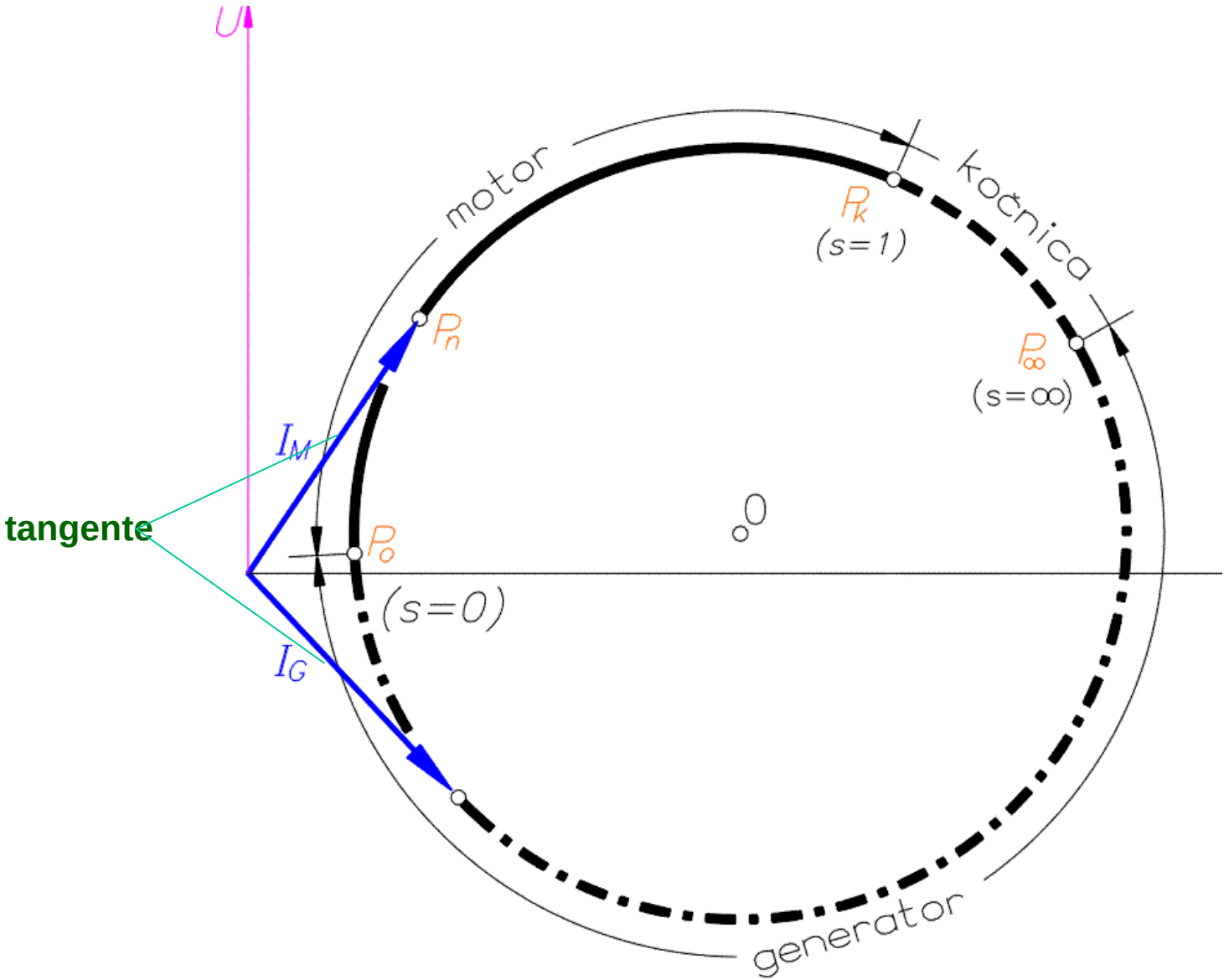


tangenta iz ishodišta

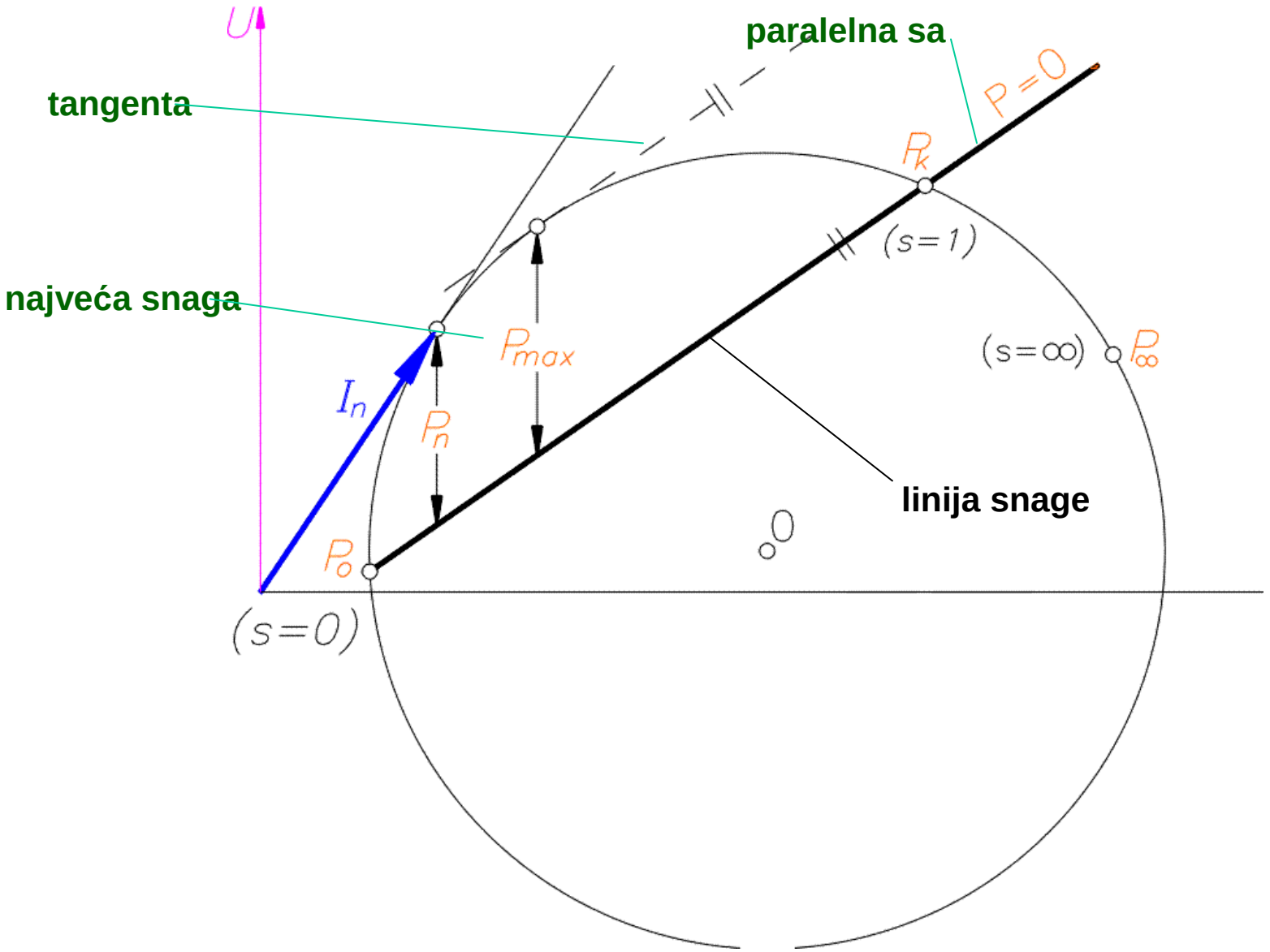
P_o – prazni hod
P_k – zakočeni motor

P_{gk} – gubitci
P_{gR} – gubitci u bakru rotora
P_{gS} – gubitci u bakru statora

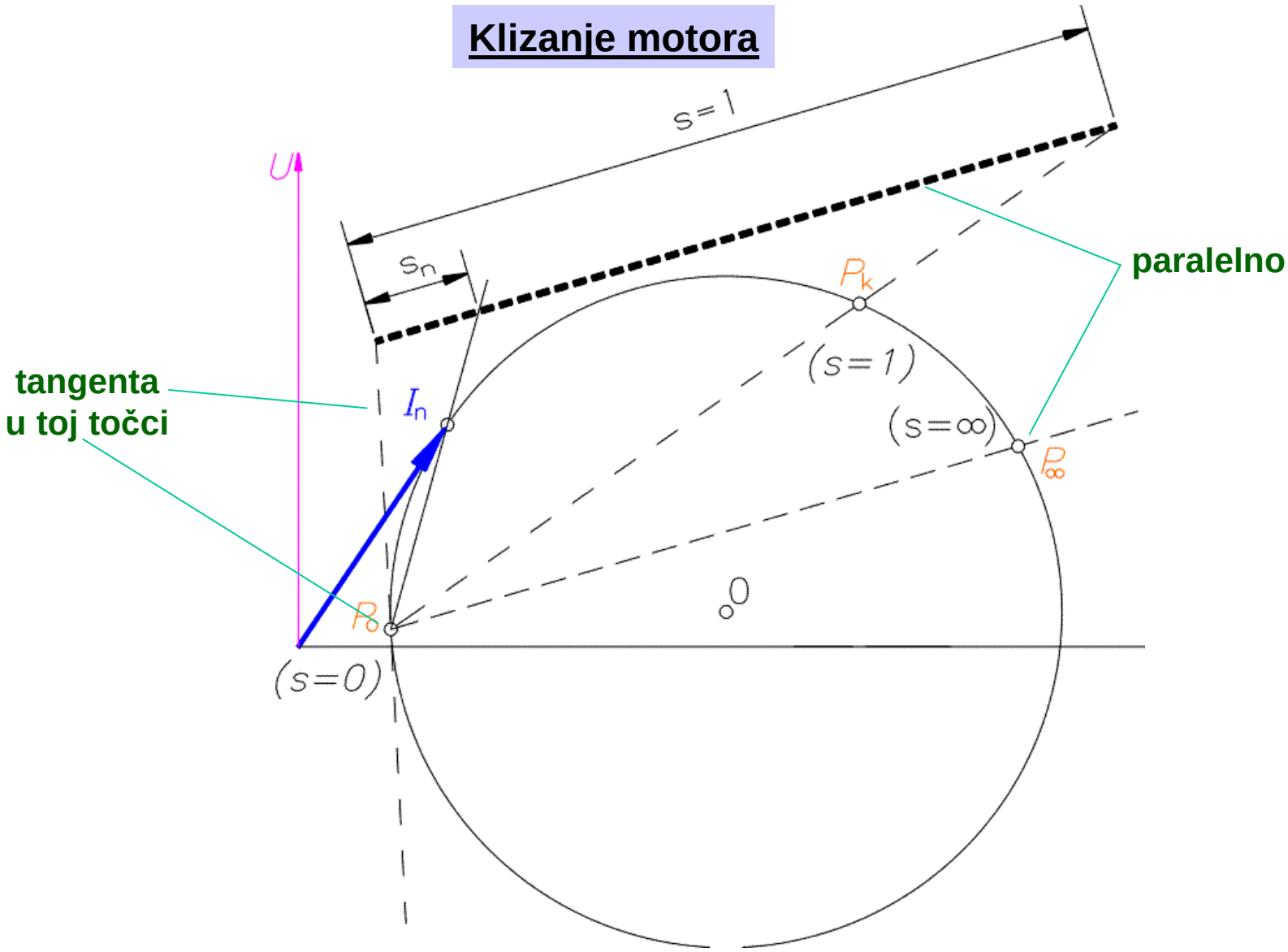
Područje rada asinkronog stroja



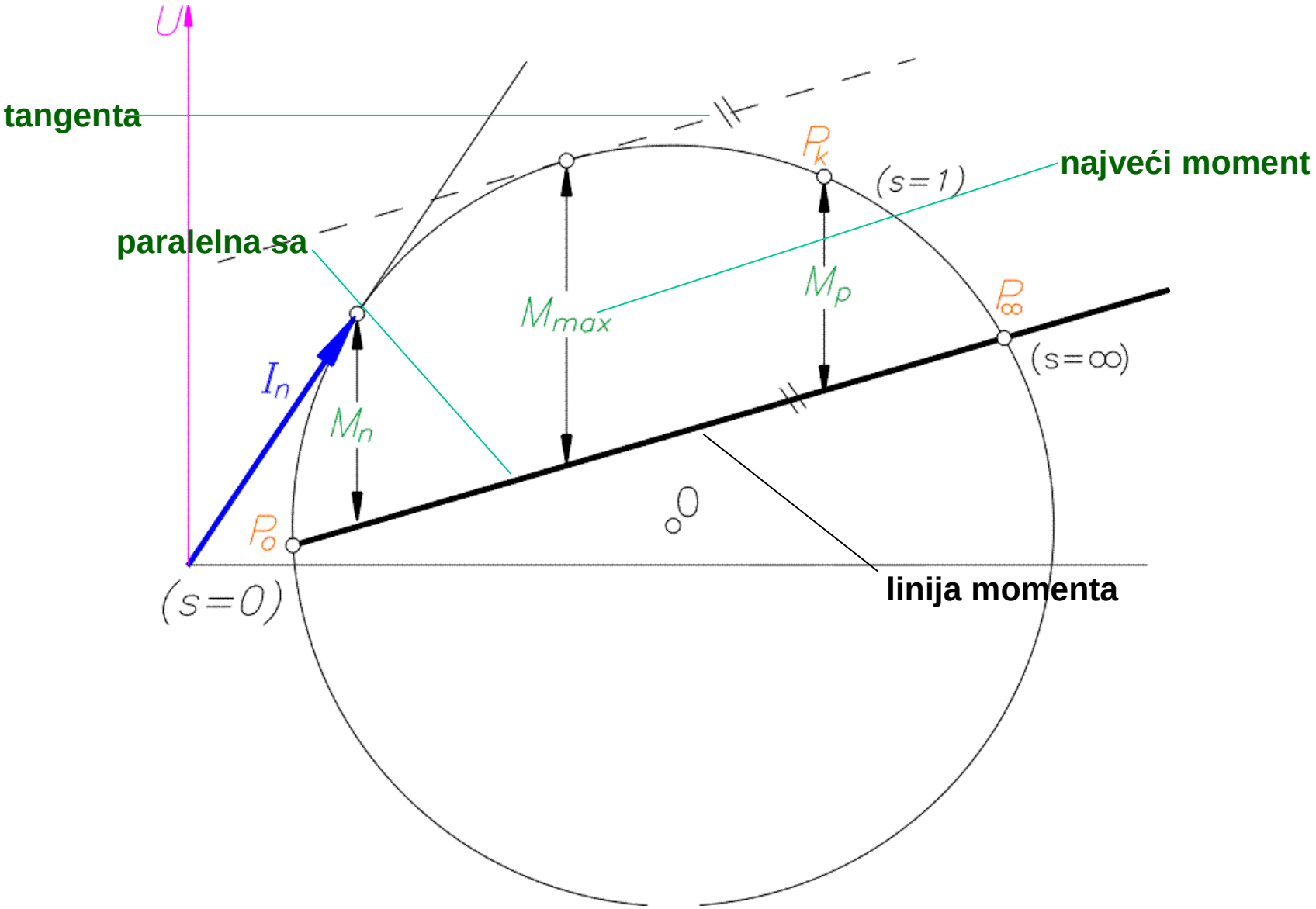
Snaga motora



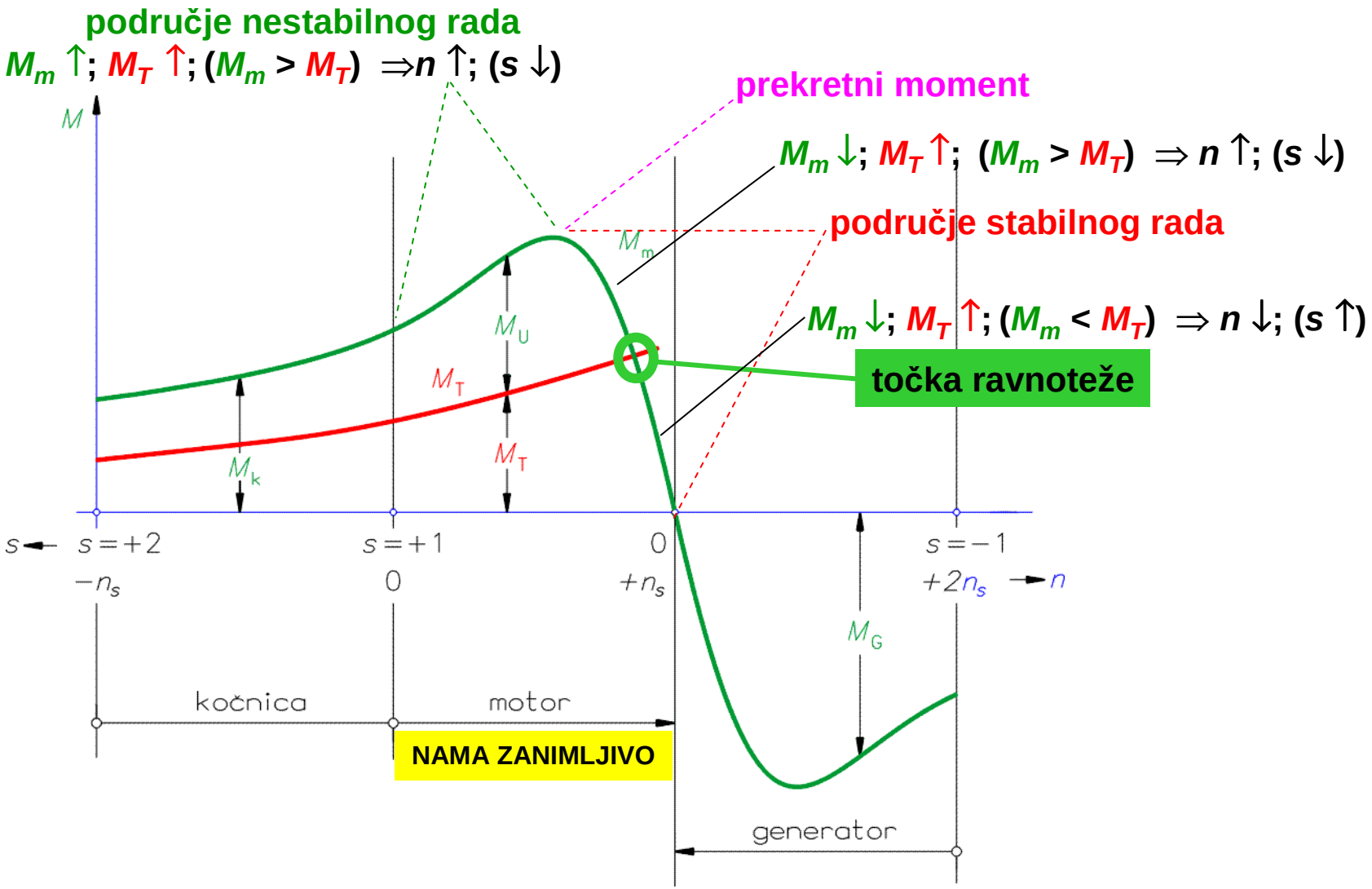
Klizanje motora

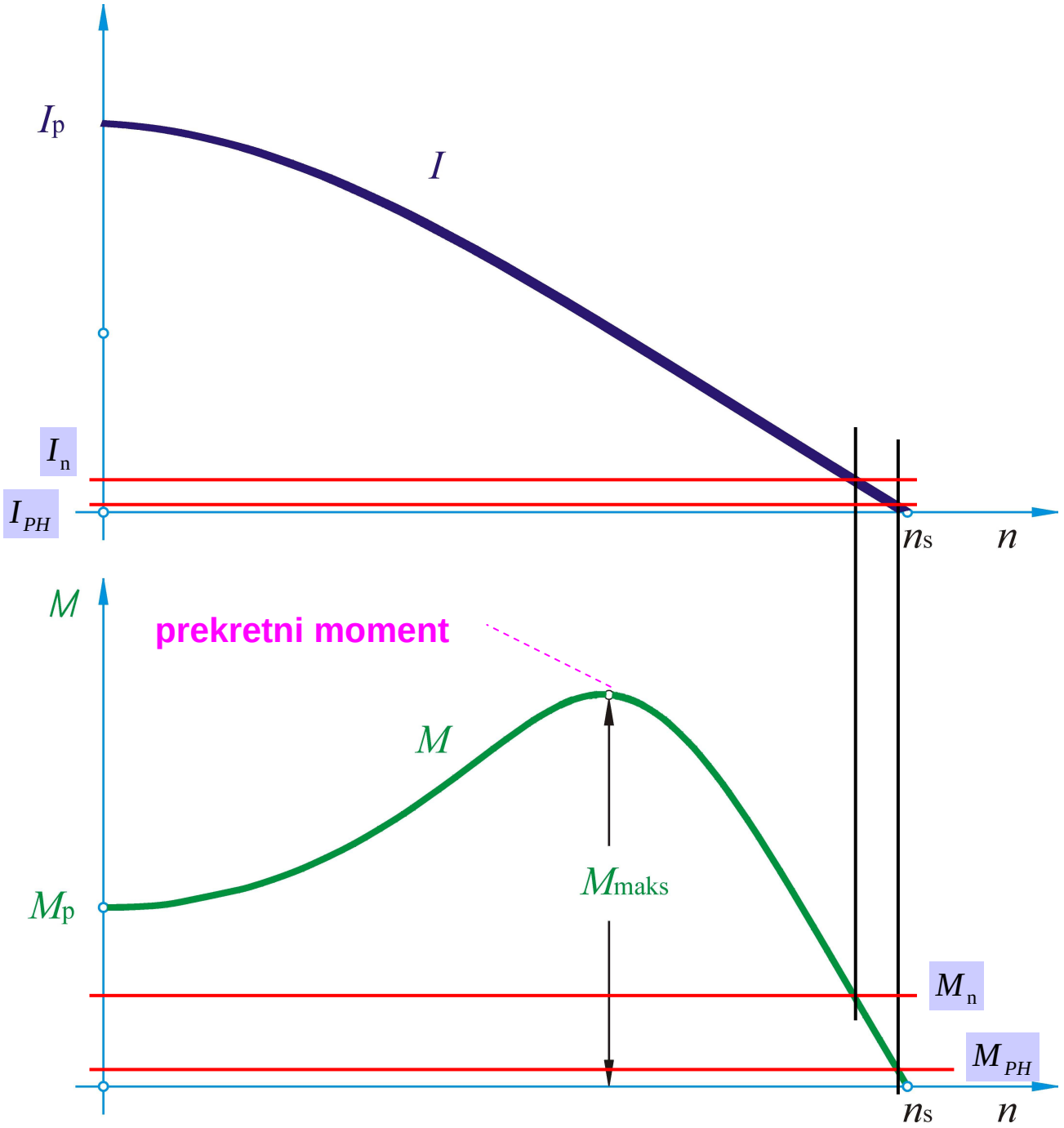


Moment vrtnje

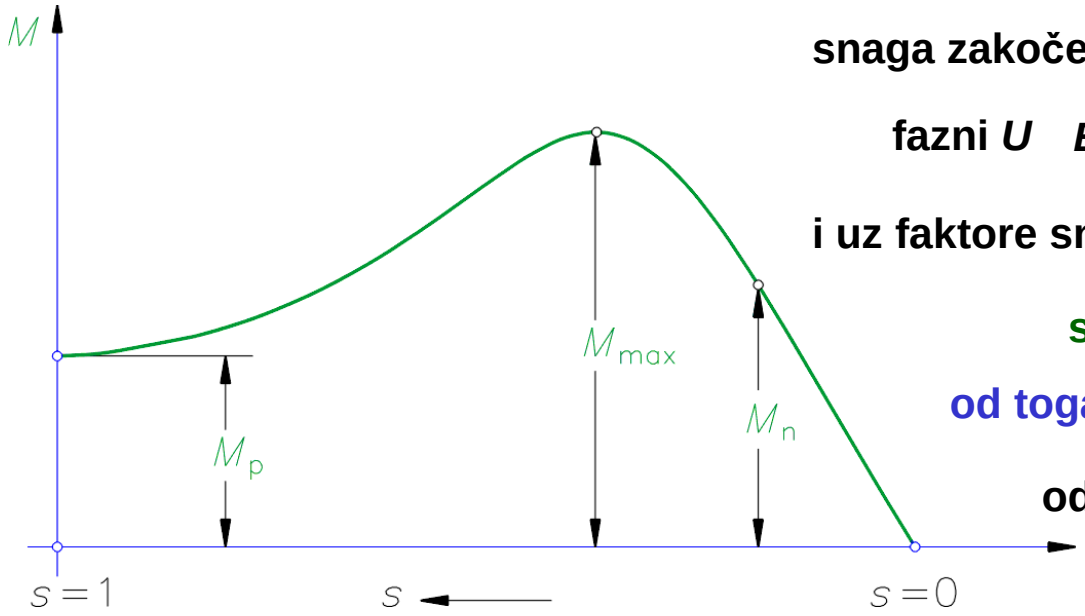


međuovisnost momenta, brzine vrtne i klizanja asinkronog stroja




I_p
I
I_n
I_{PH}
n_s
n
M
prekretni moment
M
M_p
M_{maks}
M_n
M_{PH}
n_s
n

međuovisnost momenta i klizanja asinkronog motora



snaga zakočenog motora je $P_{20} = 3 \cdot E_1 \cdot I_2' \cdot \cos\varphi_2$

fazni U $E_1 = E_{20} \dfrac{N_1}{N_2}$ fazna I $I_2' = I_2 \dfrac{N_2}{N_1}$

i uz faktore snage statora i rotora $\cos'\varphi_2 = \cos\varphi_2$

snaga je $P_{20} = 3 \cdot E_{20} \cdot I_{20} \cdot \cos\varphi_2$

od toga su gubici u rotoru $P_{2g} = 3 \cdot I_2^{\,2} \cdot R_2$

odnosno $P_{2g} = 3 \cdot E_{20} \cdot I_{20} \cdot \cos\varphi_2 \cdot s$

ili $P_{2g} = s \cdot P_{20}$

a raspoloživa snaga $P_2 = P_{20} - P_{2g}$

$$P_2 = 3 \cdot E_{20} \cdot \frac{s \cdot E_{20}^{\,2}}{\sqrt{R_2^{\,2} + (s \cdot X_{20})^2}} \cdot (1 - s) \cdot \frac{R_2}{\sqrt{R_2^{\,2} + (s \cdot X_{20})^2}}$$

moment motora je $M = \dfrac{P_2}{\omega}$ odnosno $M = k_1 \cdot \dfrac{s \cdot E_{20}^{\,2} \cdot R_2}{R_2^{\,2} + (s \cdot X_{20})^2}$ uz $k_1 = \dfrac{3 \cdot 60}{2\pi n_s}$

ako se izrazi E_{20} kao $E_{20} = \dfrac{U_1}{k_2}$

moment motora $M = \dfrac{k_1}{k_2} \cdot \dfrac{s \cdot U_1^{\,2} \cdot R_2}{R_2^{\,2} + (s \cdot X_{20})^2}$

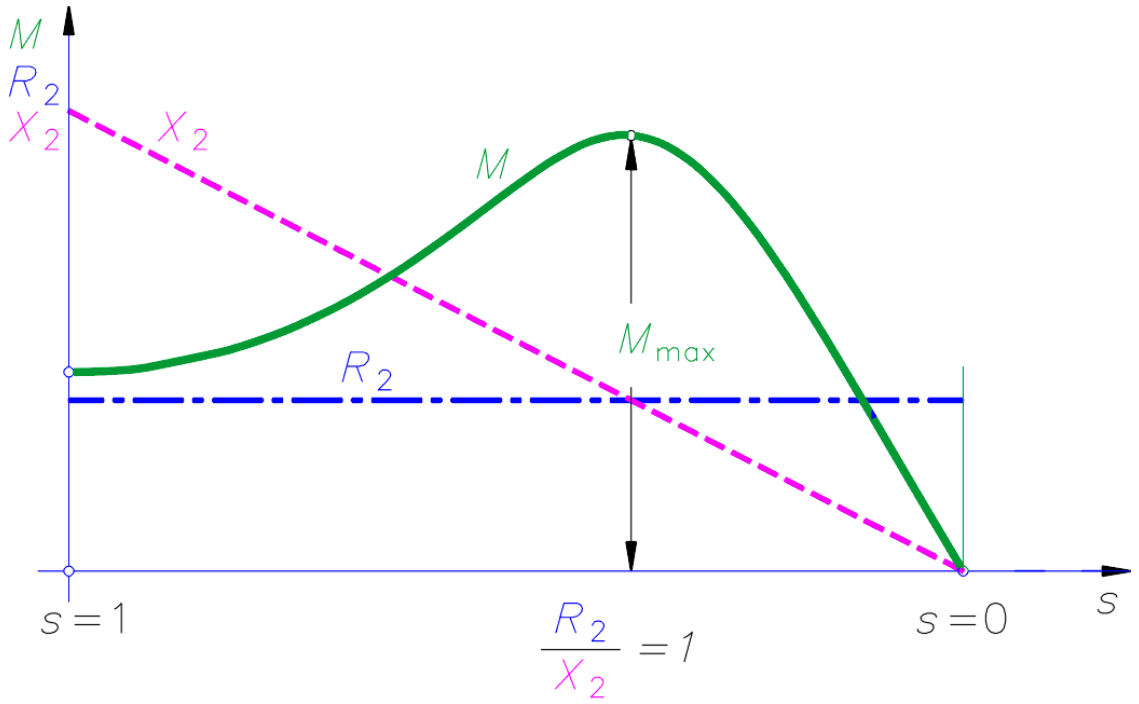
ovisnost o naponu mreže

ovisnost o klizanju

pri stalnom klizanju
15% ↓ U ⇒ 28% ↓ M

uz neki U_1 može se pisati $k = \frac{k_1}{k_2} \cdot U_1^2$ pa je $M = k \cdot \frac{s \cdot R_2}{R_2^2 + (s \cdot X_{20})^2}$

M_{max} kada je $\frac{dM}{ds} = 0$ a to se događa kada je $s \cdot X_{20} = R_2$ odnosno $\omega L_2 = 2\pi f_1 \cdot s \cdot L_2 = R_2$

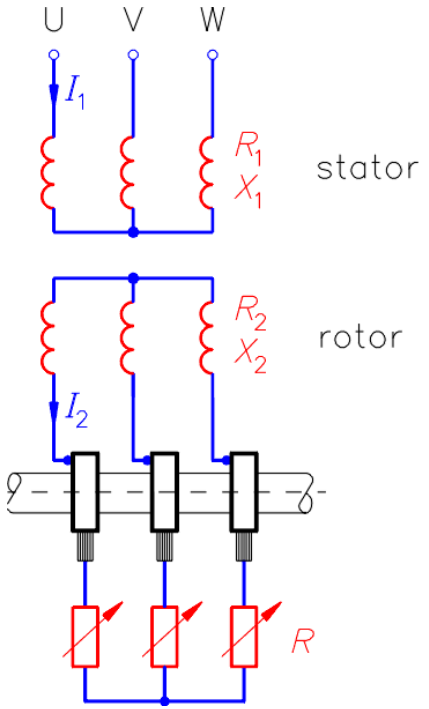


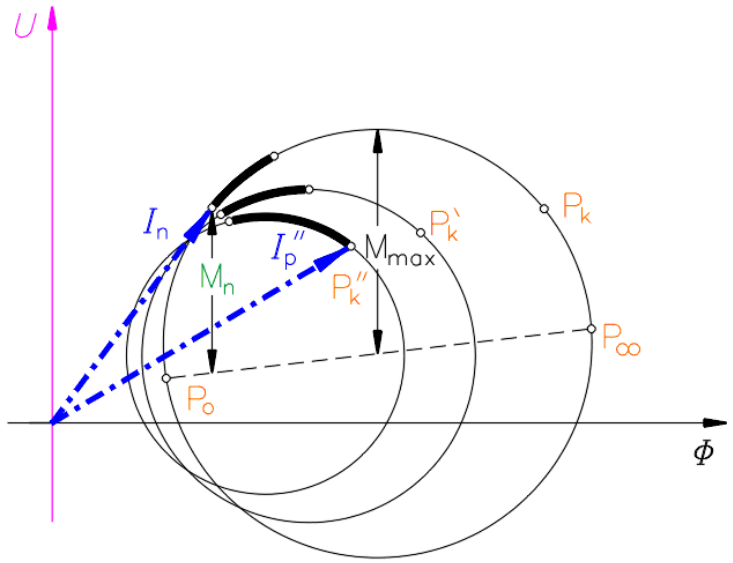
$R_2 = konstantno$ $X_2 = sX_{20}$

POKRETANJE TROFAZNIH MOTORA

Moment pokretanja

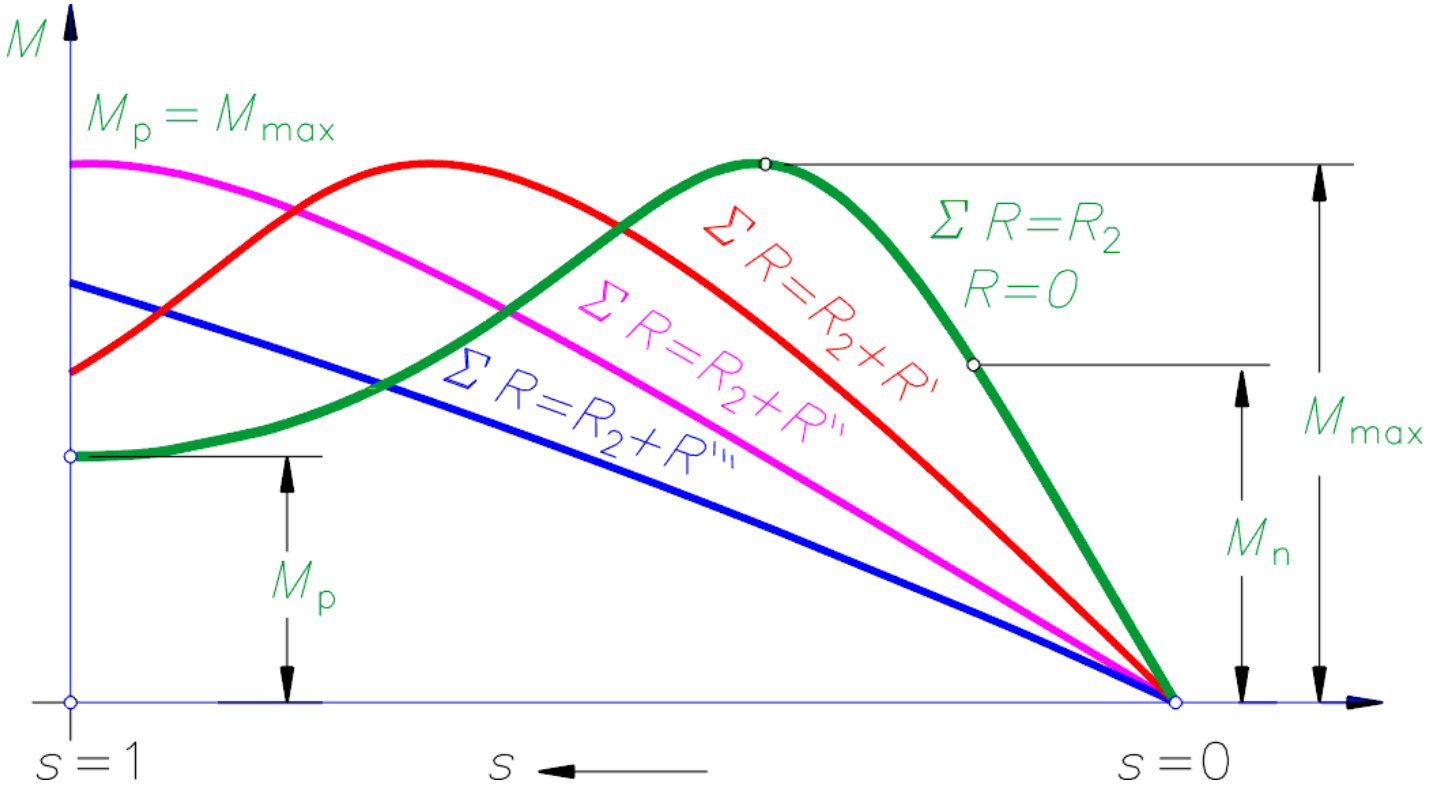
- pri pokretanju je motor u KS
- struje do 6 x veće od nominalnih
- kod velikih snaga neke mreže to ne mogu podnjeti
- zato samanjenje struje pokretanja dodavanjem otpora (kolutni)





R'' > R' > R ***$I_p'' < 2\ I_n$***

Otpori rotora za pokretanje kolutnih motora



R''' > R'' > R' > R=0; R_2 – otpor rotora

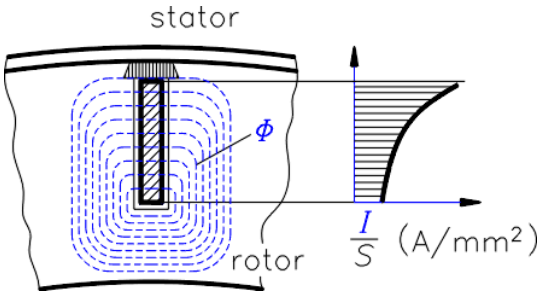
$\uparrow \sum R \rightarrow M_{max}$ bliže *s* =1 $\rightarrow$ lakše pokretanje, manje struje pokretanja

kolutni motori pogodni za teška pokretanja

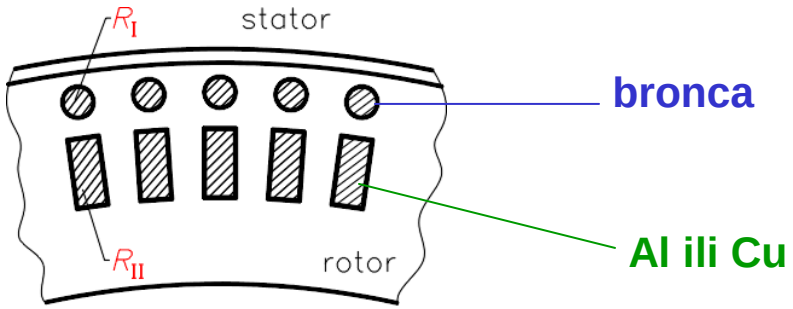
Smanjenje struje pokretanja kaveznih motora

temelj - vrtložne struje

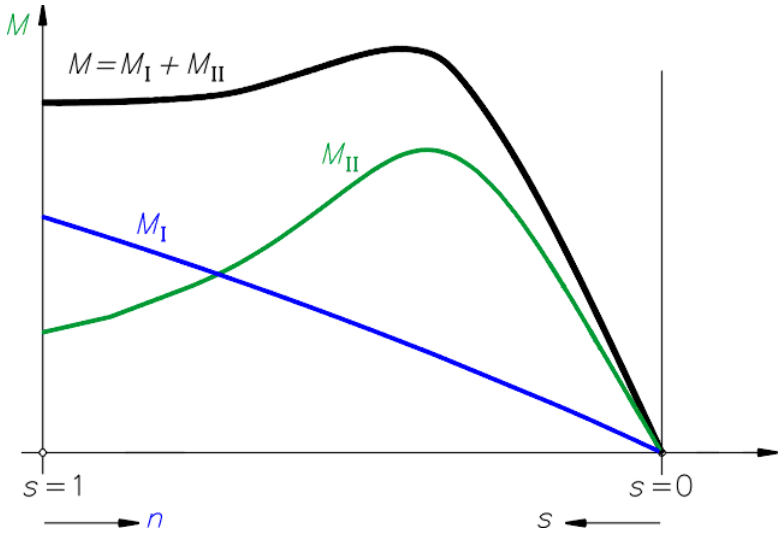
duboki utori



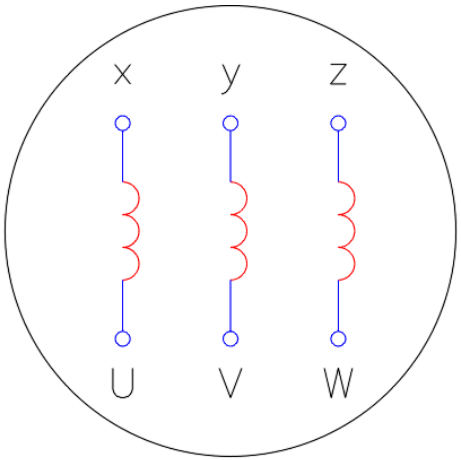
dvostruki kavez

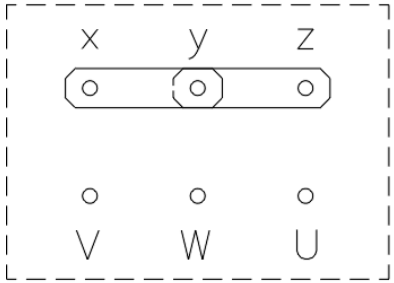


$R_I > R_{II}$

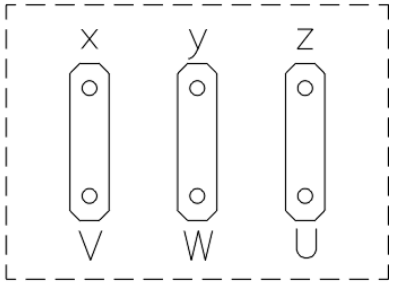


Priključak asinkronih motora





spoj Y

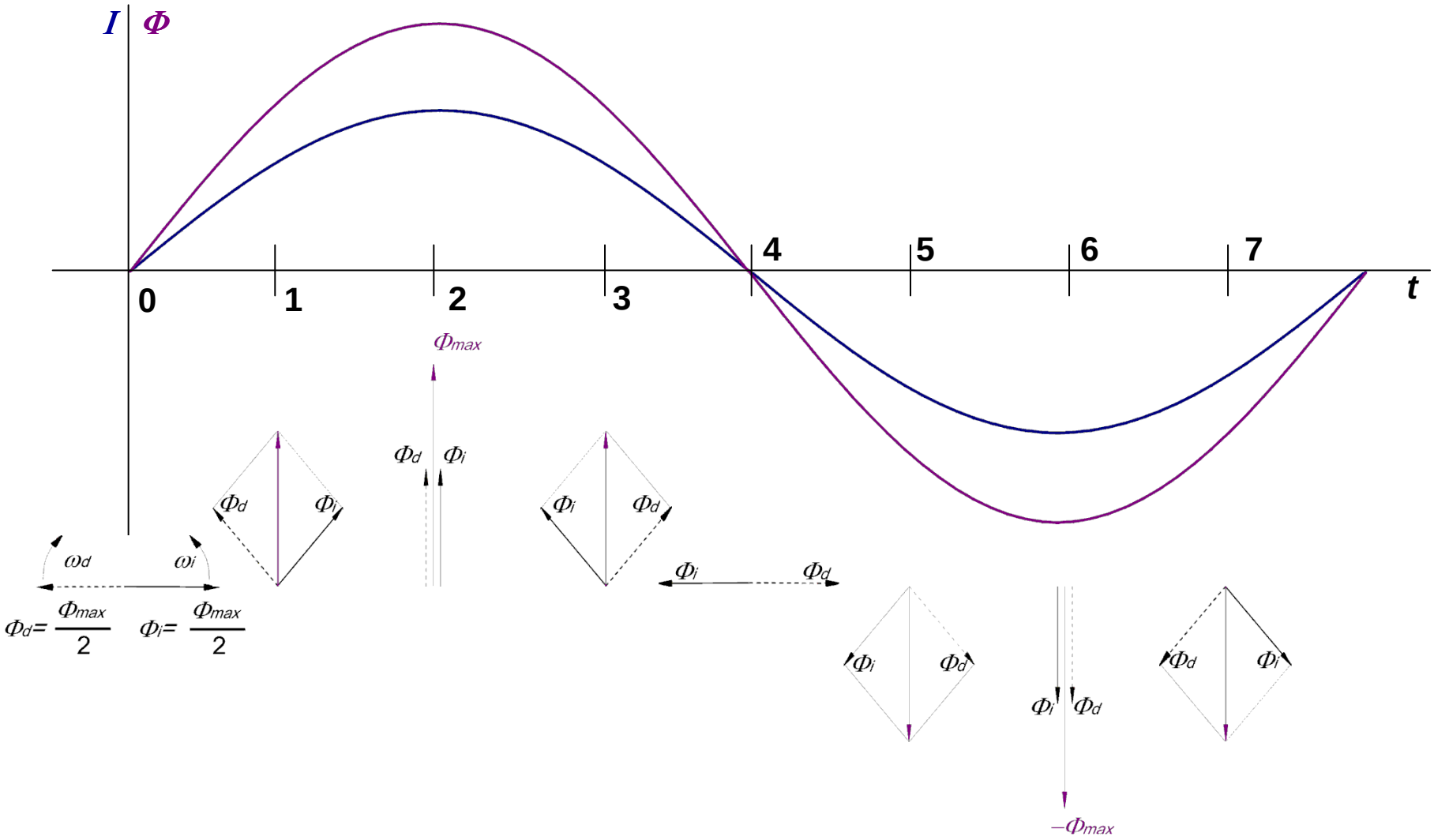


spoj Δ

JEDNOFAZNI ASINKRONI MOTORI

jedna faza i jedan svitak = pulsirajuće magetno polje

pulsirajuće magetno polje kao suma dva suprotno rotirajuča magnetna polja



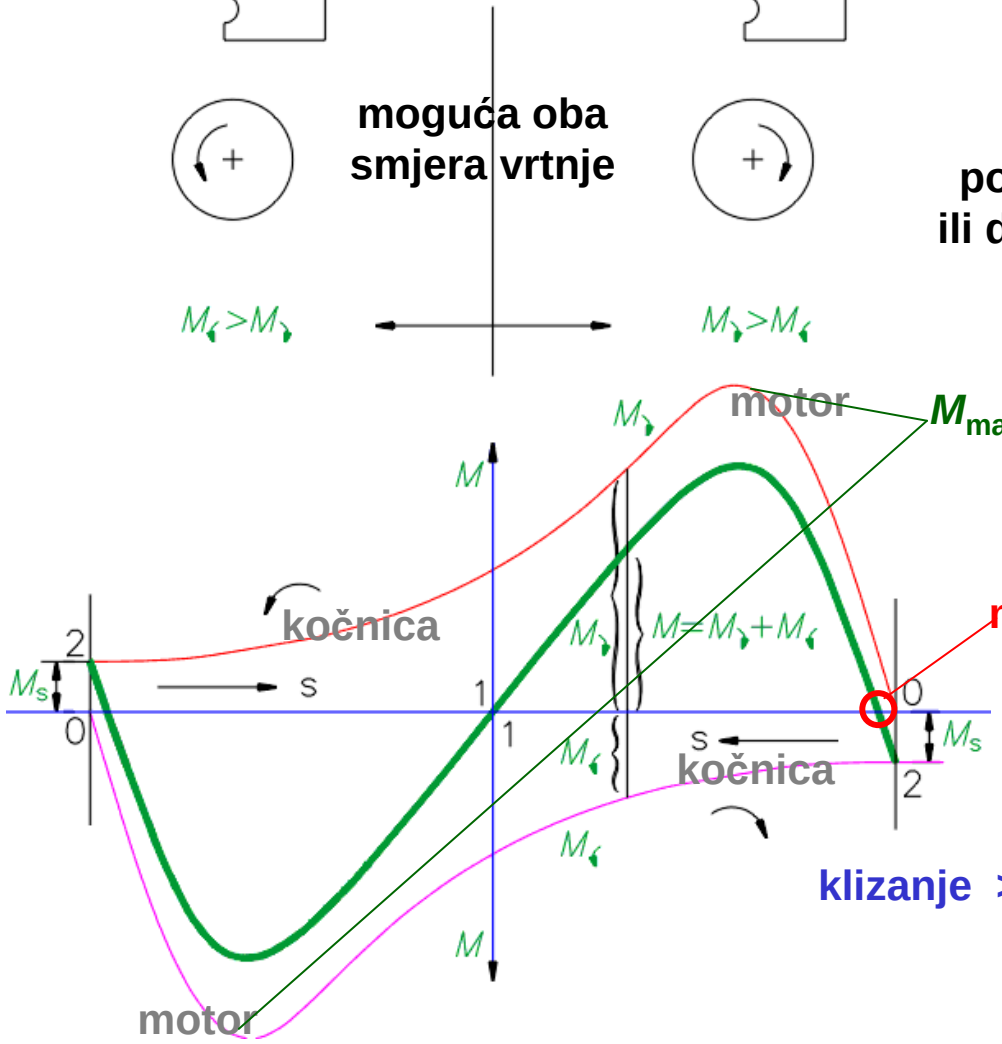
Moment i smjer vrtnje

dva rotirajuća polja = dva suprotna momenta (svaki kao i kod trofaznog motora)

moguća oba smjera vrtnje

pokretanje ručno ili dodatnim poljem

potreban dodatni moment za pokretanje



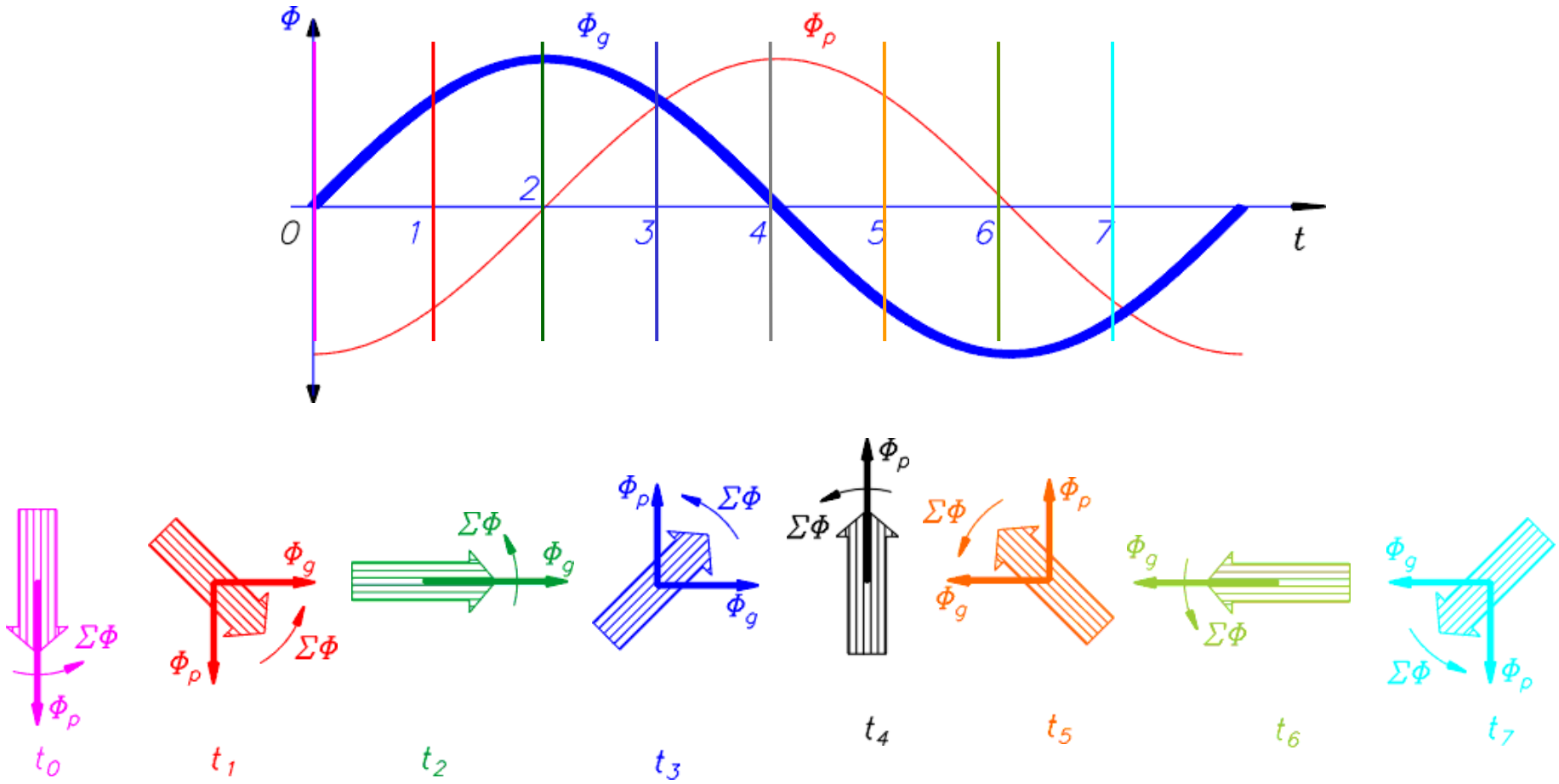
M_{max} uz R i X_L rotora jednaki

prije sinkrone brzine moment = 0

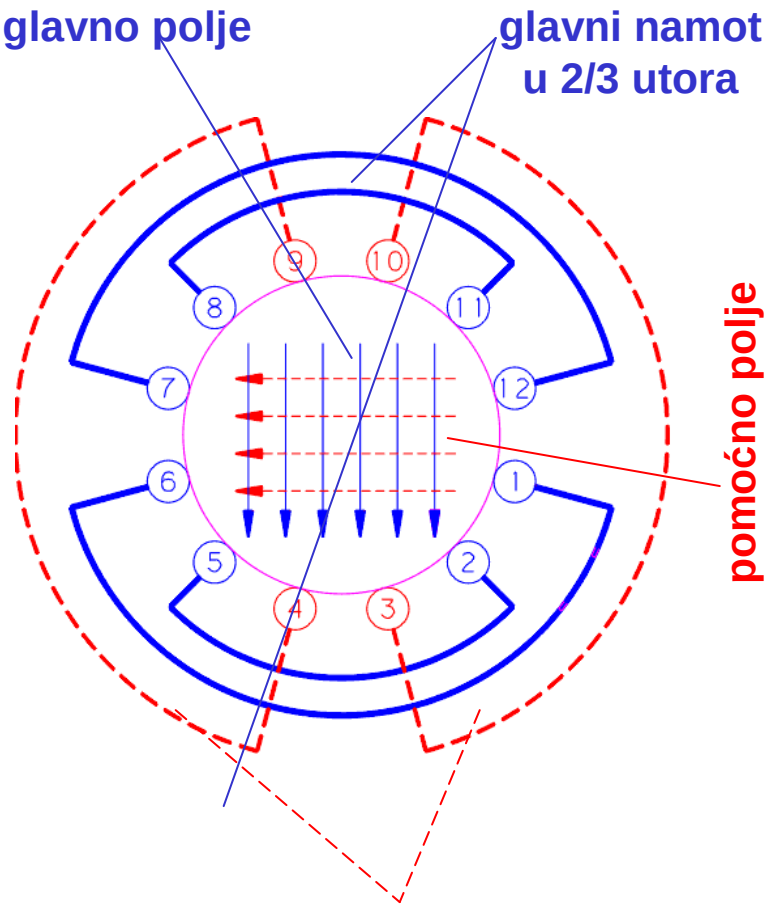
nego kod trofaznih motora pri jednakom opterećenju klizanje >

Pokretanje (okretno magnetno polje)

dva magnetna polja pod 90° prostorno i ≈ π/2 vremenski

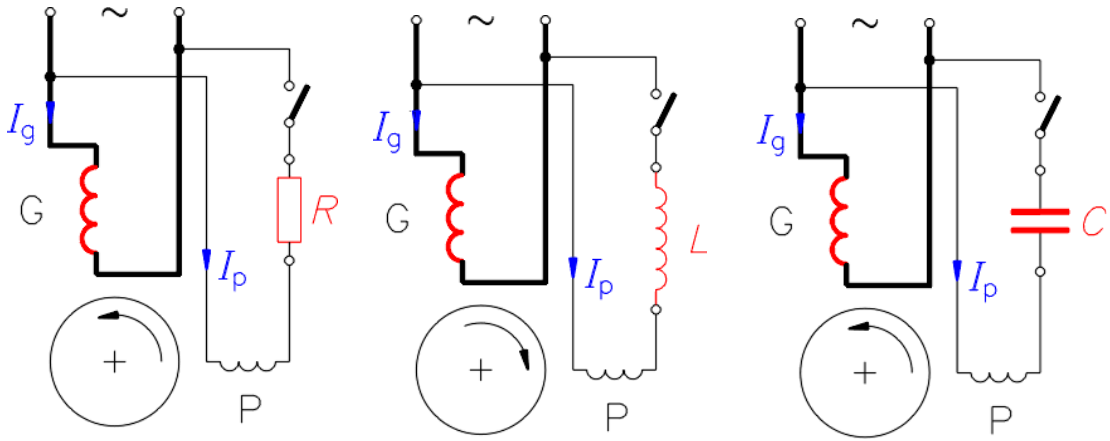


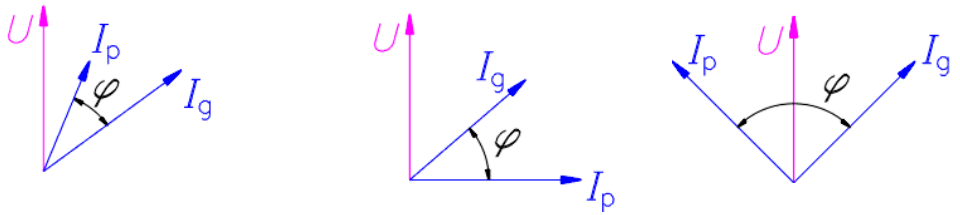
Raspored namota statora



Pokretanje pomoćnom fazom

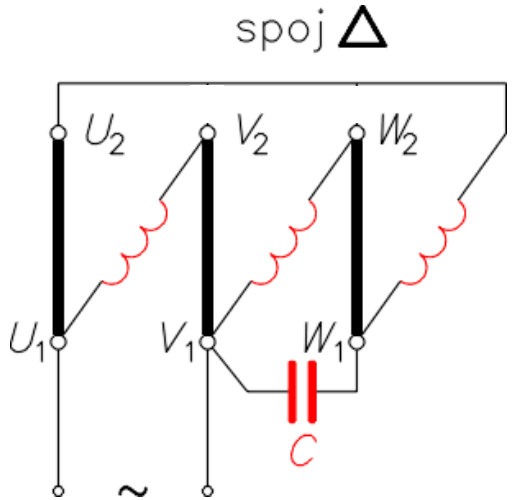
pomoćna faza do postizanja momenta > momenta tereta (centrifugalna sklopka)





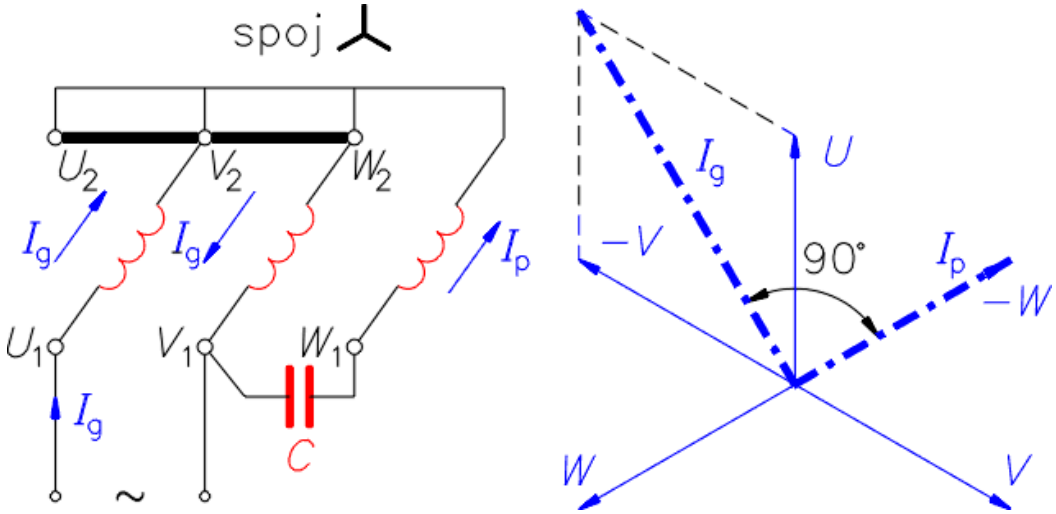
pomoću R **pomoću L** **pomoću C**

Trofazni motori priljučeni kao jednofazni



motor za 400/231V smije jednofazno u Δ (fazni napon je 231V)

motor za 400/231V ne smije jednofazno u Y (treba međufazni napon 400V a ima 231V 42% manje a dozvoljeno 15 % manje) NE MOŽE SE POKRENUTI!



samo u nuždi

manja snaga od nazivne

lošiji stupanj korisnog djelovanja