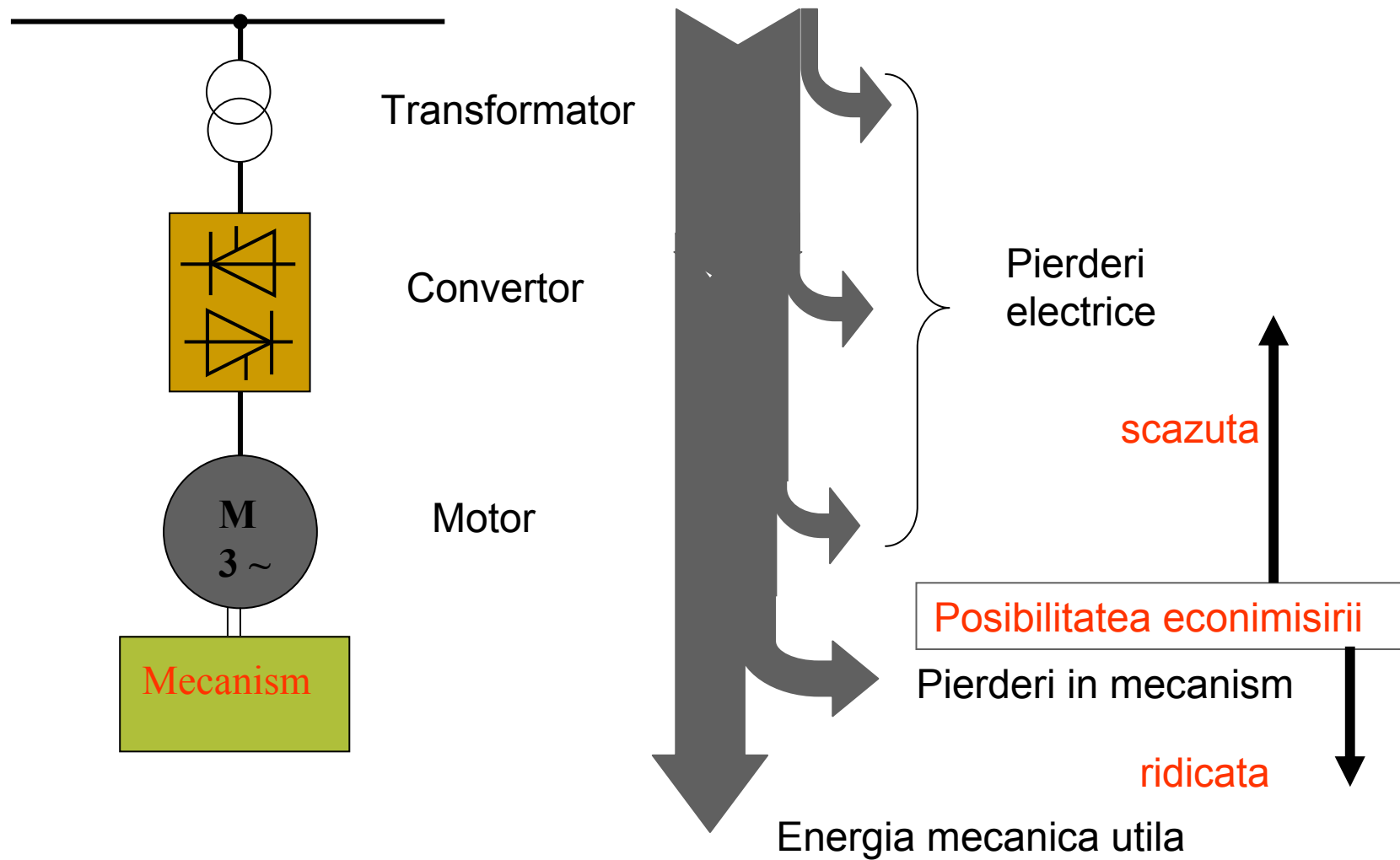
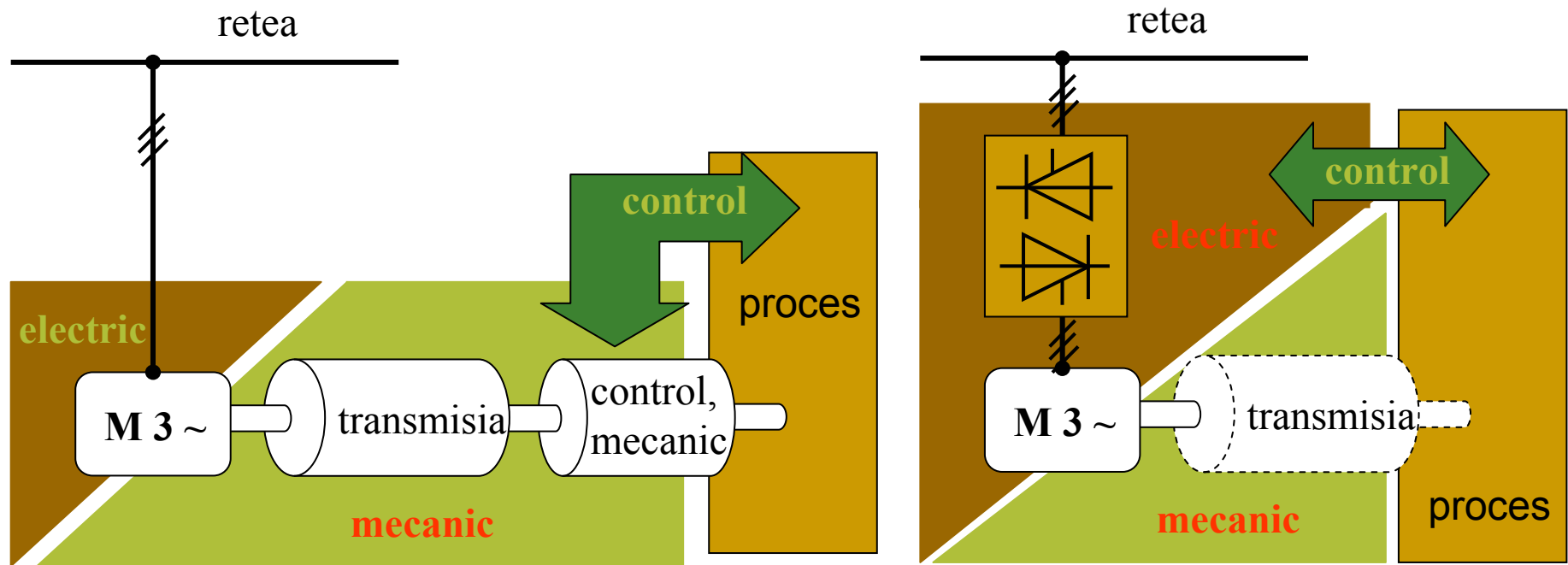

Actionari electrice cu turatia variabila

Consumuri energetice

Consumul de energie electrica in sistemele de actionare

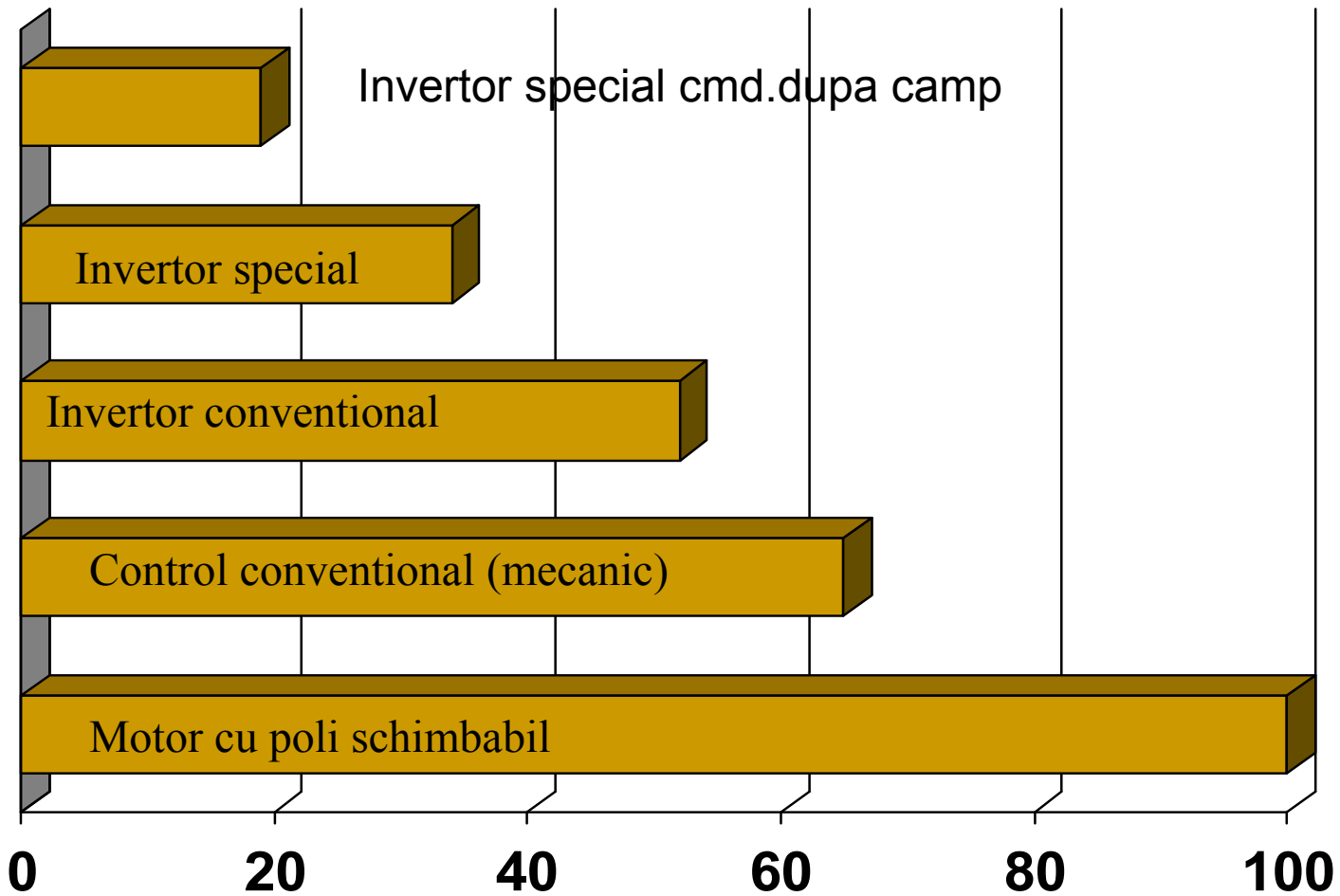


Avantajele sistemelor cu turatie variabila

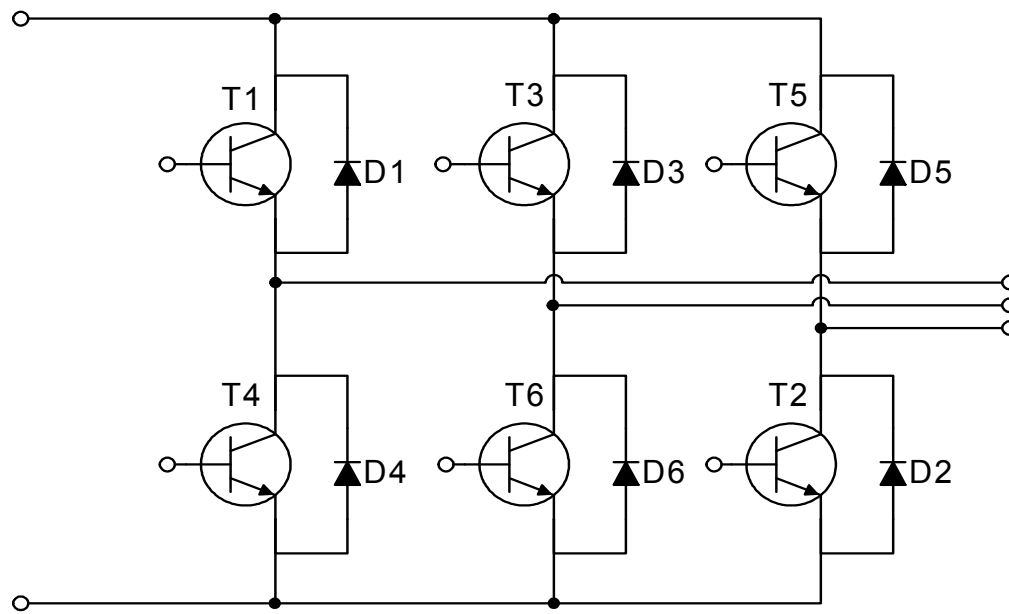


Reducerea pierderilor in transmisie (mecanice)

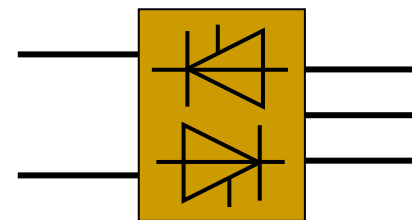
Consumul de energie la un elevator



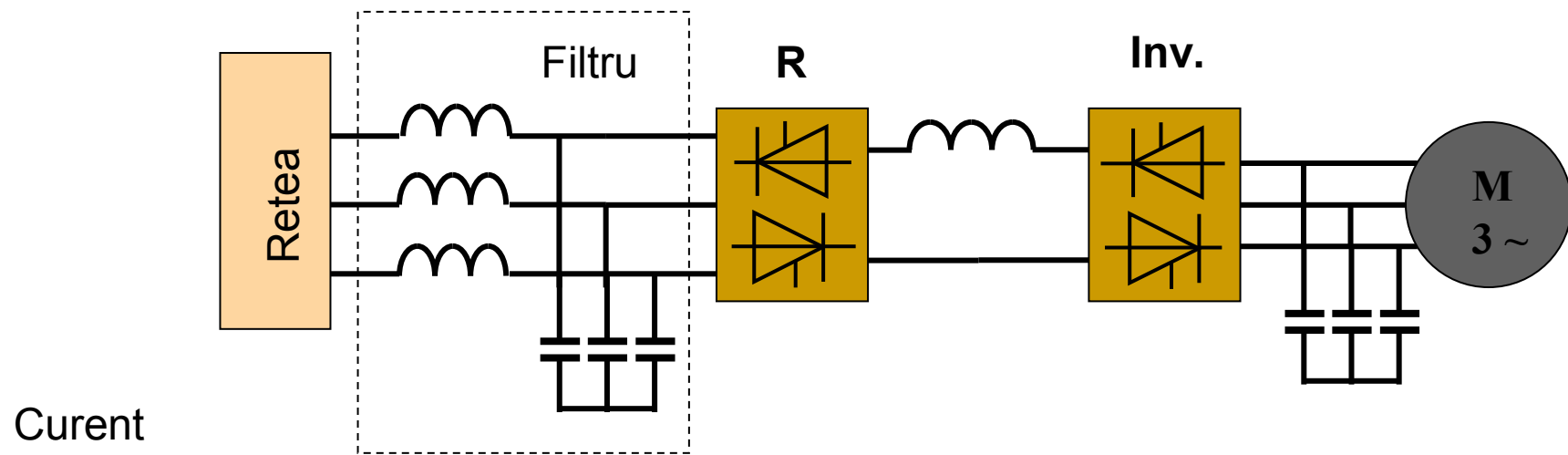
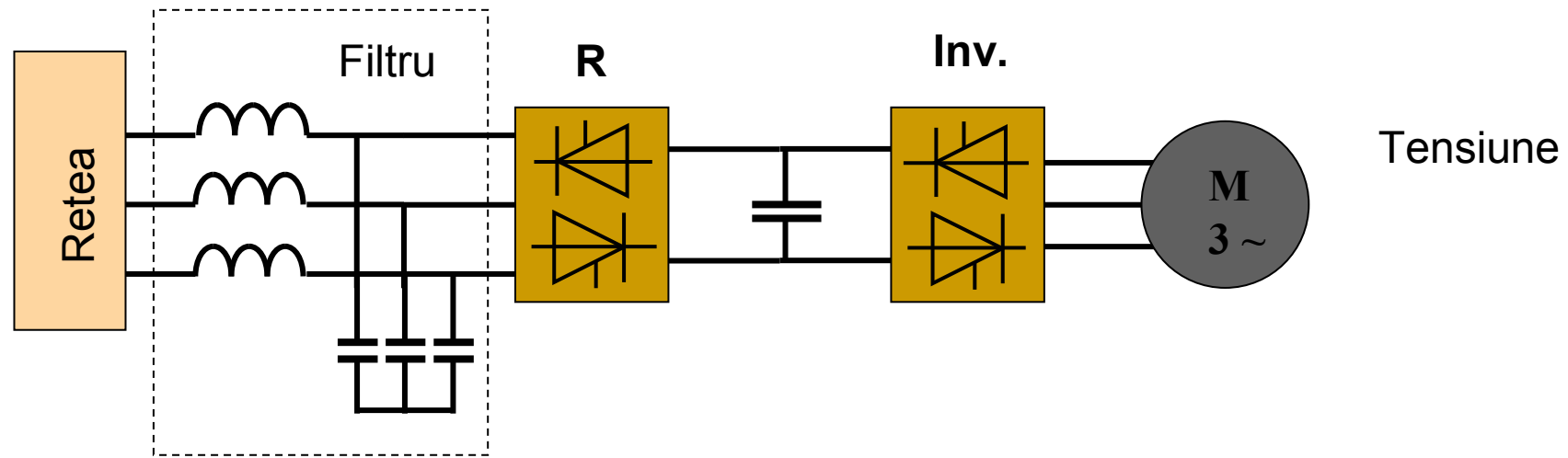
Pierderile in invertoare



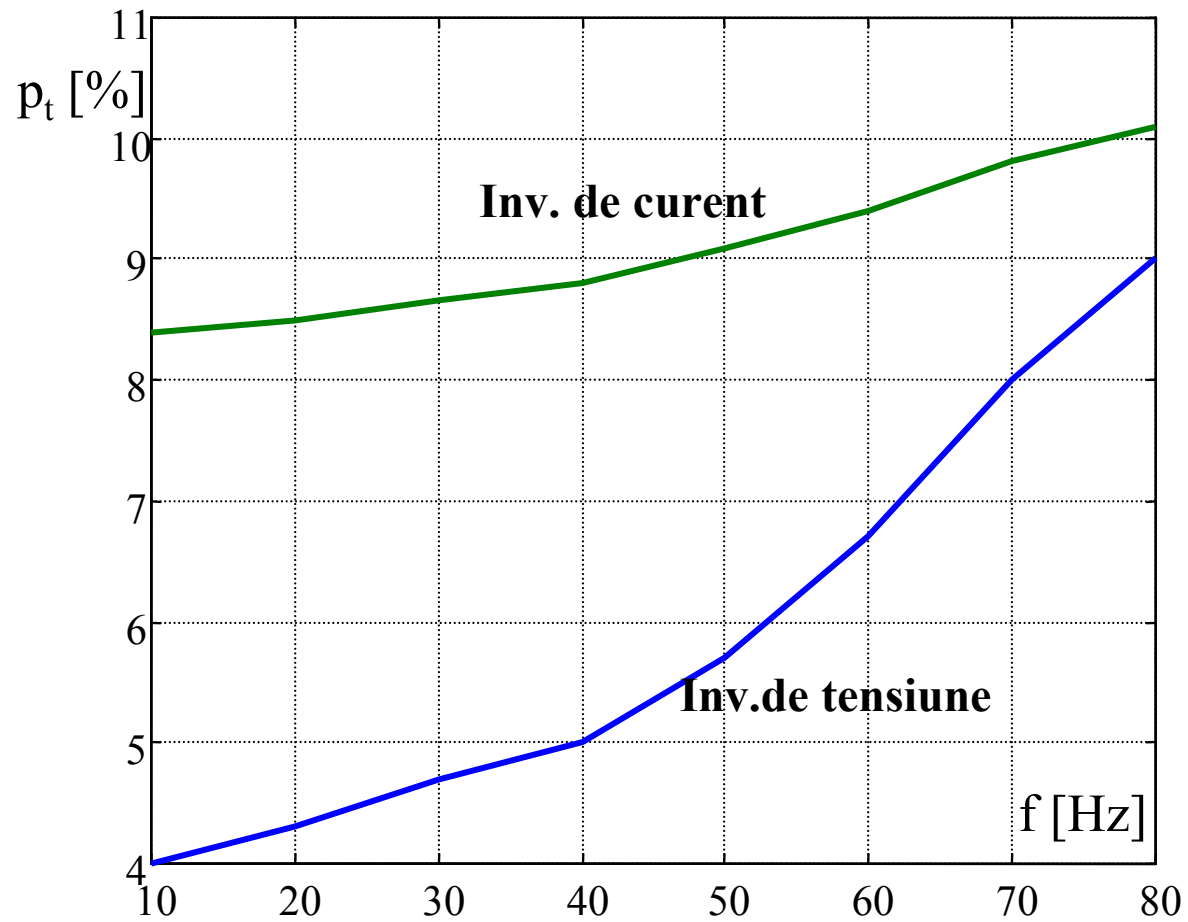
Schema de principiu a unui inverter trifazat cu tranzistoare.



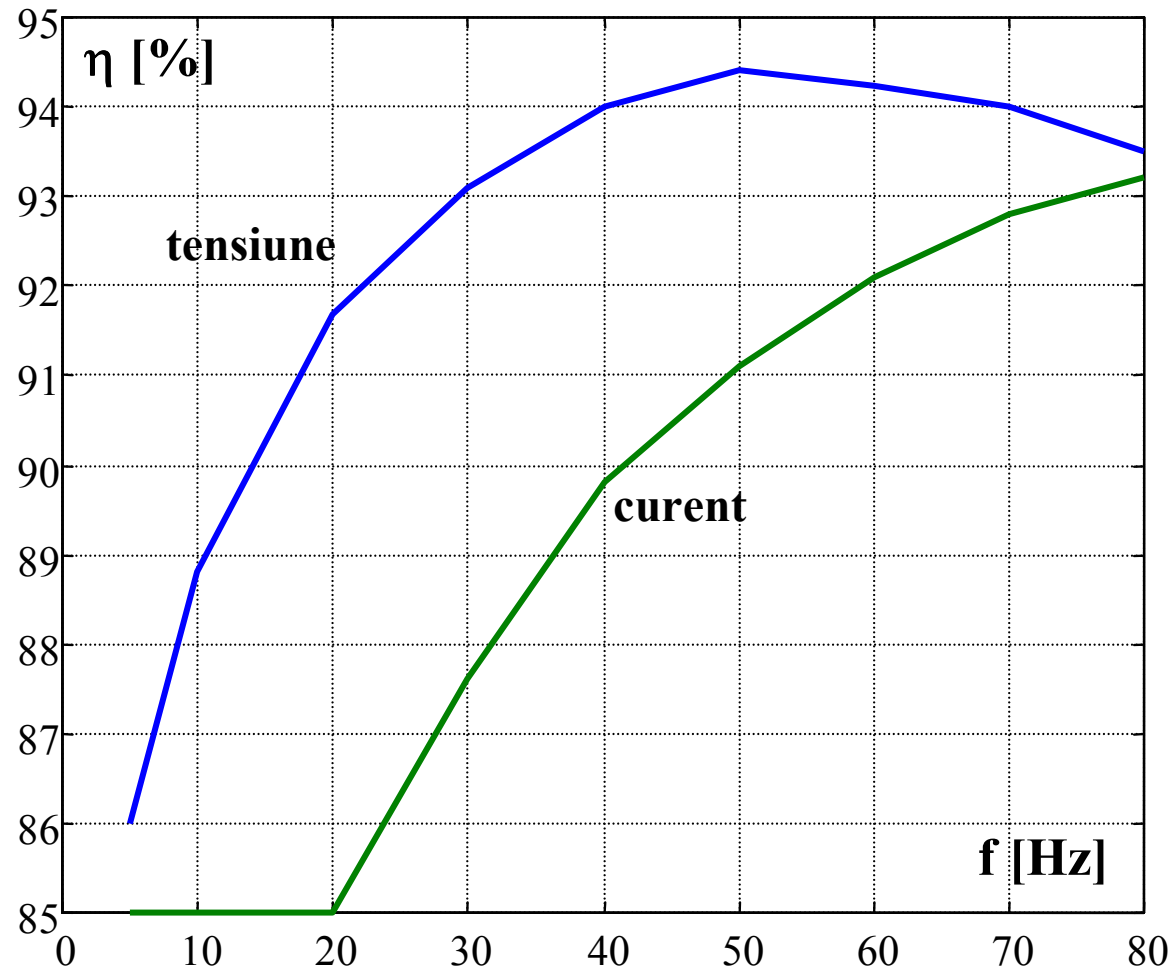
Tipuri de invertoare



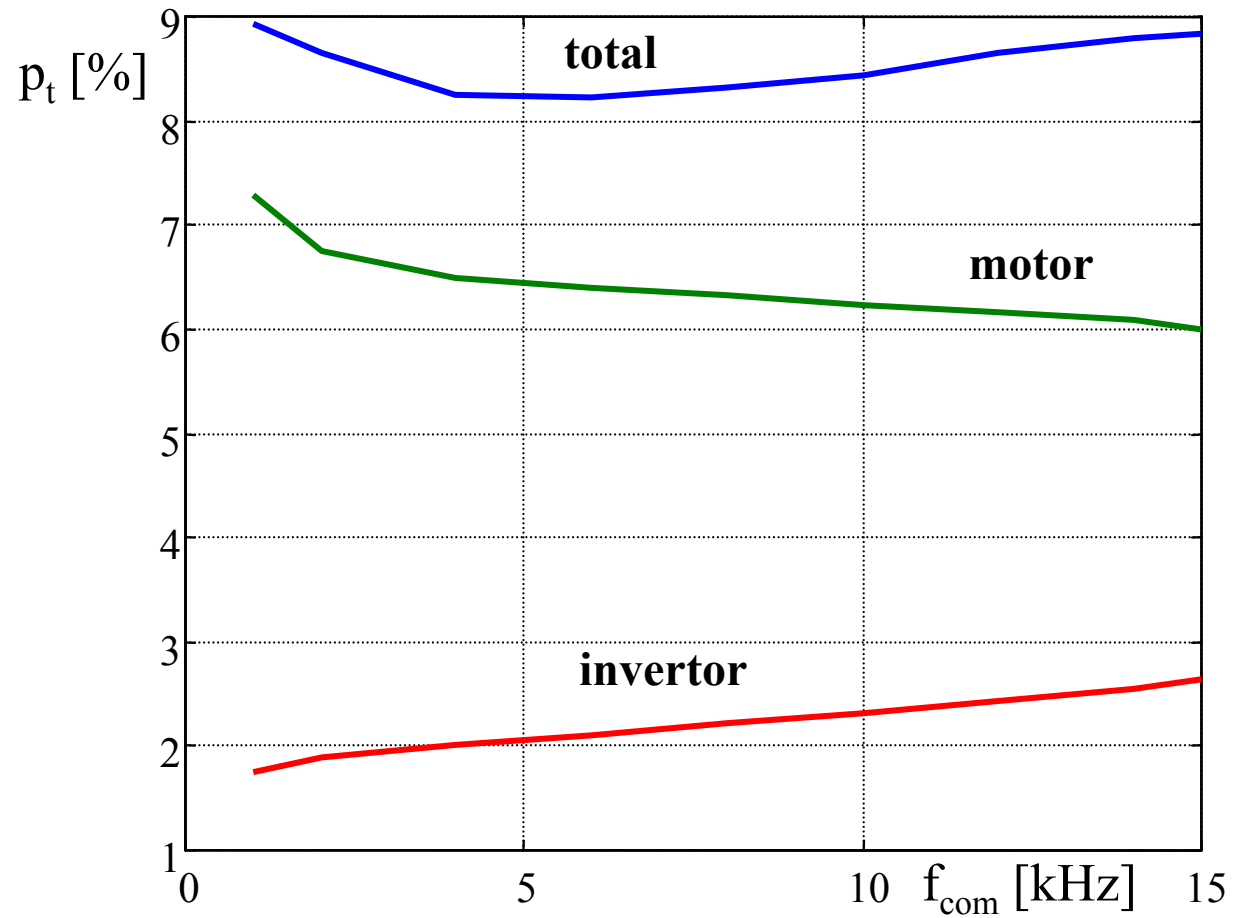
Pierderile in invertoare



Randamentul invertoarelor

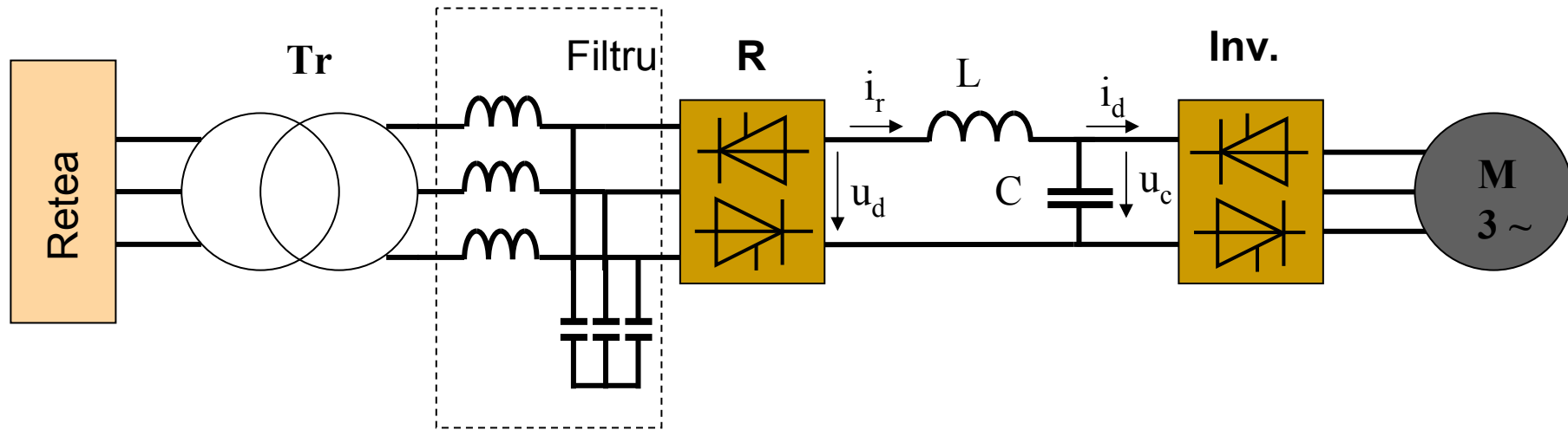


Influenta frecventei de comutatie



$P_n = 37$ [kW]

Schema de principiu a unui sistem de actionare cu convertor static si motor de inductie



Circuit intermediar de curent continuu format din L si C

Legatura dintre retea si convertorul static

Se presupune reseaua de putere infinita.

Tensiunea este sinusoidala

$$u(t) = \sqrt{2} \cdot U \cdot \sin(\omega \cdot t)$$

Curentul este nesinusoidal

$$i(t) = \sqrt{2} \cdot \sum_{\nu} I_{\nu} \cdot \sin(\nu \cdot \omega \cdot t - \varphi_{\nu})$$

Puterea activa se transmite numai prin fundamentala

$$P = U \cdot I_1 \cdot \sin \varphi_1$$

Puterea aparenta este

$$S = U \cdot I = U \cdot \sqrt{\sum_{\nu} I_{\nu}^2} = U \cdot I_1 \cdot \sqrt{1 + \sum_{\nu} \left(\frac{I_{\nu}}{I_1}\right)^2} = U \cdot I_1 \cdot \sqrt{1 + THD_i^2}$$

Puterea aparenta si reactiva

THD_i factorul total de distorsiune a curentului

Tinind seama ca puterea activa este data de fundamentala curentului

Puterea aparenta se poate scrie

$$S = \frac{P}{\cos \varphi_1} \sqrt{1 + THD_i^2}$$

Factorul de putere global

$$PF = \frac{P}{S} = \frac{\cos \varphi_1}{\sqrt{1 + THD_i^2}}$$

Puterea reactiva se poate defini in mai multe moduri (Budeanu, Czarnecki,)

Budeanu

$$Q_B = P \cdot \operatorname{tg} \varphi_1 \qquad Q_C = U \cdot \sqrt{\sum_{\nu=1}^{\infty} (I_{\nu} \sin \varphi_{\nu})^2}$$

$$\frac{Q_C}{Q_B} = \sqrt{1 + \sum_{\nu=2}^{\infty} \left(\frac{I_{\nu} \sin \varphi_{\nu}}{I_1 \sin \varphi_1} \right)^2}$$

Puterea deformanta

$$D_B = \sqrt{S^2 - P^2 - Q_B^2} = S \frac{THD_i}{\sqrt{1 + THD_i^2}} = \frac{P}{\cos \varphi_1} THD_i$$

Diferenta dintre cele doua relatii

$$D_C = \sqrt{S^2 - P^2 - Q_C^2} = \frac{P}{\cos \varphi_1} \sqrt{THD_i^2 - \sum_{v=2}^{\infty} \left(\frac{I_v}{I_1} \sin \varphi_v \right)^2}$$

La puterea activa impusa

Se poate minimiza puterea aparenta daca:

$$\cos \varphi_1 = 1 \text{ si } THD_i = 0 \text{ deci in regim sinusoidal}$$

Deoarece $\cos \varphi_1$ si THD_i depind de componentele filtrului,
factorul de putere global este deasemenea dependent de filtru.

Expresia puterilor la motorul de inductie

Tensiunea si curentul sunt nesinusoidali

$$u(t) = \sqrt{2} \cdot \sum_{\nu=1}^{\infty} U_{\nu} \sin(\nu \cdot \omega \cdot t - \varphi_{u\nu})$$

$$i(t) = \sqrt{2} \cdot \sum_{\nu=1}^{\infty} I_{\nu} \sin(\nu \cdot \omega \cdot t - \varphi_{i\nu})$$

Puterea activa

$$P = \sum_{\nu=1}^{\infty} U_{\nu} I_{\nu} \cos \varphi_{\nu}$$

Puterea aparenta

$$S = \sqrt{\sum_{\nu=1}^{\infty} U_{\nu}^2} \sqrt{\sum_{\nu=1}^{\infty} I_{\nu}^2} = U_1 I_1 \sqrt{1 + THD_u^2} \sqrt{1 + THD_i^2}$$

Minimizarea puterii aparente

Se calculeaza derivatele partiale ale puterii aparente daca puterea activa totala este constanta

$$\frac{\partial S}{\partial \cos \varphi_1} = -\frac{1}{\cos^2 \varphi_1} \left(P - \sum_{\nu=2}^{\infty} U_{\nu} I_{\nu} \cos \varphi_{\nu} \right) \sqrt{1 + THD_u^2} \sqrt{1 + THD_i^2}$$

Expresia este negativa si diferita de zero, deci valoarea minima se obtine pentru $\cos \varphi_1 = 1$.

$$\frac{\partial S}{\partial \cos \varphi_{\nu}} = -\frac{1}{\cos^2 \varphi_1} U_{\nu} I_{\nu} \sqrt{1 + THD_u^2} \sqrt{1 + THD_i^2}$$

Similar si pentru derivatele in raport cu $\cos \varphi_{\nu}$

$$\begin{aligned} \frac{\partial S}{\partial I_{\nu}} = & -\frac{\cos \varphi_{\nu}}{\cos \varphi_1} U_{\nu} \sqrt{1 + THD_u^2} \sqrt{1 + THD_i^2} + \\ & + \frac{1}{\cos \varphi_1} \left(P - \sum_{\mu=2}^{\infty} U_{\mu} I_{\mu} \cos \varphi_{\mu} \right) \frac{\sqrt{1 + THD_u^2}}{\sqrt{1 + THD_i^2}} \frac{I_{\nu}}{I_1^2} \end{aligned}$$

Minimizarea puterii aparente

Derivatele puterii aparente in raport cu curenti armonici se anuleaza pentru

$$\frac{U_\nu \cos \varphi_\nu}{I_\nu} = \frac{U_\mu \cos \varphi_\mu}{I_\mu} \quad \mu \neq \nu$$

Se observa ca ecuatia are solutii nenule.

Dupa simplificari pentru doua armonici $\nu > \mu$

$$U_\nu \left(1 + THD_i^2\right) \cos \varphi_\nu = \left(P - \sum_{\mu=2}^{\infty} U_\mu I_\mu \cos \varphi_\mu \right) \frac{I_\nu}{I_1^2}$$

Cu conditia de extrem rezulta ecuatia

$$\frac{\sum_{\mu=2}^{\infty} \left(U_\mu \cos \varphi_\mu \right)^2}{\left(U_\nu \cos \varphi_\nu \right)^2} \left(\frac{I_\nu}{I_1} \right)^2 - \frac{U_1 \cos \varphi_1}{U_\nu \cos \varphi_\nu} \frac{I_\nu}{I_1} + 1 = 0$$

Minimizarea puterii aparente

Solutia generala a ecuatiei

$$\frac{I_v}{I_1} = \frac{U_v \cos \varphi_v}{2 \sum_{\mu=2}^{\infty} (U_{\mu} \cos \varphi_{\mu})^2} \left(U_1 \cos \varphi_1 \pm \sqrt{(U_1 \cos \varphi_1)^2 - 4 \sum_{\mu=2}^{\infty} (U_{\mu} \cos \varphi_{\mu})^2} \right)$$

Expresia puterii aparente optime rezulta

$$S_o = \sqrt{\frac{U_1}{2 \cdot \cos \varphi_1}} \frac{\sqrt{1 + THD_u^2}}{\sqrt{\sum_{v=2}^{\infty} (U_v \cos \varphi_v)^2}} \sqrt{U_1 \cos \varphi_1 \pm \sqrt{(U_1 \cos \varphi_1)^2 - 4 \sum_{v=2}^{\infty} (U_v \cos \varphi_v)^2}} \cdot \left\{ P - \frac{I_1}{2} \left[U_1 \cos \varphi_1 \pm \sqrt{U_1 \cos \varphi_1 \pm \sqrt{(U_1 \cos \varphi_1)^2 - 4 \sum_{v=2}^{\infty} (U_v \cos \varphi_v)^2}} \right] \right\}$$

Pentru semnul “-” rezulta puterea minima, iar pentru “+” puterea maxima.

Particularizare pentru un motor asincron

$$\frac{U_v \cos \varphi_v}{I_v} = \frac{U_\mu \cos \varphi_\mu}{I_\mu} \quad \mu \neq v$$

Pentru doua impedante \underline{Z}_v si \underline{Z}_μ corespunzatoare armonicilor rezulta

$$\Re\{\underline{Z}_v\} = \Re\{\underline{Z}_\mu\} \quad \mu \geq 2 \quad v \neq \mu$$

Considerand schema echivalenta in T si neglijand pierderile in fier pentru armonica v

$$\underline{Z}_v = R_S + \frac{R_R}{s_v} \frac{X_{mv}^2}{\left(\frac{R_R}{s_v}\right)^2 + (X_{R\sigma v} + X_{mv})^2} +$$

$$+ j \left[X_{S\sigma v} + X_{mv} \frac{\left(\frac{R_R}{s_v}\right)^2 + X_{R\sigma v} (X_{R\sigma v} + X_{mv})}{\left(\frac{R_R}{s_v}\right)^2 + (X_{R\sigma v} + X_{mv})^2} \right]$$

Particularizare pentru un motor asincron

Tinand seama de expresia alunecarii fata de armonica ν si de viteza relativa n/n_1

$$s_\nu = \frac{\nu \cdot n_1 - n}{\nu \cdot n_1} = \frac{\nu - n_r}{\nu}$$

Partea reala a impedantei devine

$$\Re\{Z_\nu\} = R_S + \frac{\nu(\nu - n_r)R_R X_m^2}{R_R^2 + (\nu - n_r)^2 (X_{R\sigma} + X_m)^2}$$

Punand conditia de egalitate a partilor reale

$$\frac{\nu(\nu - n_r)R_R X_m^2}{R_R^2 + (\nu - n_r)^2 (X_{R\sigma} + X_m)^2} = \frac{\mu(\mu - n_r)R_R X_m^2}{R_R^2 + (\mu - n_r)^2 (X_{R\sigma} + X_m)^2}$$

Particularizare pentru un motor asincron

Rezulta

$$X_R^2 n_r^3 - (\nu + \mu) X_R^2 n_r^2 + (R_R^2 + \nu \mu X_R^2) n_r - R_R^2 (\nu + \mu) = 0$$

Se poate calcula viteza relativa la care are loc egalitatea partilor reale.

Se obtine totdeauna o solutie reala subunitara- apropiata de $n_r = 0$

Concluzie :

Este necesar realizarea unor filtre astfel ca $\cos\varphi$ sa fie apropiat de unitate

Sa poate realiza comanda corespunzatoare a redresorului.

Dependentia partii reale ale impedantelor motorului de inductie in functie de alunecare

