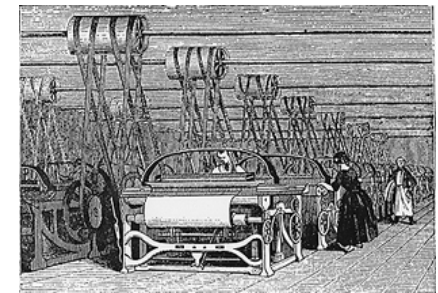
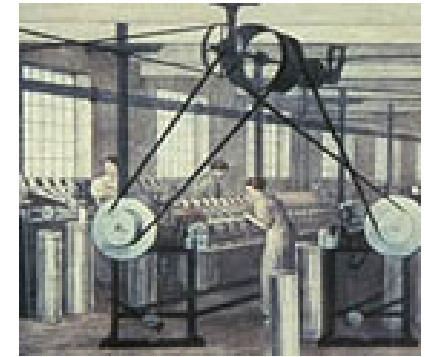
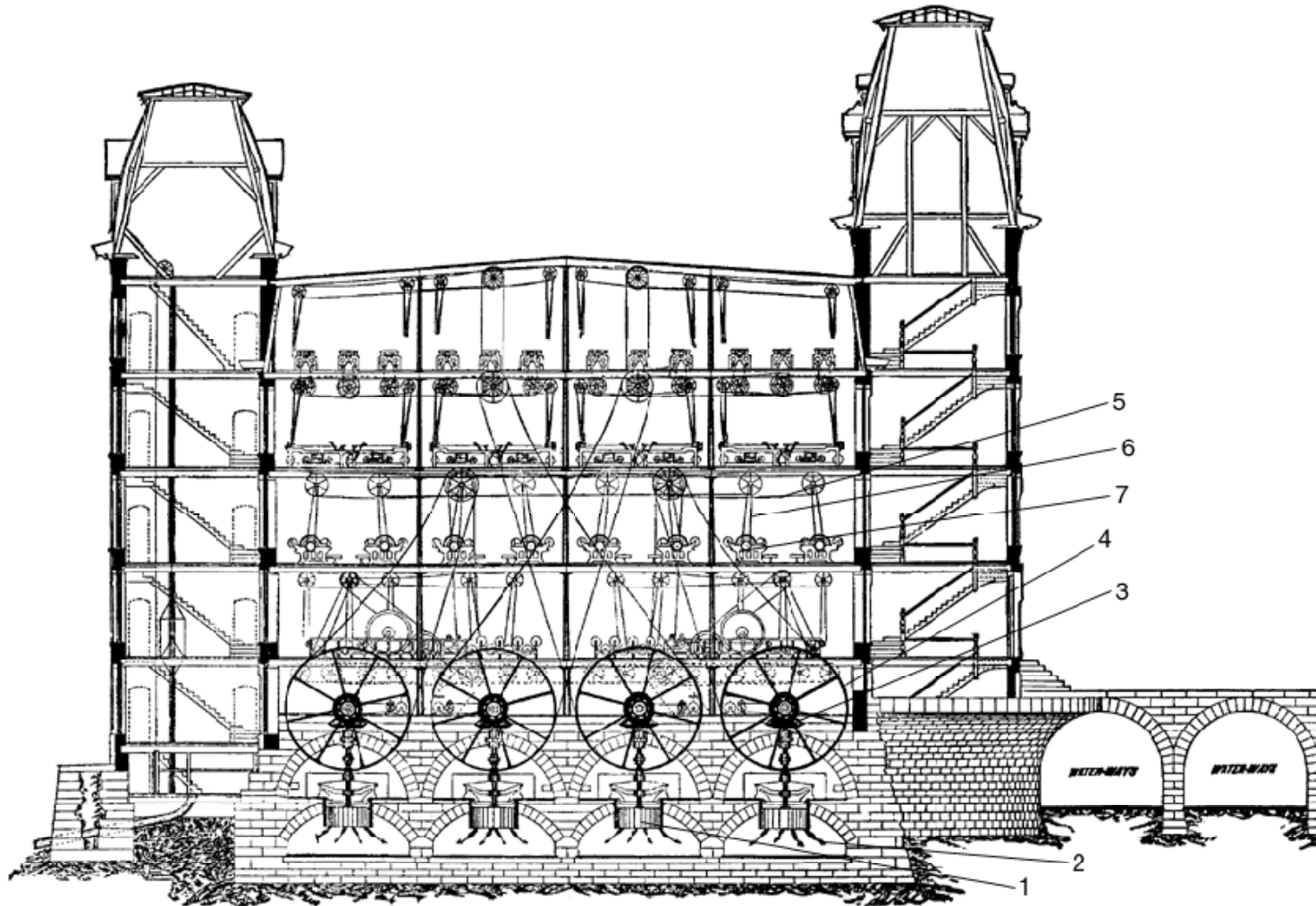


Razvod mehaničke energije po postrojenju

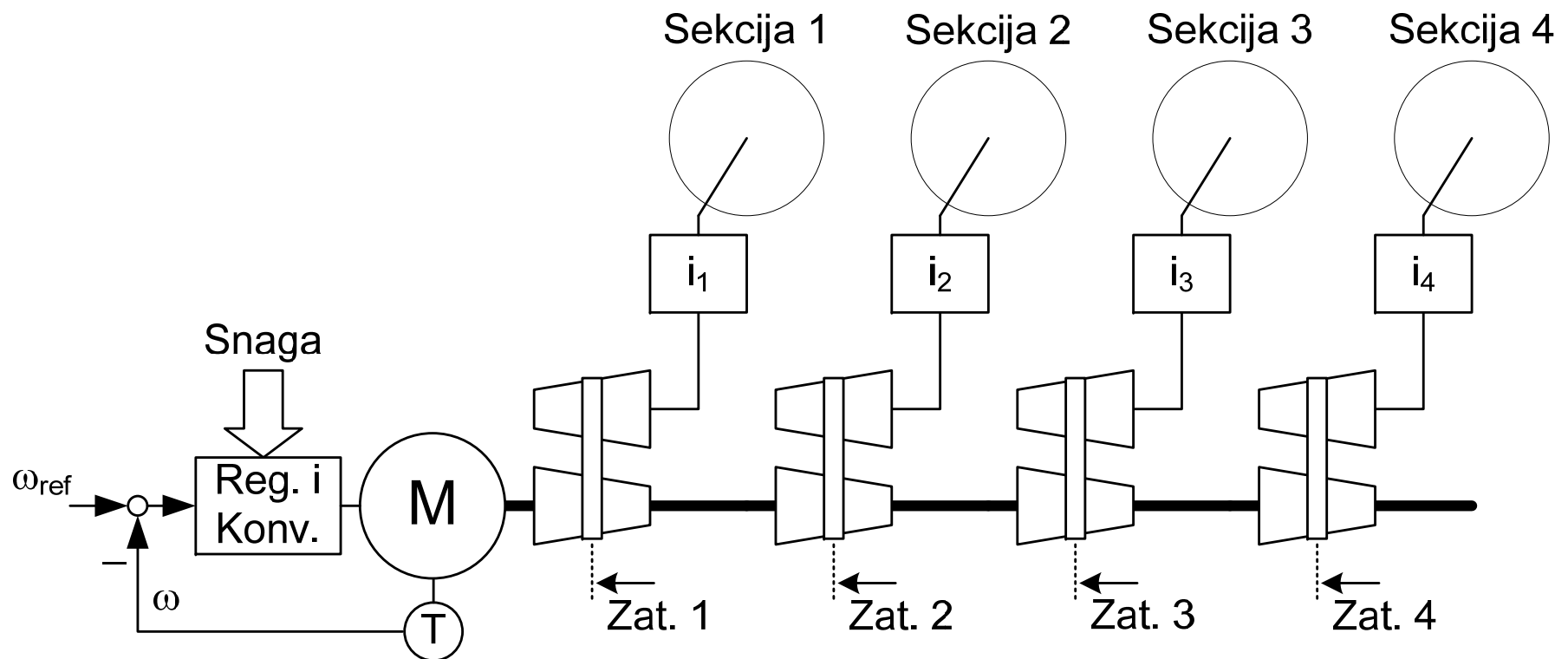


Vodne turbine (1 i 2),
zupčanici (3),
kaišnici (4) i kaiševi
linijska vratila (5) na
svakom spratu.

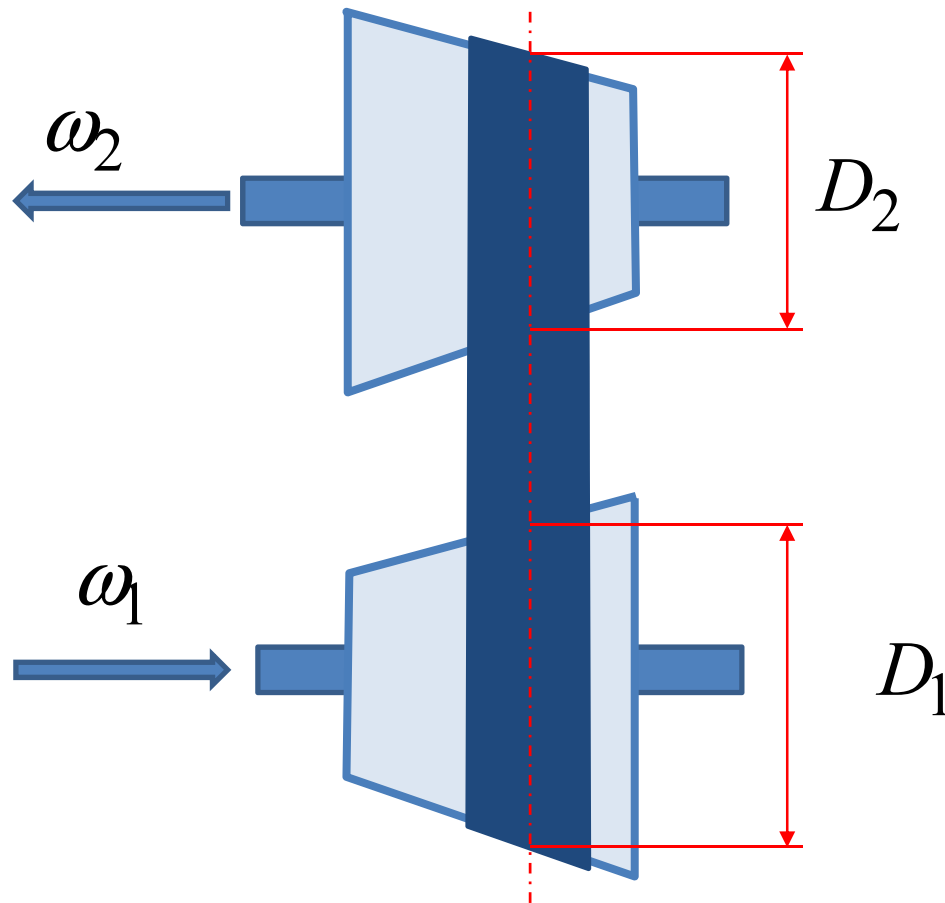
Sa linijskog vratila
pomoću zasebnih
kaiševa (6) i kaišnika
mehanička energija se
prenosila do pojedinih
tekstilnih mašina



Pokretanje linijskim vratilom



Podešavanje brzine kod linijskog vratila



$$\frac{\omega_1}{\omega_2} = \frac{D_2}{D_1}$$

Nedostaci pokretanja linijskim vratilom:

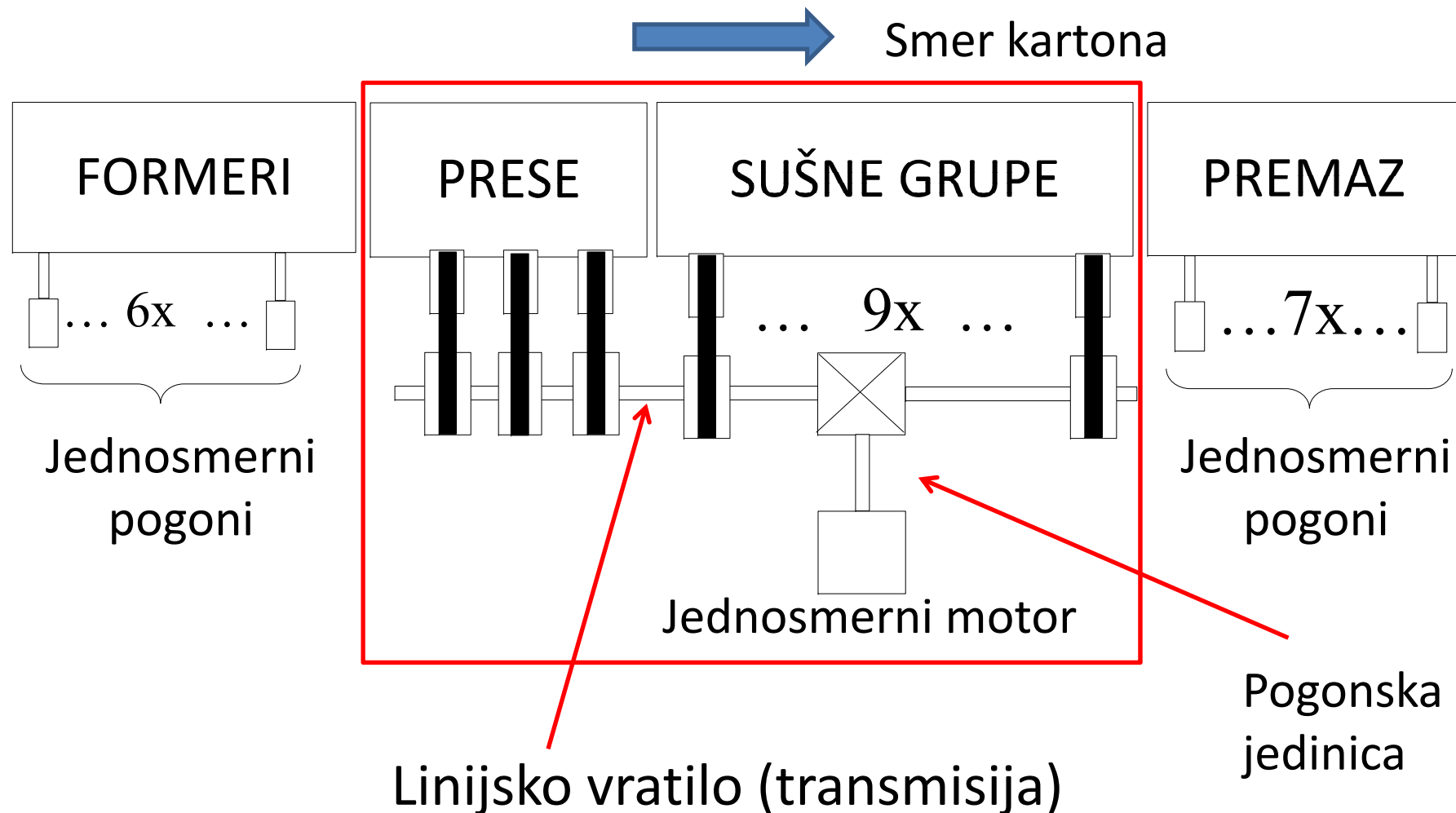
- Motorna jedinica je velika i skupa, zbog toga je teško zamenljiva;
- Loš stepen iskorišćenja;
- Habanje svih pokretnih delova;
- Proizvodi vibracije i buku;
- Troškovi održavanja su izuzetno veliki;
- Ograničavajući faktor za povećanje brzine odnosno povećanje kapaciteta;
- Teško i sporo se podešavaju pojedinačne brzine;
- Nije moguće pojedinačno upravljanje pogonima.

Dobre strane pokretanja linijskim vratilom:

- Ako jedan pogon uspori zbog povećanja opterećenja na isti način usporavaju i svi ostali pogoni;
- Raspodela opterećenja između pogona u radu se prirodno ostvaruje,
- Instalirana snaga se optimalno koristi;
- Proklizavanje i elastičnost koje postoji kod pljosnatih kaiševa amortizuje udarna opterećenja;
- Ujednačavanje opterećenje između pogona koji su u krutoj mehaničkoj sprezi.

Pokretanje dela postrojenja linijskim vratilom

Fabrika kartona "Umka"



Linijsko vratilo (transmisija)



Pogonska jedinica

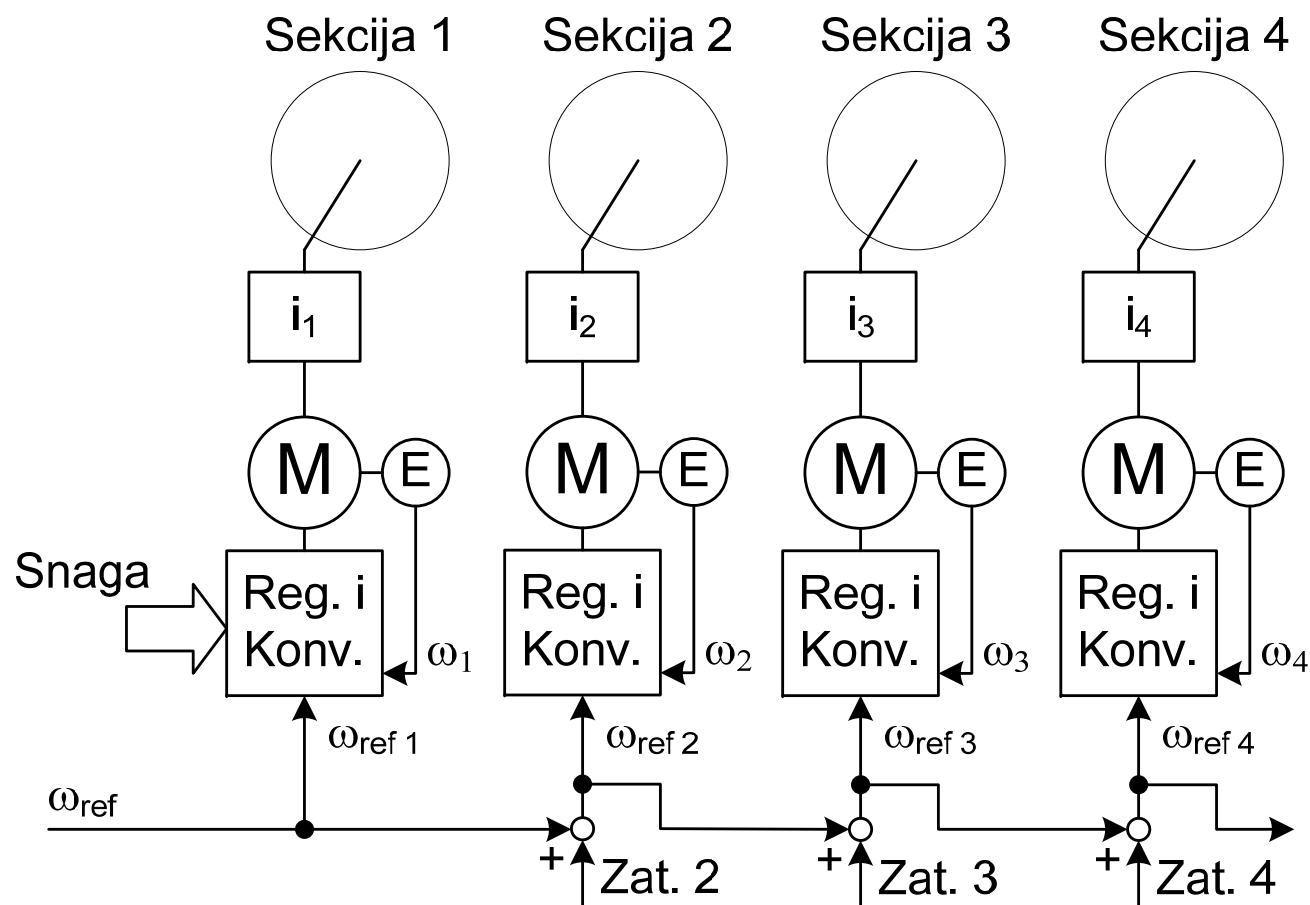


Motor za jednosmernu struju



Reduktor sa dva izlazna vratila

Pojedinačni (sekcioni) pogoni



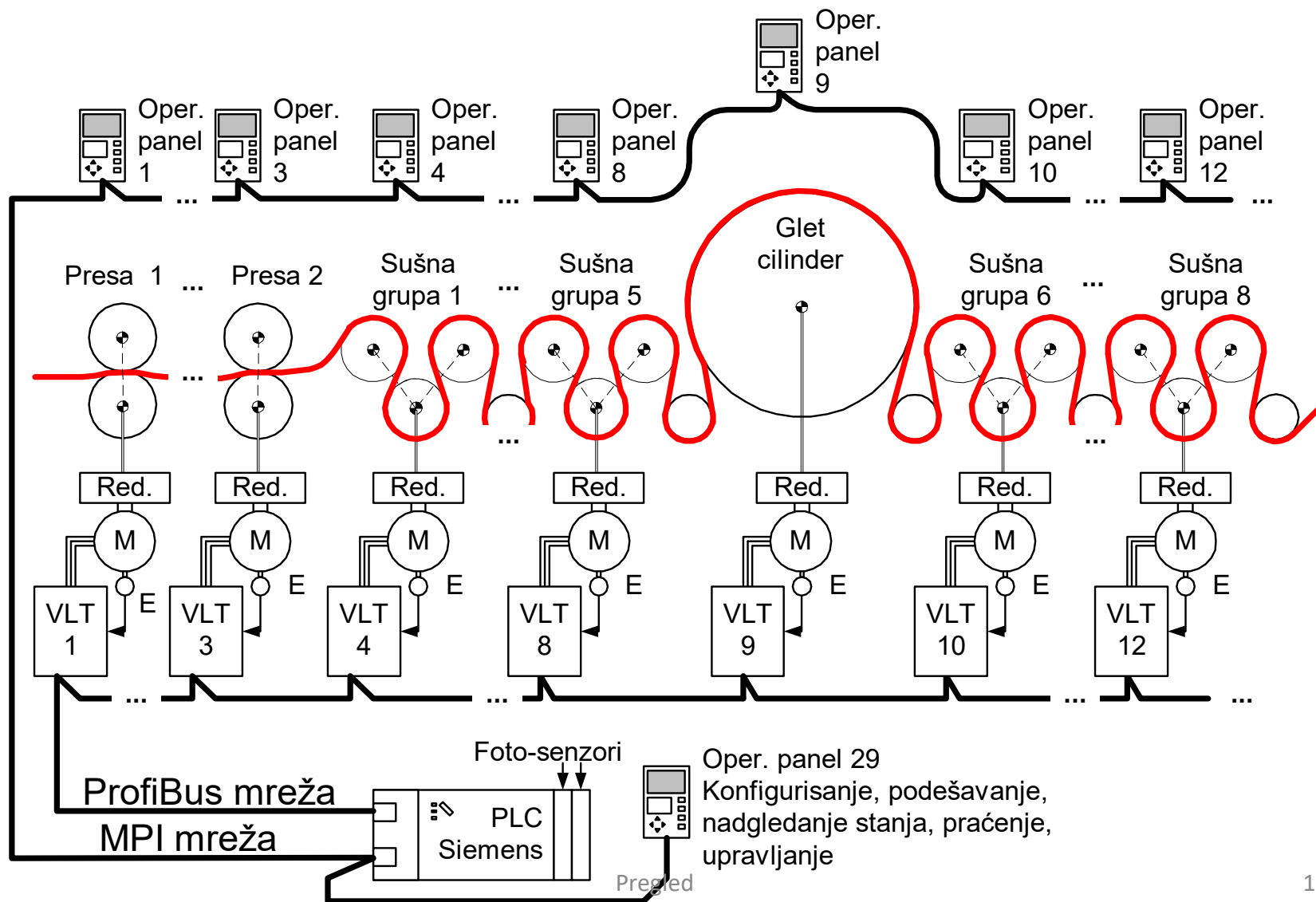
Pojedinačni (sekcioni) pogoni

- Omogućavaju da se nedostaci linijskog vratila prevaziđu.
- Dodatno unapređenje tehnologije proizvodnje.
- Povećanje maksimalnih brzina trake, što direktno utiče na kapacitet proizvodnje.

Međutim,

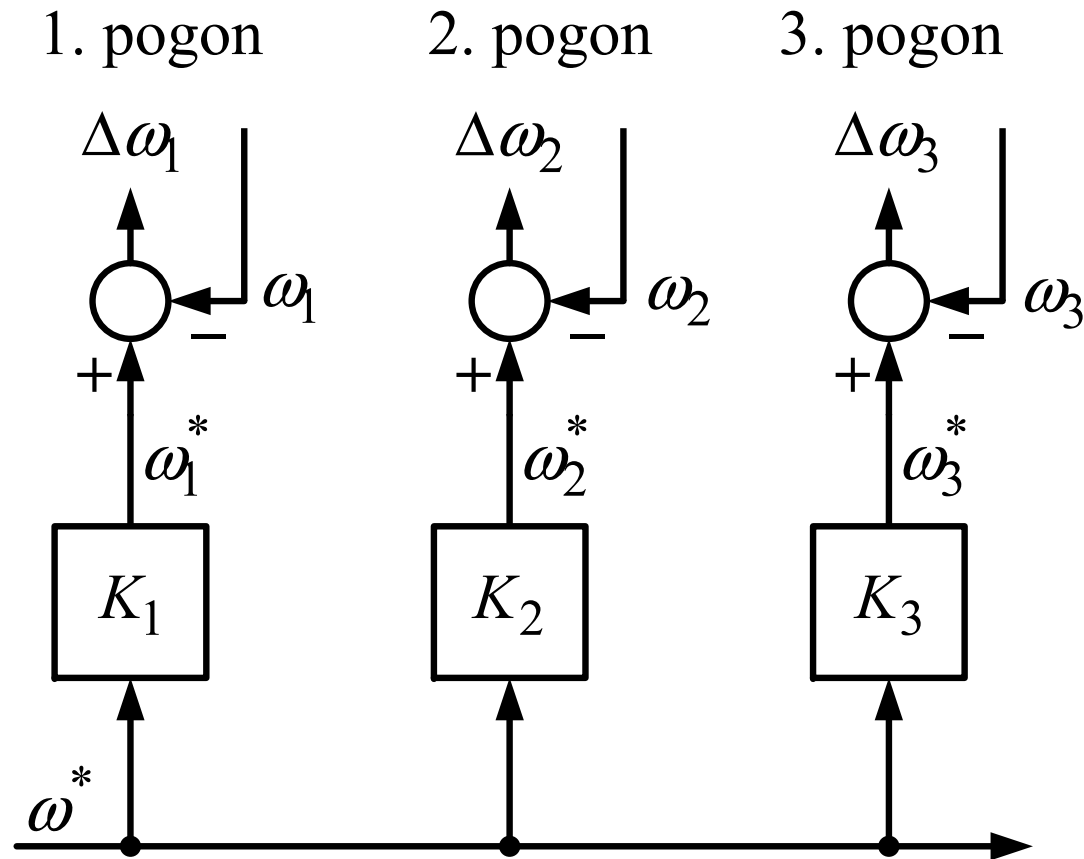
- Pojavljuju se novi problemi, pre svega kod upravljanja;
- Neophodno je da se sa strane upravljanja pogonima obezbedi potrebna sinhronizacija i zadavanje zatezanja.
- Kod pogona koji su mehanički povezani, mora se pored sinhronizacije brzine obezbediti i raspodela opterećenja.

Savremena realizacija pogona sa pojedinačnim pogonima



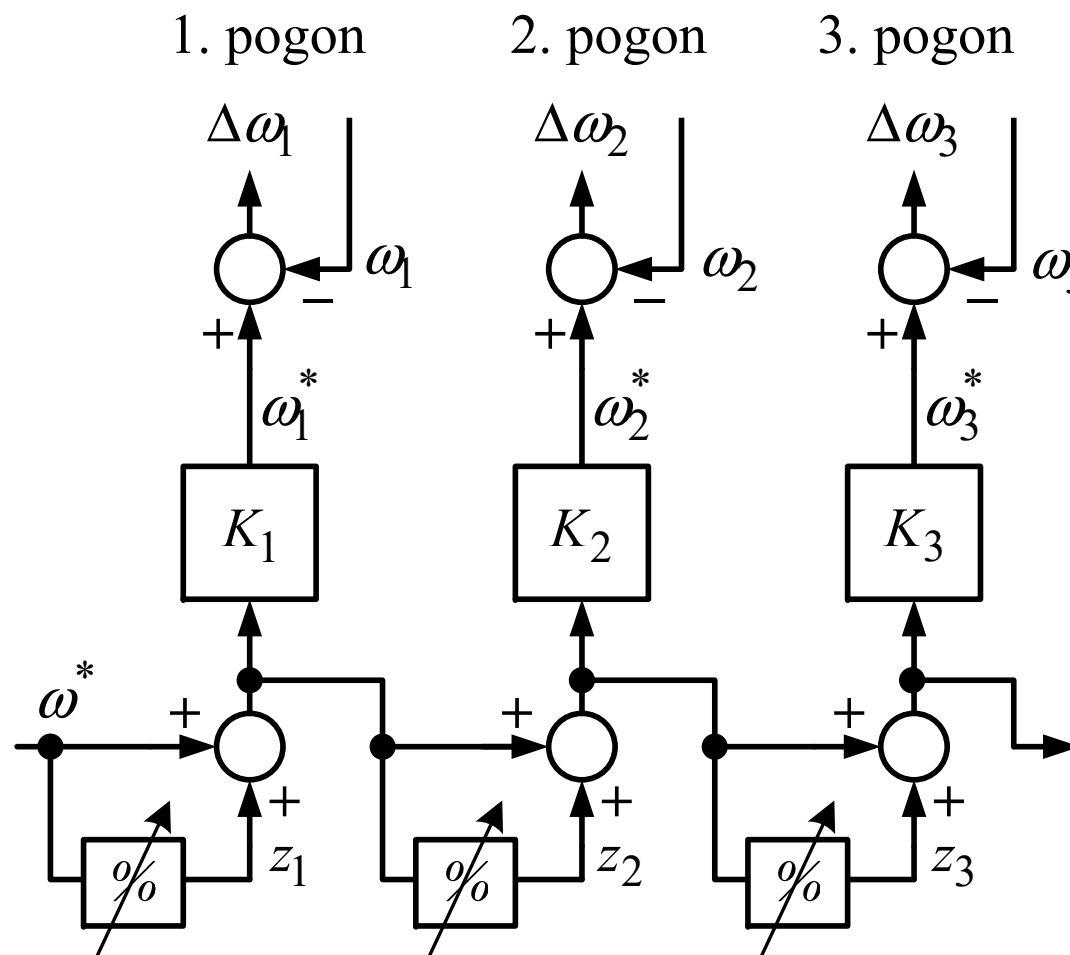
Upravljanje pogonima u nizu

Stalni odnos brzina



Upravljanje pogonima u nizu

Promenljiv odnos brzina



Electronic Line-Shafting Control for Paper Machine Drives

M. Aníbal Valenzuela and Robert D. Lorenz, *Fellow, IEEE*

YASKAWA AC Drive - A1000

Electronic Line Shaft with Alignment

Custom Software Supplement

Software Number: VSA91003□

Drive Models: AU□A□□□□□□□-064

AU□A□□□□□□□-065

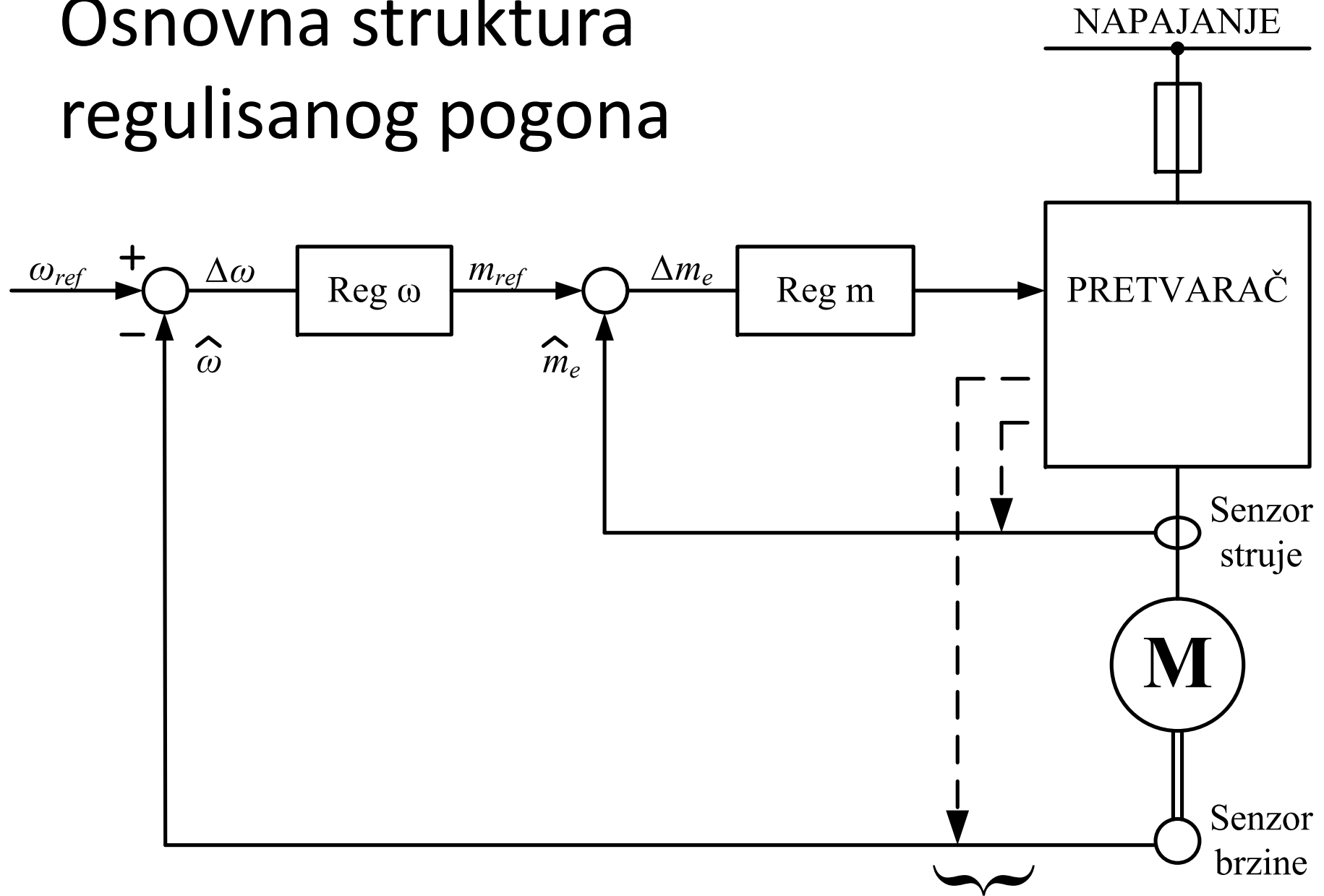
To properly use the product, read this manual thoroughly and retain for easy reference, inspection, and maintenance. Ensure the end user receives this manual.



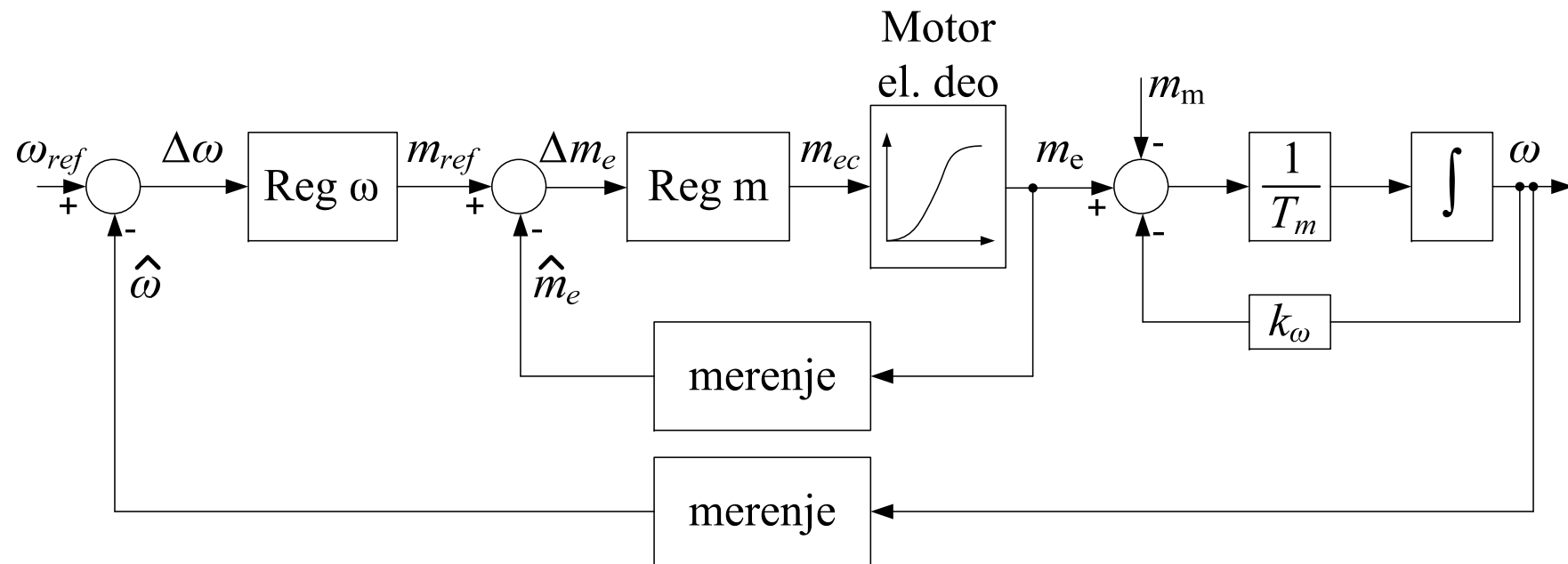
Abstract—The current synchronized motion control methods used in paper machine drives are not designed to possess the inter-shaft stiffness properties which were responsible for the coordinating force inherent in classical, mechanically coupled paper machines. Consequently, these controllers cannot easily maintain coordination for all operating conditions. This paper presents the application of an “electronic line-shafting” control technique which serves to replicate and even improve on the historical, mechanical line-shafted properties. This technique was tested on a four-shaft experimental setup to evaluate such control during periods of drive-limited torque as well as sectional drive load disturbances. The experimental results demonstrate that the “electronic line-shafting” technique significantly improves the coordination, robustness, and overall stability of paper machine drives subjected to realistic physical limitations.

Index Terms—Multi-axis synchronization, paper machine control, relative stiffness control, virtual line-shaft control.

Osnovna struktura regulisanog pogona



Uprošćeni blok dijagram osnovne strukture regulisanog pogona



Sistem jednačina koje čine model

Regulator brzine

$$\hat{\omega} = \omega \cdot K_{p\omega} \quad \Delta\omega = \omega_{ref} - \hat{\omega}$$

$$m_{ref} = \frac{K_{\omega}}{T_{\omega}} \cdot \int_0^t \Delta\omega \cdot dt + K_{\omega} \cdot \Delta\omega$$

Regulator momenta

$$\hat{m}_e = m_e \cdot K_{pm} \quad \Delta m_e = m_{ref} - \hat{m}_e$$

$$m_{ec} = \frac{K_{em}}{T_{em}} \cdot \int_0^t \Delta m_e \cdot dt + K_{em} \cdot \Delta m_e$$

Sistem jednačina koje čine model

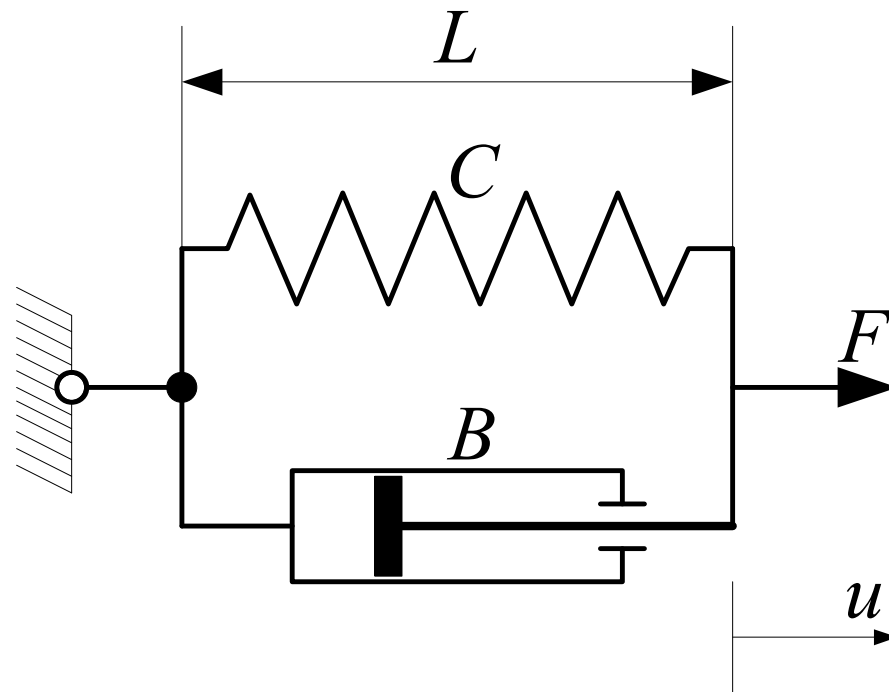
Odziv momenta (m_e) na zadatu komandu (m_{ec})

$$m_e = \frac{1}{T_e} \int (m_{ec} - m_e) dt \quad \text{Kašnjenje prvog reda}$$

Njutnova jednačina

$$\omega = \frac{1}{T_m} \int (m_e - m_m - K_m \cdot \omega) dt$$

Mehanička povezanost pogona



Kelvin-Voigt-ov model

Osnovne relacije Kelvin-Voigt-ovog modela

$$f = f_c = C \cdot u + B \cdot \frac{du}{dt}$$

$$C = \frac{E \cdot A}{L} \qquad B = \frac{\eta \cdot A}{L}$$

f – sila koja deluje na element predstavljen modelom [N];

f_c – sila usled naprezanja-deformacije materijala [N];

u – promena dužine elementa [m];

L – dužina elementa merena duž ose delovanja sile [m];

A – površina preseka elementa upravno na osu delovanja sile [m²];

Osnovne relacije Kelvin-Voigt-ovog modela

$$f = f_c = C \cdot u + B \cdot \frac{du}{dt}$$

$$C = \frac{E \cdot A}{L} \qquad B = \frac{\eta \cdot A}{L}$$

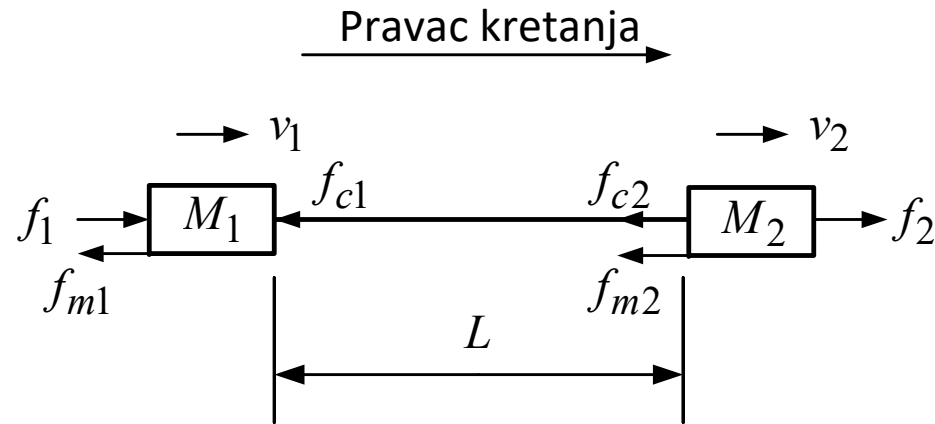
E – Young-ov modul elastičnosti materijala [N/m²];
Guma: 0,01-0,1·10⁹ Čelik: 200·10⁹ Bakar: 117·10⁹ Papir: 10-50·10⁹

η – koeficijent viskoznosti materijala [N·s/m²];

C – konstanta elastičnosti elementa [N/m];

B – konstanta viskoznosti elementa [N·s/m].

Pravolinijsko kretanje dva tela u mehaničkoj vezi preko elastičnog štapa



$$M_1 \frac{dv_1}{dt} = f_1 - f_{c1} - f_{m1}$$

$$\frac{du_1}{dt} = v_1$$

$$M_2 \frac{dv_2}{dt} = f_2 - f_{c2} - f_{m2}$$

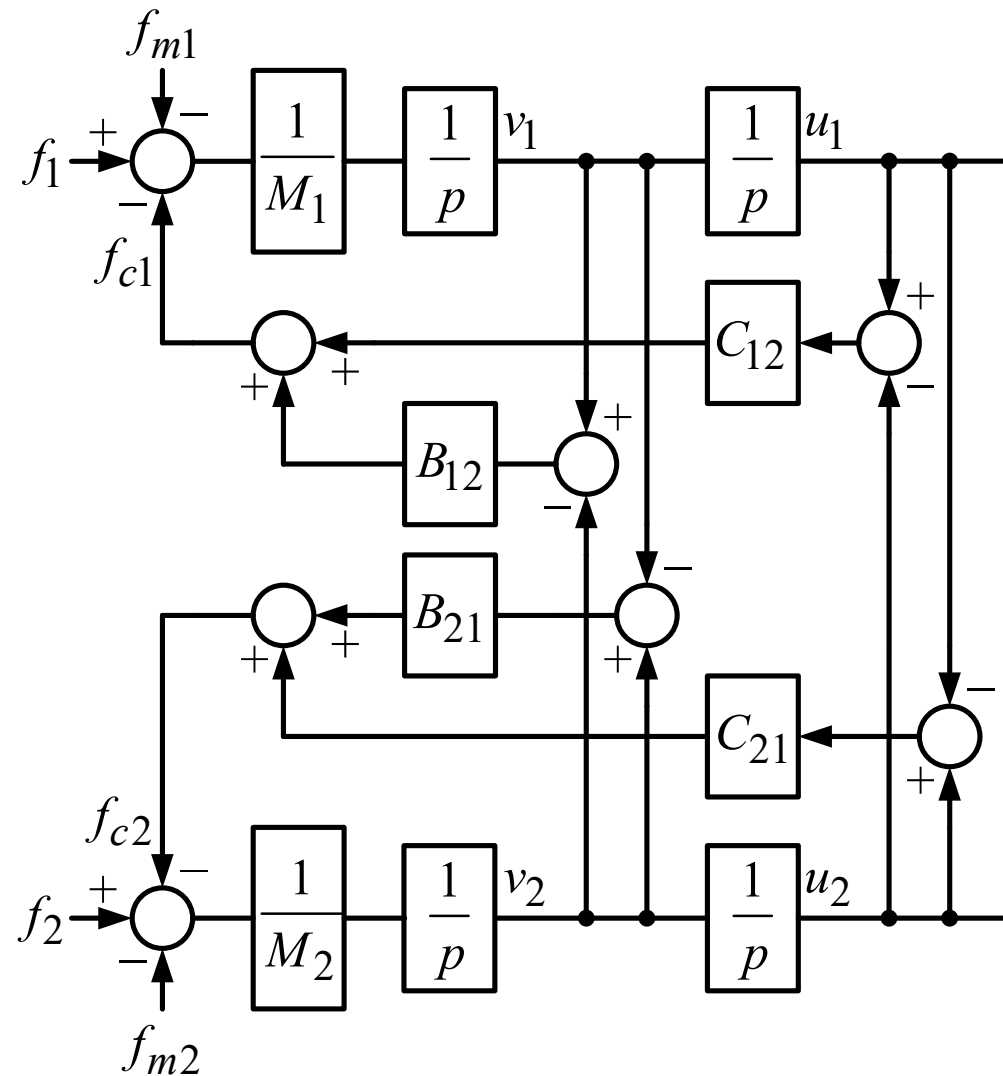
$$\frac{du_2}{dt} = v_2$$

$$f_{c1} = C_{12}(u_1 - u_2) + B_{12}(v_1 - v_2)$$

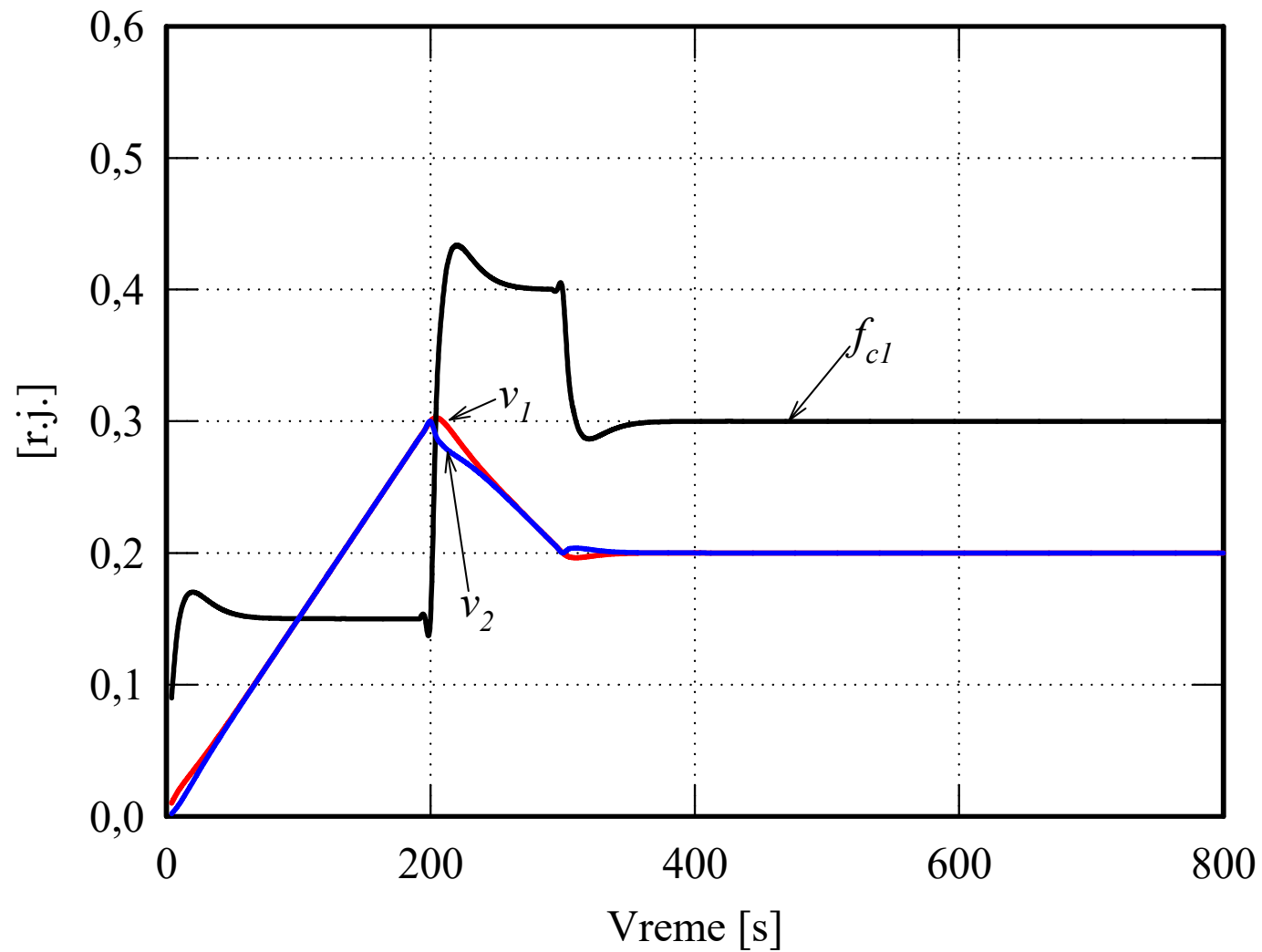
$$f_{c2} = C_{21}(u_2 - u_1) + B_{21}(v_2 - v_1)$$

$$C_{12} = C_{21} = C \quad \text{ i } \quad B_{12} = B_{21} = B$$

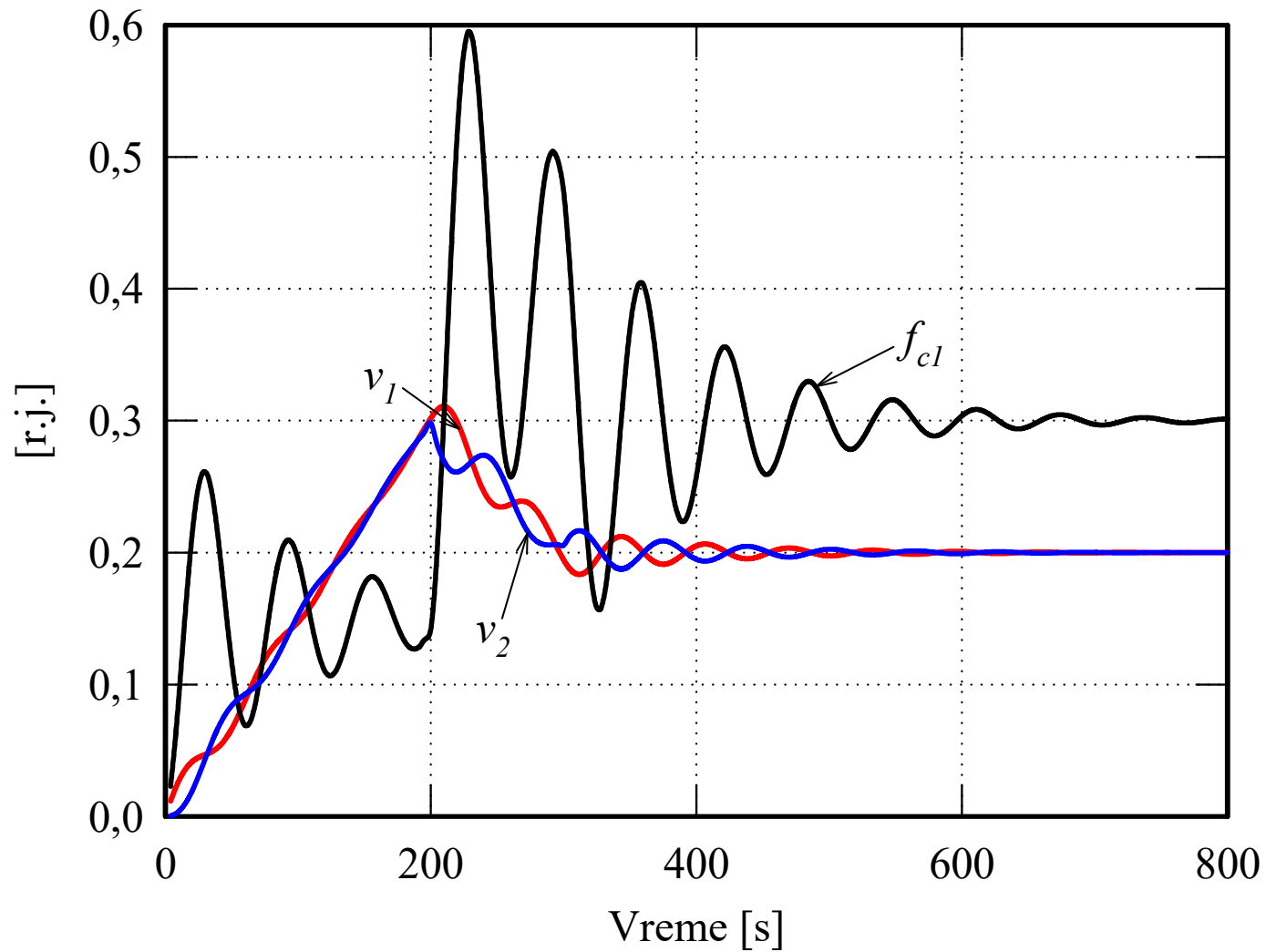
Model – blok diagram



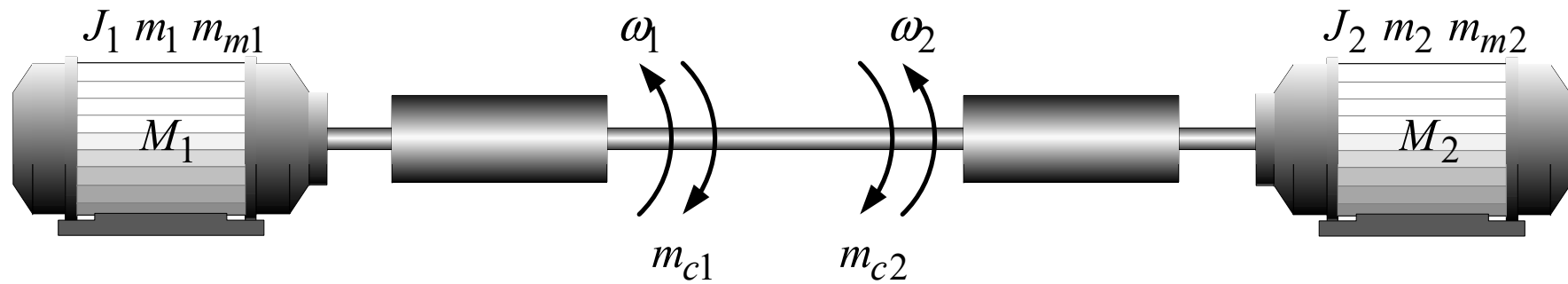
Ponašanje sistema pri $C=0,5\text{r.j.}$ i $B=10\text{r.j.}$



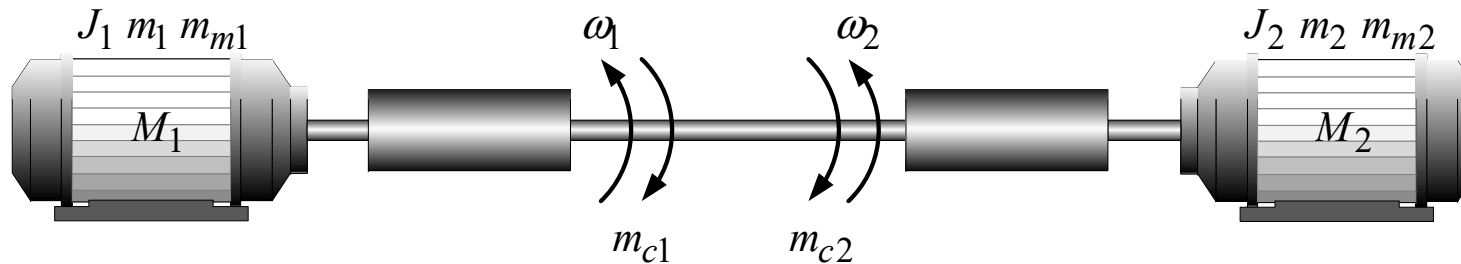
Ponašanje sistema pri $C=0,5\text{r.j.}$ i $B=1\text{r.j.}$



Spregnuti pogoni – obrtno kretanje



Sistem jednačina



$$J_1 \frac{d\omega_1}{dt} = m_1 - m_{c1} - m_{m1}$$

$$J_2 \frac{d\omega_2}{dt} = m_2 - m_{c2} - m_{m2}$$

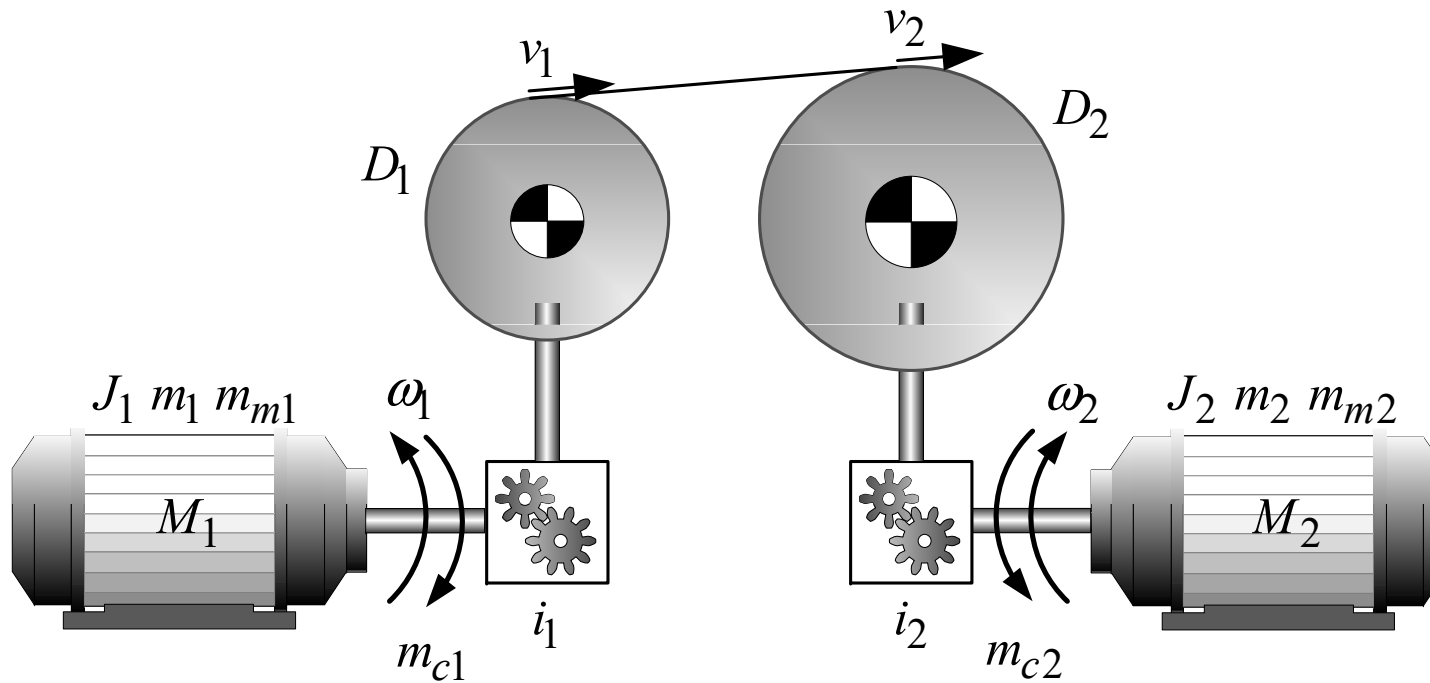
$$\frac{d\theta_1}{dt} = \omega_1$$

$$\frac{d\theta_2}{dt} = \omega_2$$

$$m_{c1} = C_{12}(\theta_1 - \theta_2) + B_{12}(\omega_1 - \omega_2) \quad m_{c2} = C_{21}(\theta_2 - \theta_1) + B_{21}(\omega_2 - \omega_1)$$

$$C_{12} = C_{21} = C \quad \text{i} \quad B_{12} = B_{21} = B$$

Slučaj sa nejednakim prenosnim odnosima reduktora i prečnicima



Slučaj sa nejednakim prenosnim odnosima reduktora i prečnicima

$$J_1 \frac{d\omega_1}{dt} = m_1 - m_{c1} - m_{m1}$$

$$J_2 \frac{d\omega_2}{dt} = m_2 - m_{c2} - m_{m2}$$

$$v_1 = \frac{D_1}{2} \cdot \frac{1}{i_1} \cdot \omega_1 \quad \frac{du_1}{dt} = v_1$$

$$v_2 = \frac{D_2}{2} \cdot \frac{1}{i_2} \cdot \omega_2 \quad \frac{du_2}{dt} = v_2$$

$$f_{c1} = C_{12} \cdot (u_1 - u_2) + B_{12} \cdot (v_1 - v_2) \quad f_{c2} = C_{21} \cdot (u_2 - u_1) + B_{21} \cdot (v_2 - v_1)$$

$$m_{c1} = \frac{D_1}{2} \cdot \frac{1}{i_1} \cdot f_{c1}$$

$$m_{c2} = \frac{D_2}{2} \cdot \frac{1}{i_2} \cdot f_{c2}$$

Slučaj sa nejednakim prenosnim odnosima reduktora i prečnicima

$$J_1 \frac{d\omega_1}{dt} = m_1 - m_{c1} - m_{m1}$$

$$J_2 \frac{d\omega_2}{dt} = m_2 - m_{c2} - m_{m2}$$

$$v_1 = \frac{D_1}{2} \cdot \frac{1}{i_1} \cdot \omega_1 \quad \frac{du_1}{dt} = v_1$$

$$v_2 = \frac{D_2}{2} \cdot \frac{1}{i_2} \cdot \omega_2 \quad \frac{du_2}{dt} = v_2$$

$$C_{12} = C_{21} = C \quad \text{ i } \quad B_{12} = B_{21} = B$$

$$f_c = f_{c2} = C \cdot (u_2 - u_1) + B \cdot (v_2 - v_1) = -f_{c1}$$

$$m_{c1} = -\frac{D_1}{2} \cdot \frac{1}{i_1} \cdot f_c$$

$$m_{c2} = \frac{D_2}{2} \cdot \frac{1}{i_2} \cdot f_c$$

Model – blok diagram

