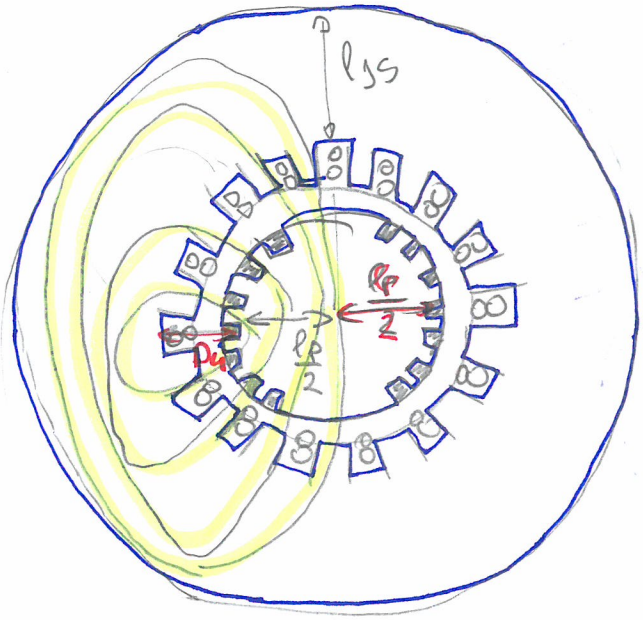
DIS - AUDITORNE VJEŽBE

04.03.2014

- DVOPOLNI
- SINHRONI TURBOGENERATOR IMA PUNO ZRAČOS RASPOR
- VEOMA DEBELI JARAM



$$l_{JS} \approx \frac{l_P}{2}$$

zračni raspor

$$X_d \sim \delta$$

$$\delta = \frac{1}{2} \frac{A \tau_p}{B_\delta X_{d1}}$$

$$B_\delta \approx 0.8\,T$$

$$A = 30 \div 80 \ \frac{kA}{m}$$

$$\tau_p = \frac{D_u \pi}{2p}$$

$$\delta = k \cdot \frac{D_u}{X_{d1} \cdot p}$$

$$\delta = \frac{1}{2} \frac{A}{B_\delta} \cdot \frac{D_u \cdot \pi}{2p}$$

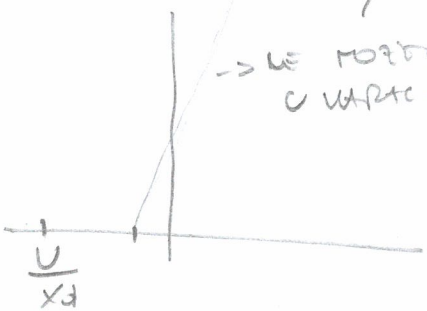
- KOD HIDROGENERATORA ZBOG p i D_u JE RUKOMAK:

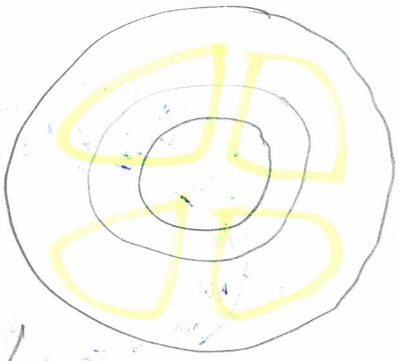
k_S X_d ↑

PM X_d ↓

-> ZATO SE UDARNU OKO 100 ÷ 200%

-> JE MANJE IĆ U MARGINALNO

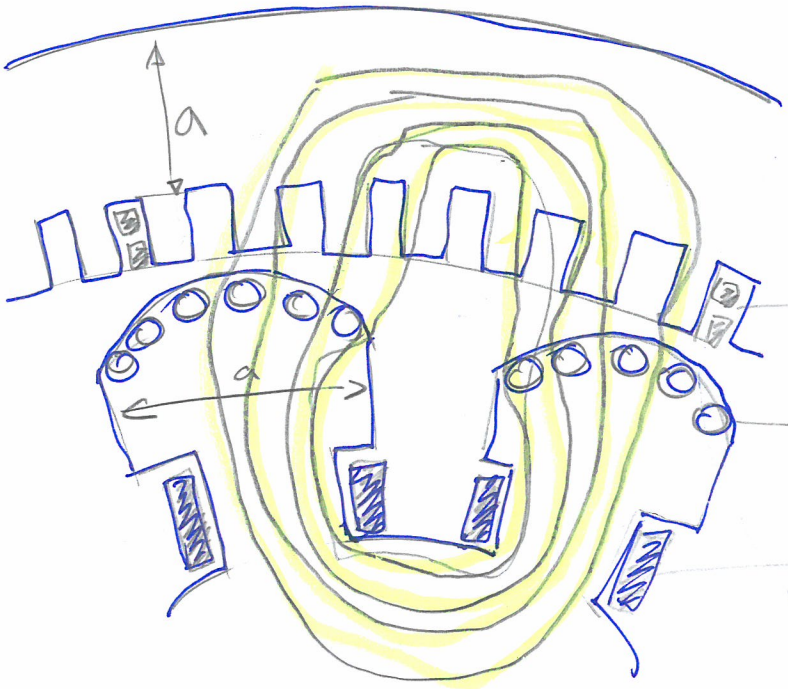




6 4 POLNI

SINHRONI HIDROGENERATOR

$$B = \frac{\Phi}{S}$$



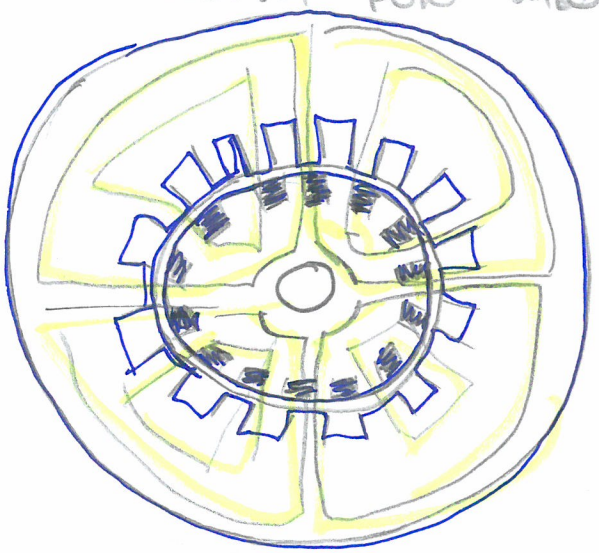
- VIŠE POLOVA, MANJI JARM
- → STATORSKI
- → PRIGUŠNI
- → ARMATURNI

ASINHRONI STROJ - VAŽNO!

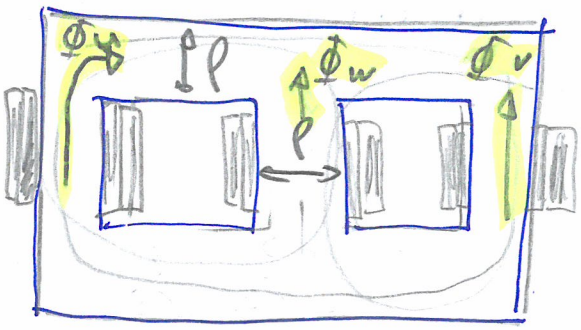
- δ MORA BITI STO MANJI

JAKO MALI ZRAČNI RASTOR MORA BITI ZBOG ONDA JE STRUJA MAGNETIZIRANJA MALA I NE KORISTI PUNO SNAGOM, A COS φ JE BOLJI

- MAG. MATERIAL - TOK IDE KROZ OSOVINU, U PROTILOM SE IDE

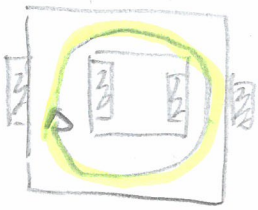


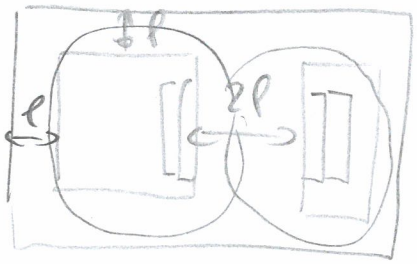
TRANSFORMATOR - 3F - 3 STUPNI - DVONAPOTNI



- 3 NAPOJI PRIMAR i 2 SEKUNDAR
  - ILI 5 PRIKLJUČAKA
  - 3 JEDNOFAZNA NAMOTA
- 2 NAPOJI - PRIMAR ; SEKUNDAR
  - 2 TROFAZNA NAMOTA

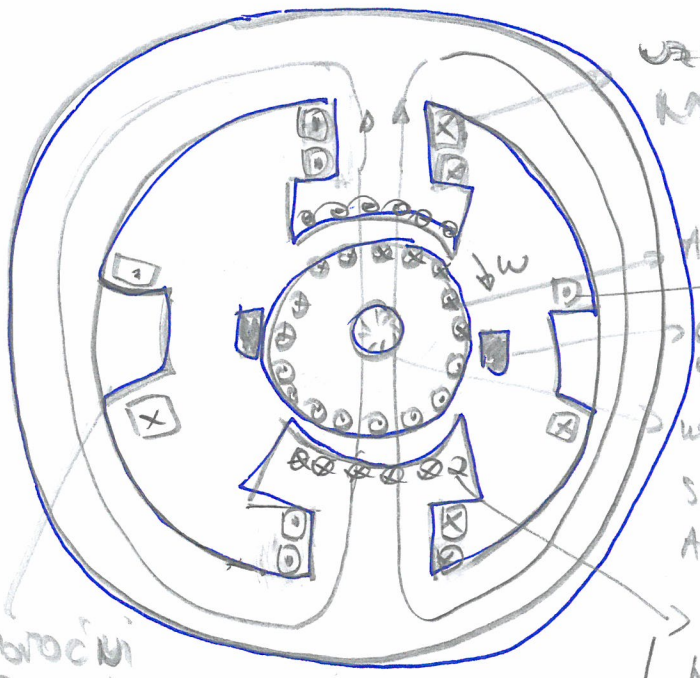
- JEDNOFAZNI





ISTOSMJERNI STROJ

$$F = l \times B\, I$$



UZBUDNI NAMOT

- NOSI GLAVNOM OBUTI POL

GLAVNI POL

ia

ČETKE i KOLEKTOR S LAMELAMA

KOMPENZACIJSKI NAMOT

ia

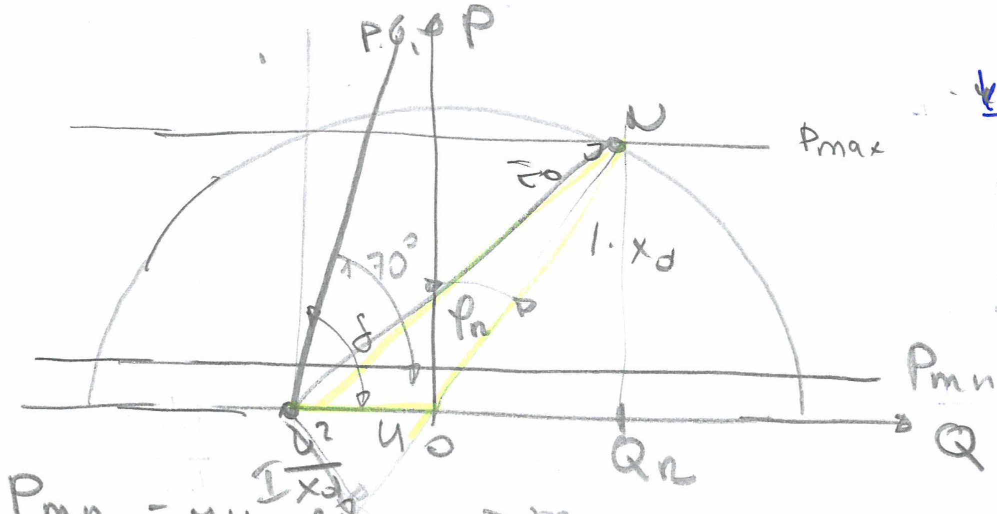
POMOĆNI POLOVI

- PONIŠTI PROTJECAJ KOJI STVARA GLAVNI NAMOT
- U SERIJI S ARMATUROM

δ - ŠTO MANJI

POGONSKA KARTA

: DOLAZIMO DO PODRUČJA GDJE S.G. MOŽE RADITI



KRUŽNICA - PRIVIDNA SNAGA

↳ S = const

S = 1 p.u.

$$S[p.u.] = \frac{U \cdot I}{S_n}$$

$$S_n = U_n \cdot I_n$$

$$S[p.u.] = \frac{U_n \cdot I}{U_n \cdot I_n} = \frac{I}{I_n}$$

$$S[p.u.] = I[p.u.]$$

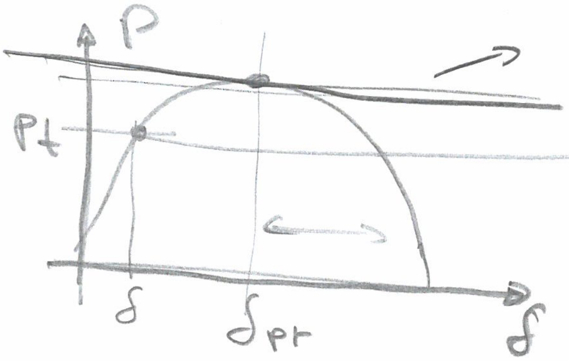
P_{mn} - MIN. SNAGA TURBINE.

P_{max} - MAX. RADNA SNAGA TURBINE

N - NAZIVNA RADNA TOČKA S.G.

T.S. - TEORIJSKA GRANICA STABILNOSTI

$$P = \frac{U E_0}{x_d} \sin \delta$$

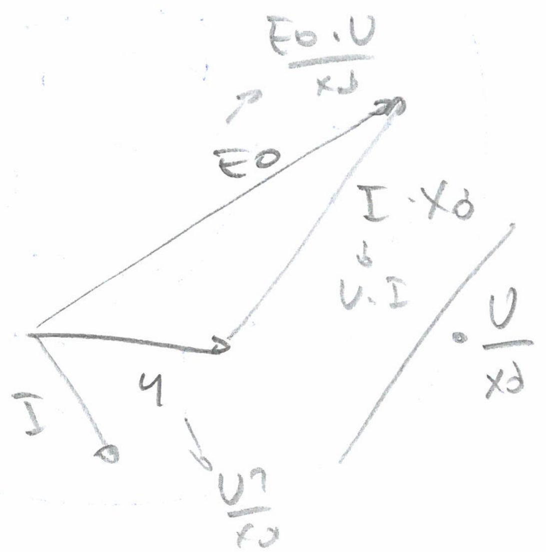


PRIJE OVE GRANICE GEN. ISPADA IZ SINKRONIZMA, ROTOR SE VRTI BRŽE OD ω_s

→ TOČKA JE STATIČKI STABILNA

P.G. - PRAKTIČNA GRANICA STABILNOSTI

E_0 - TAKO JE MJERA ZA E_0



DIS - AUDITORNE

11.03.2014

(1.) NACRTAJTE OVISNOST DJELATNE SNAGE $P(\delta)$ i JALOVE SNAGE $Q(\delta)$ O KUTU OPTEREĆENJA ZA 12 POLNI S.G. U RADU NA KRUTU MREŽU i OZNAČITE KARAKTERISTIČNE VRIJEDNOSTI U MW ODNOSNO MVAr, AKO SU POZNATI NAZIVNI PODATCI:

35 MVA
$\cos\varphi = 0.9$
10.5 kV
50 Hz

- TE SINKRONE REAKTANCIJE $X_d = 140\,\%$, $X_q = 85\,\%$
- $I_f = I_{fn}$

- KARAKTERISTIKU TREBA NACRTATI ZA NAZIVNU UZBUDU, TE OZNAČITI NAZIVNU RADNU TOČKU (δ_n, P_n), (δ_n, Q_n). OSTALE KARAK. TOČKE ZA SLUČAJ GEN. i MOTOR. RADA, GUBITCI SE ZANEMARUJU.
- SNAGE IZRAZITI U APSOLUTNIM VR.:

RJEŠENJE

12 POLNI
35 MVA
$\cos\varphi = 0.9$
10.5 kV
50 Hz
$X_d = 140\,\%$
$X_q = 85\,\%$
$I_f = I_{fn}$

$P(\delta)$, $Q(\delta)$

- SNAGA KOJU S. STROJ MOŽE PRETVORITI IZ MEHANIČKE.

$$P = \frac{U \cdot E_0}{X_d} \sin\delta + \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$$

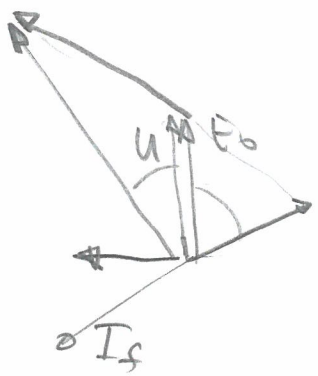
- JALOVA SNAGA

$$Q = \frac{U E_0}{X_d} \cos\delta + \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\cdot\cos 2\delta - \frac{U^2}{2}\left(\frac{1}{X_q} + \frac{1}{X_d}\right)$$

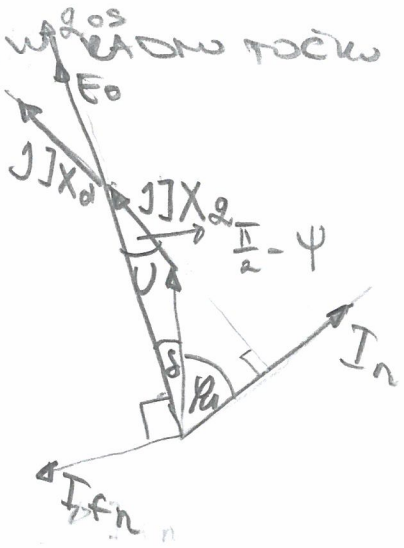
$E_0 \sim I_U$ -> KOLIKO JE UZBUDA U P.U. TOLIKO I E_U

- 1 P.U. UZBUDNE STRUJE = I_{f0} (A) - TO JE UZB. STRUJA P.H.

P.H. -> $E_0 = U \cdot 1$ P.U.



· TRAŽIMO NAZIVNU RADNU TOČKU



$$tg\,\psi = \frac{I_n \cdot X_2 + U_n \cdot \sin\varphi_n}{U_n \cdot \cos\varphi_n}$$

$$tg\,\psi = \frac{1 \cdot 0.85 + 1 \cdot 0.436}{1 \cdot 0.9} = 1.4289$$

$$\psi_n = 55°$$

$$\delta_n = \psi_n - \varphi_n = 55° - 25.84° = 29.16°$$

$$E_0 = U_n \cdot \cos\delta_n + I_n X_d \cdot \sin\psi_n = 2.02\ p.u$$

· SAD MOŽEMO VREMENT NA SNAGE

$$P_n = S_n \cdot \cos\varphi_n = 31.5\ MW$$

$$Q_n = S_n \cdot \sin\varphi_n = 15.26\ MVAr$$

· MAX. PRENOSNA SNAGA - KOLIKO MAX MOŽEMO OPTEREĆITI PRENOSNU
→ MAX. FIZ. P(δ) - PRIJE NEGO S.S. ISPADA IZ SINKRONIZMA

$$\frac{dP}{d\delta} = \frac{U \cdot E_0}{X_d} \cos\delta + U^2\left(\frac{1}{X_2} - \frac{1}{X_d}\right) = 0$$

($E_0 = 2.02$, $X_d = 1.4$) → δ koji dobijemo je δ prenosni

$$0.9245\cos^2\delta + 1.443\cos\delta - 0.462 = 0$$

NAZIVNA OPTEREĆENJA - 1 KARAKTERISTIKA $E_0 = konst$

- AKO JE $E_0 \neq konst$ ONDA DOBIJAMO FAMILIJU KARAKTERISTIKA

$$\delta_{pr} = 74.18°$$

· KOD S. TURBO. G. NETKO OVO OBJASNI I ZATO JE KOD NJIH JE MAX U 90°, A MI IMAMO OKO 74° JER SE DOPRINOS RELUKTANSE MONSTRA

$P_{max} = 1.51 \ p.u.$

$P_{max} = 52.83 \ MW$

$Q_{max} \rightarrow \delta = 0$

$$Q_{max} = \frac{U_n E_{0n}}{X_d} \cdot \cos 0 + \frac{U_n^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) \cdot \cos 0 - \frac{U^2}{2}\left(\frac{1}{X_q} + \frac{1}{X_d}\right)$$

$P_n = 0.9 \ p.u.$

$Q_n = 0.436 \ p.u.$

$Q_{max} = 0.7285 \ p.u.$

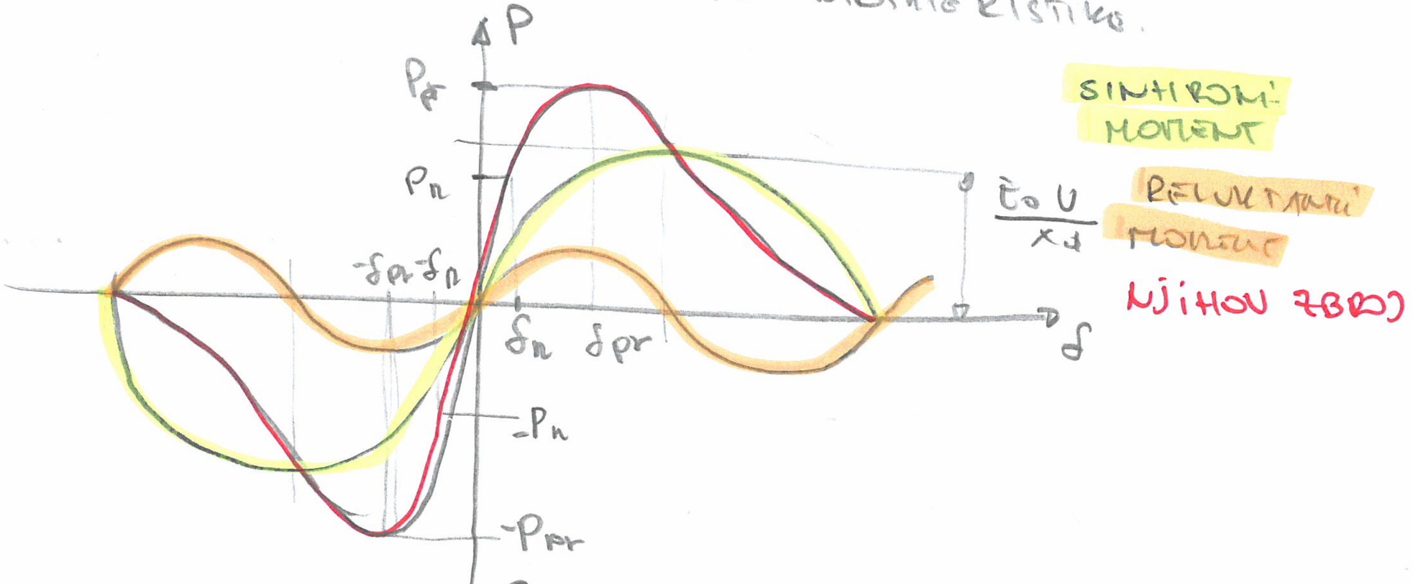
$Q_{pr}(\delta_{pr}) = 0.7487 \ p.u.$

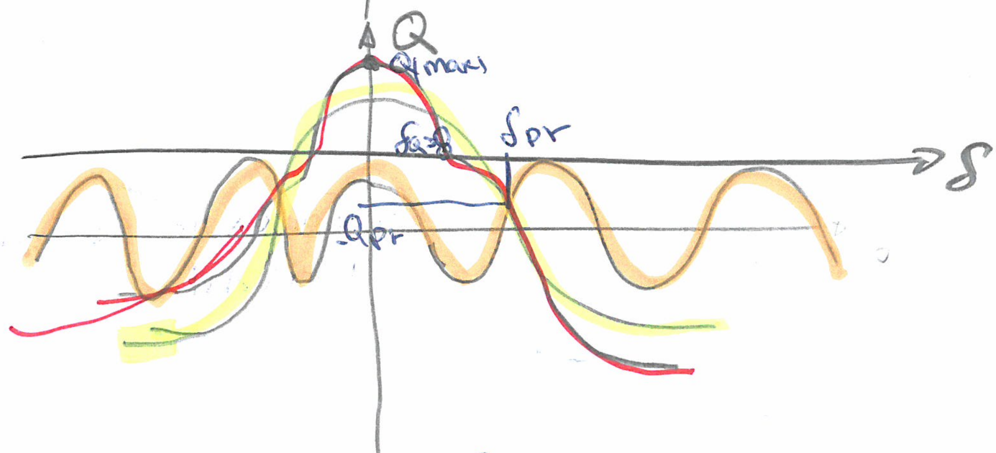
- ZANIMA NAS PRI KOJEM δ JE JALOVINA $= 0$

$$Q = \frac{U E_0}{X_d} \cos\delta + \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\cos 2\delta - \frac{U^2}{2}\left(\frac{1}{X_q} + \frac{1}{X_d}\right) = 0$$

$$0.231 \cos^2\delta + 1.443 \cos\delta - 1{,}176 = 0 \Rightarrow \delta_{Q=0} = 43.16°$$

- SAMO JE OSTALO ZA NACRTAT TE KARAKTERISTIKE.





(2.) 3F. S.G. IMA NAZ. PODATKE 10MVA, 10.5kV, 375 rpm 50 Hz, $\cos\varphi_n = 0.8$ i, $X_d = 100\%$, $X_q = 50\%$. ŠTO ĆE SE DOGODITI AKO STROJU UZ NAZIVNI NAPON I FREKVENCIJU I PRI OPTEREĆENJU OD 8 MVA i $\cos\varphi = 0.6$ (IND) PREKINEMO UZBUDU.

RJEŠENJE:

- OĆE LI GEN OSTATI U SINKRONIZMU ILI NE
- OĆE LI RELUKTANTNI MOMENT MOĆI ODRŽATI ILI ĆE ISPAST IZ KORAKA

$S_n = 10$ MVA

$U_n = 10.5$ kV

$n = 375$ rpm

$X_d = 100\%$

$X_q = 50\%$

$\cos\varphi_n = 0.8$ i

TERET

$S = 8$ MVA

$\cos\varphi = 0.6$ i

PREKID UZBUDE

$S = 8$ MVA

$P = S\cos\varphi = 4.8$ MW $= 0.48$ p.u.

$$P = \frac{U E_0}{X_d}\sin\delta + \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$$

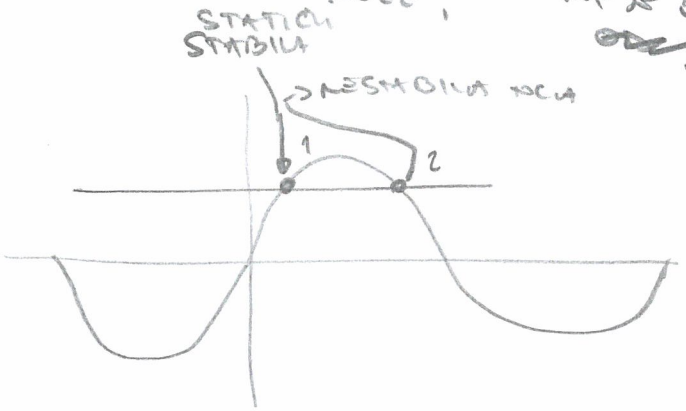
E_0

$$0.48 = \frac{1}{2}^2 \left(\frac{1}{0.5} - \frac{1}{1}\right)\sin 2\delta \;/:2$$

$$0.96 = \sin 2\delta \Rightarrow \delta = 36.87°$$

DA JE OVO VEĆE OD 1 ONDA NEBI SIN MOGAO DATI

$\delta > 45°$ -> NESTABILNO?



ZA VEĆU SILU SE POVEĆA δ

A ZA 2. TOČKU ONDA JE STABILNO

δ

UVEŠAVANJE

KOLIKA ĆE BITI JALOVA SNAGA AKO SE ISKLJUČI UZBUDA

$$Q = \frac{E_0 U}{X_d}\cos\delta + \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\cos 2\delta - \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) =$$

$= -1.36$ p.u.

ZABORAVIO JE OVO NAPISATI

$$S = \sqrt{P^2 + Q^2} = 1.44 \text{ p.u.} \qquad I = 1.44 \text{ p.u.}$$

- SINHRONI KOEFICIENT SNAGE

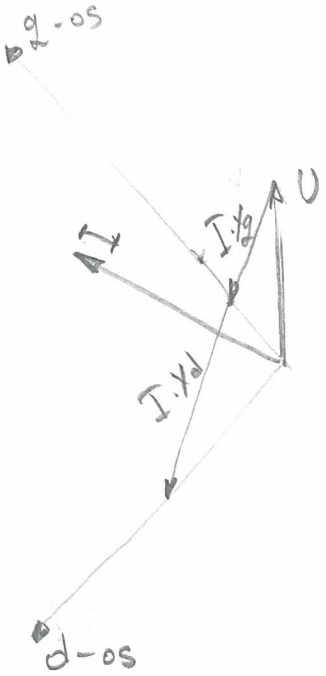
$$k_{sp} = \frac{dP}{d\delta} = \frac{UE_0}{x_{01}} \cos\delta + U^2 \left(\frac{1}{x_q} - \frac{1}{x_d} \right) \cos 2\delta$$

$k_{sp} = 0.2\,\delta \Rightarrow$ $k_{sp} > 0$ → STABILAN

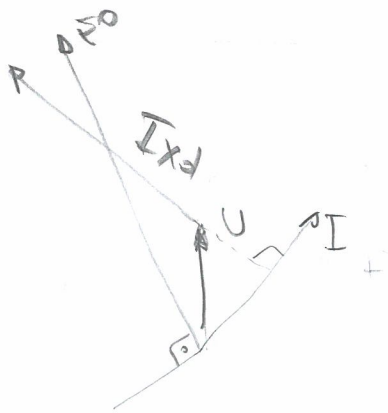
$k_{sp} = 0$ → GRANIČNO STABILAN

$k_{sp} < 0$ → NESTABILAN

- DOĆ NACRTAT VEKTORSKI DIJAGRAM

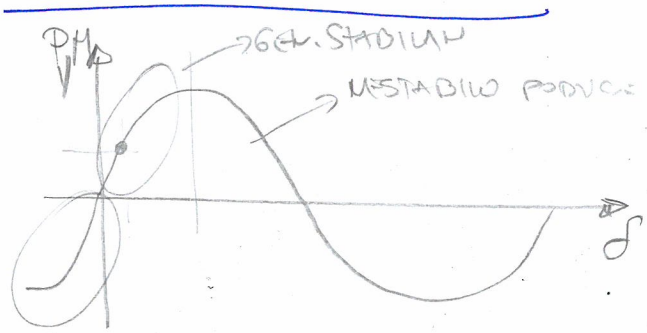


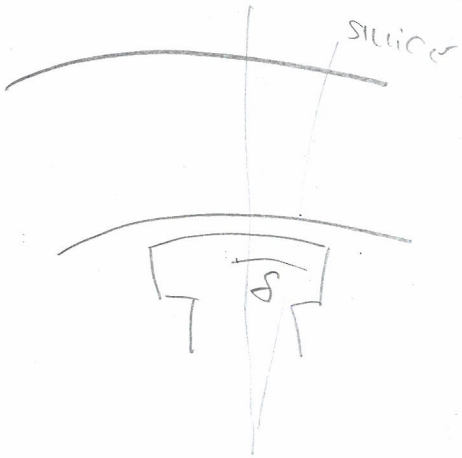
NORMALNO



DIS - AUDITORNE

18. 3. 2014



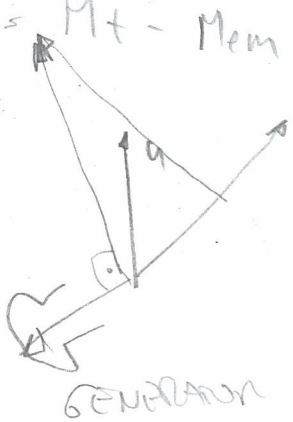


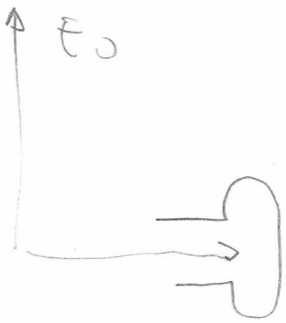
MOTORSKI SMJER

$$J\frac{d\omega}{dt} = M_t - M_{em}$$

• KAD SE POVEĆA OPTEREĆENJE, POVEĆAVA SE KUT δ

$$J\frac{d\delta}{dt} = M_t - M_{em}$$





ON U NESTABILNOM ISPADA IZ SINKRONIZMA

PRI LIMA MOMENTA TURBINE i M_{em} IZVAN POVEĆANJA δ

DOK NE DOĐE U NOVU TOČKU $M_{em} = M_t$

Moment inercije S.G. i konstanta tromosti

1. Podaci 2polnog industr. turbogeneratora su: 5 MVA, 50 Hz, ima moment tromosti 190 kg m². Odredi meh. vr. konst. i konst. tromosti H. Kolika je kin. energija pohranjena u rotoru turbogeneratora pri sinkronoj brzini.

Rješenje:

5 MVA

50 Hz

190 kgm²

$T_m = ?$

$H = ?$

$E_k = ?$

$$H = J\frac{\omega_s^2}{2}\cdot\frac{1}{S_n}\ [s]$$

(kin. energija)

$$E_k = H \cdot S_n$$

$$T_m = 2 \cdot H\ [s]$$

→ M konst. koja odgovara S_n i pritom se ubrzava od 0 do n_n za T_n sekundi

Pmoment koji odgovara S_n, pritom ubrzava od 0 do n_n za vrijeme T_n

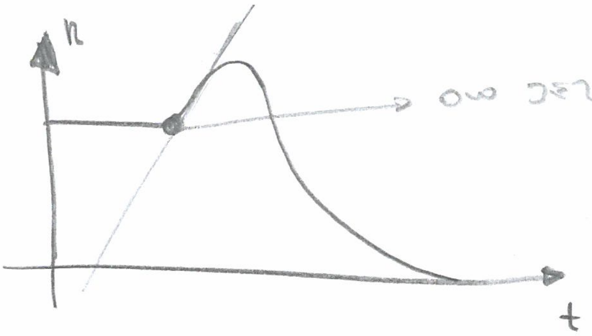
Neki autori to kažu $\frac{MWs}{MVA}$ ili $\frac{Ws}{VA}$

$$T_m = J\frac{\omega_s^2}{S_n} = 190\cdot\frac{(100\pi)^2}{5\cdot10^6} = 3.747\ s$$

$$H_m = \frac{T_m}{2} = 1.8073\ s$$

$$E_k = H\cdot S_n = 1.873\cdot5\cdot10^6 = 9.365\cdot10^6\ J = 2.601\ kWh$$

2) ODREDITE MOMENT INERCIJE, VR. MEH. KONST i KORISNU POLOVINU.
6 POLNOG SIN. GEN NAZIVNE SNAGE $S_n = 400\,kVA$ i $\cos\varphi_n = 0.8$
AKO PRI ODBACIVANJU TERETA $P = 0.1\,P_n$ i $\cos\varphi = 1$ AGREGAT IMA UBRZANJE
$\alpha = 21\ \frac{rad}{s^2}$.



RJEŠENJE:

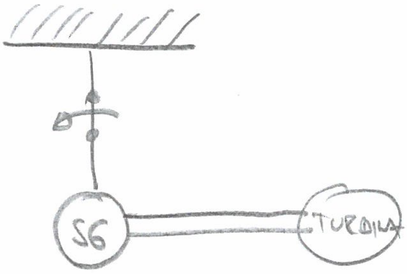
$2p = 6$

$S_n = 400\,kVA$

$\cos\varphi_n = 0.8$

$P = 0.1\,P_n$, $\cos\varphi = 1$

$\alpha = 21\ rad/s$



$$T_m = \omega_n \cdot \frac{\Delta t}{\Delta\omega} \frac{P_1}{P_n}\ [s]$$

P_1 – SNAGA PRIJE ODBACIVANJA TERETA

P_n – NAZIVNA

$$\omega_s = \frac{60f}{p}\frac{\pi}{30} = 104.719\ \frac{rad}{s}$$

$$\frac{\Delta t}{\Delta\omega} = \frac{1}{21\,\frac{rad}{s}} = 0.04762$$

$$T_m = 0.49865\ s$$

$$H = \frac{T_m}{2} = 0.2493\ s$$

$$H = J\frac{\omega^2}{2S_n}$$

$$J = \frac{2S_n \cdot \omega^2}{J} = 18.194\ kgm^2$$

3. 3F S.G. 12 MVA, 6300V, 50Hz, $\cos\varphi_n = 0.7$, $n = 214 \frac{o}{min}$ IMA SINKRONE REAKTANCIJE $X_d = 126\%$, $X_q = 60\%$. GUBITCI TRENJA I VENT IZNOSE 140 kW. POMOĆNI ZAMAJAC U MOTORNOM RADU ODREĐENO JE FIKTIVNO VRIJEME ZALETA $T_1 = 22 s$.

ODREDITE VLASTITU FREQ. NEPRIGUŠENIH OSCILACIJA KOD NOM. OPT. GENERATORA ZANEMARUJUĆI PRIGUŠNI MOMENT.

RJEŠENJE:

12 MVA
6300V
50 Hz
$\cos\varphi = 0.7$
$n = 214 \frac{o}{min}$
$X_d = 126\%$
$X_q = 60\%$
$P_{TR.V.} = 140$ kW
$T_1 = 22 s$

$f_{VLASTITO} = ?$

KAD SU S. OPTEREĆENI I KAD SE DESI SKOKOVITA POBUDA MOMENTA, ON TITRA S NEKOM VLASTITOM FREKVENCIJOM.

$$f_v = \frac{1}{2\pi}\sqrt{\frac{P \cdot k_{SM}}{J}}$$

k_{SM} - FAKTOR SINKRONE ZATEZNOG MOMENTA

KOEFICIJENT KOJI

$$k_{SM} = \frac{dM}{d\delta} = \frac{S_n \cdot P}{\omega}\left[\frac{E_0 \cdot U}{X_d}\cos\delta + U^2\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\cdot\cos 2\delta\right]$$

SNAGA U P.J.

ω

$\Downarrow$

MOMENT S_n

$\Downarrow$

DA BI DOBILI SI JEDINICE

k_{SM} JE ZA SVAKU RADNU TOČKU RAZLIČIT - MORAMO SE S OPTEREĆENJEM,

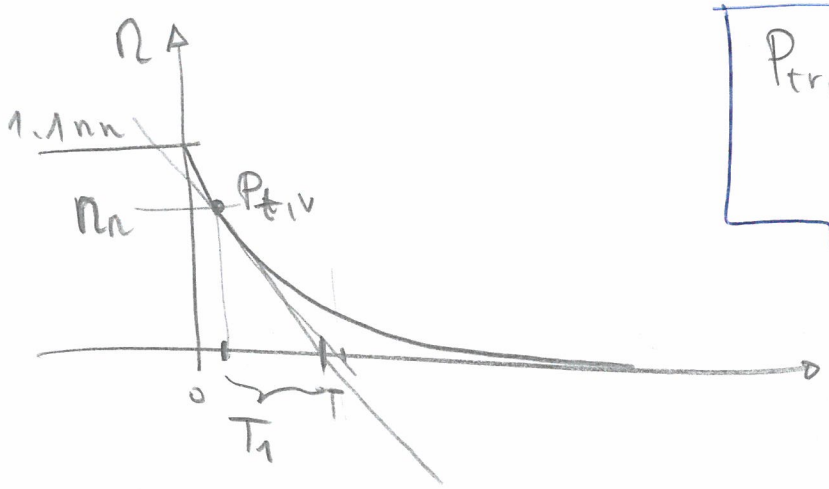
E_0 i δ_n - PREKO VEKTORSKOG DIJAGRAMA

$E_0 = 2.07$ PJ
$\delta_n = 19.6°$

$$P = \frac{60 \cdot f}{n} = \frac{60 \cdot 50}{214} = 14$$

$$k_{SM} = \frac{30}{\pi \cdot n} \cdot S_n\left[\frac{E_0 U}{X_d}\cos\delta + U^2\left(\frac{1}{X_d} - \frac{1}{X_q}\right)\cos 2\delta\right]$$

$$= 1.23 \cdot 10^6 \ \frac{Nm}{rad}$$



$$P_{tr.v} = M_{tr.v} \cdot \omega_s$$

$$= J \frac{d\omega}{dt} \cdot \omega_s = J \frac{d\Omega}{dt} \cdot n_s \left(\frac{\pi}{30}\right)^2$$

$$= J \cdot \frac{n_s}{T_1} \cdot n_s \left(\frac{\pi}{30}\right)^2$$

$$+ \quad P_{tr.v} = J \frac{n_s^2}{T_1} \left(\frac{\pi}{30}\right)^2$$

$$J = \frac{P_{Tr.v}}{\frac{n_n^2}{T_1} \cdot \frac{\pi}{30^2}} = 62444 \ kgm^2 = 67.4 \ tm^2$$

$$f_v = \frac{1}{2\pi} \sqrt{\frac{P \cdot k_{sm}}{J}} = \frac{1}{2\pi} \sqrt{\frac{14 \cdot 1.23 \cdot 10^6}{62444}} = 2.64 \ Hz$$

DIS - AUDITORNE

25.03.2014

1. S.G. 10 POLNI IMA VLASTITU FREQ. NJIHANJA. $f_{v1} = 1.1\ Hz$, GENERATOR JE POGONJEN H. TAKTNIM MOTOROM, A RADI NA VRUTOJ MREŽI FREQ. 50 Hz. KOLIKI JE FAKTOR POJAČANJA NJIHANJA ILI MODUL REZONANCIJE ?

$2p = 10$

$f_{v1} = 1.1\ Hz$

$\xi = ?$

$$n_s = \frac{60 f}{p}\ [min^{-1}] \Rightarrow n_s[okr/sec] = \frac{f}{p}$$

$$n = \frac{f}{p} = \frac{50}{5} = 10\ \frac{okr}{s}$$

- NA (2) OKRETAJA DIZELSKOG MOTORA 1 IMPULS MOMENTA (DIZELSKOG MOTORA) (4 CILINDRA 4 PUTA UDAR, MOMENT)

$$f_{pr} = \frac{10\ \frac{okr}{s}}{2} = 5\ Hz$$

- PR. IMATO DIZELSKI MOTOR SPOJEN NA GENERATOR, PROVJERAVAMO ŠTO SE DOGODI KAD DIZELSKI IDE U KVAR

$$\xi = \frac{1}{1-\left(\frac{f_{v1}}{f_{ps}}\right)^2} = \frac{1}{1-\left(\frac{1.1}{5}\right)^2} = 1.05$$

$$\frac{f_{v1}}{f_{ps}} = \frac{1.1}{5} = 0.22 \Rightarrow 0.8 \leq \frac{f_{v1}}{f_{ps}} \leq 1.25$$

- NIJE DOBRO DIMENZIONIRAN

2) ODREDITI INDUKTIVITETE POTREBNE ZA DINAMIČKI MODEL S. MOTORA U P.U. SUSTAVU. PODATCI: $X_d = 150\%$ $X_q = 90\%$, $X_\sigma = 12\%$, $X_d'' = 21\%$, $X_d' = 32\%$, $X_2 = 25\%$ (INVERZNA REAKTANCIJA).

RJEŠENJE:

$$u_d = R_s i_d + \frac{d\psi_d}{dt} - \omega \psi_q$$
$$u_q = R_s i_q + \frac{d\psi_q}{dt} - \omega \psi_d$$
$$u_f = R_f i_f + \frac{d\psi_f}{dt}$$
$$u_D = 0 = R_D i_D + \frac{d\psi_D}{dt}$$
$$u_Q = 0 = R_Q i_Q + \frac{d\psi_Q}{dt}$$

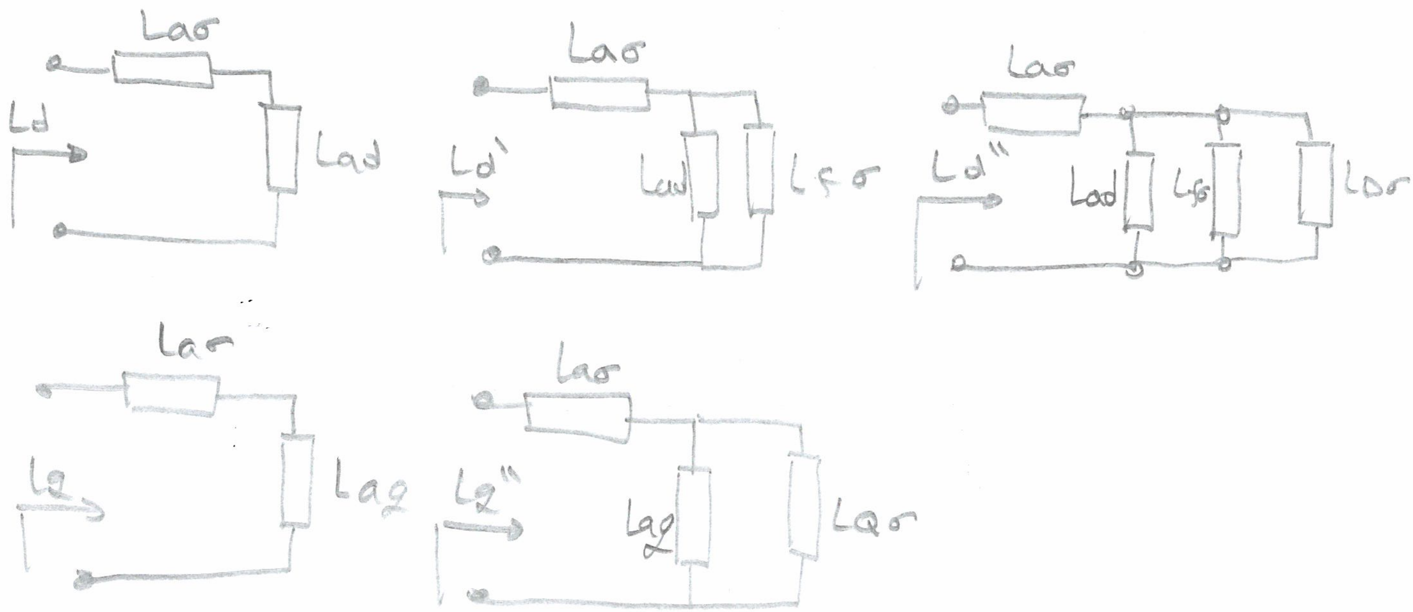
} DINAMIČKI SUSTAV

IZ OVOG. ODREDIMO PARAMETRE

$$\psi_d = i_d \cdot L_d + i_f \cdot L_{ad} + i_D \cdot L_{ad}$$
$$\psi_q = i_q L_q + i_Q L_{aq}$$
$$\psi_f = i_f \cdot L_f + i_d L_{ad} + i_D L_{ad}$$
$$\psi_D = i_D L_D + i_d L_{ad} + i_f \cdot L_{ad}$$
$$\psi_Q = i_Q \cdot L_Q + i_q \cdot L_{aq}$$

UMJESTO DA RJEŠAVAMO I MODULIRAMO STROJ S FAZAMA a, b, c, MI NAPRAVIMO PARKOVU TRANSFORMACIJU, ONA PRETVARA SVE VELIČINE a, b, c, SUSTAVA TE ARMATURNI NAMOT PRELAZI U EKVIVALENTNI d_q SUSTAV KOJI SE VRTI SINHRONOM BRZINOM. R_s, R_f - MJERIMO, ALI R_D i R_Q NEMOŽEMO.

SUPTRANZIJENTNE REAKTANCIJE



$$L_q' = L_q$$

$L_d = L_{a\sigma} + L_{ad}$

$L_q = L_{a\sigma} + L_{aq}$

$L_f = L_{f\sigma} + L_{ad}$

$L_D = L_{D\sigma} + L_{ad}$

$L_Q = L_{Q\sigma} + L_{aq}$

$L_d = 150\%$ $\qquad L_{a\sigma} = L_\sigma = 12\%$

$L_q = 90\%$

$L_{ad} = L_d - L_{a\sigma} = 150\% - 12\% = 138\%$

$L_{aq} = L_q - L_{a\sigma} = 90\% - 12\% = 78\%$

$$L_d' = L_\sigma + \frac{1}{\frac{1}{L_{ad}} + \frac{1}{L_{f\sigma}}} \Rightarrow L_{f\sigma} = \left(\frac{1}{L_d' - L_\sigma} - \frac{1}{L_{ad}}\right)^{-1}$$

$$L_{f\sigma} = \left(\frac{1}{0.32 - 0.12} - \frac{1}{1.38}\right)^{-1} = 0.2339 = 23.39\%$$

$$L_f = L_{ad} + L_{f\sigma} = 1.38 + 0.2339 = 1.6139 = 161.39\%$$

$$L = \frac{\Psi}{I}$$

· ZA ONAJ NAMOT ZA KOJI SE PIŠE ULANČANI
IMAO UVJET ZBOG UMNOŠKA STRUJE I MEĐUINDUKTIVITETA

$$L_d'' = L_\sigma + \frac{1}{\frac{1}{L_{ad}} + \frac{1}{L_{f\sigma}} + \frac{1}{L_{D\sigma}}} \Rightarrow L_{D\sigma} = \left(\frac{1}{L_d'' - L_\sigma} - \frac{1}{L_{ad}} - \frac{1}{L_{f\sigma}}\right)^{-1}$$

$L_{D\sigma} = 0.163 = 16.36\%$

$L_D = L_{ad} + L_{D\sigma} = 154.36\%$

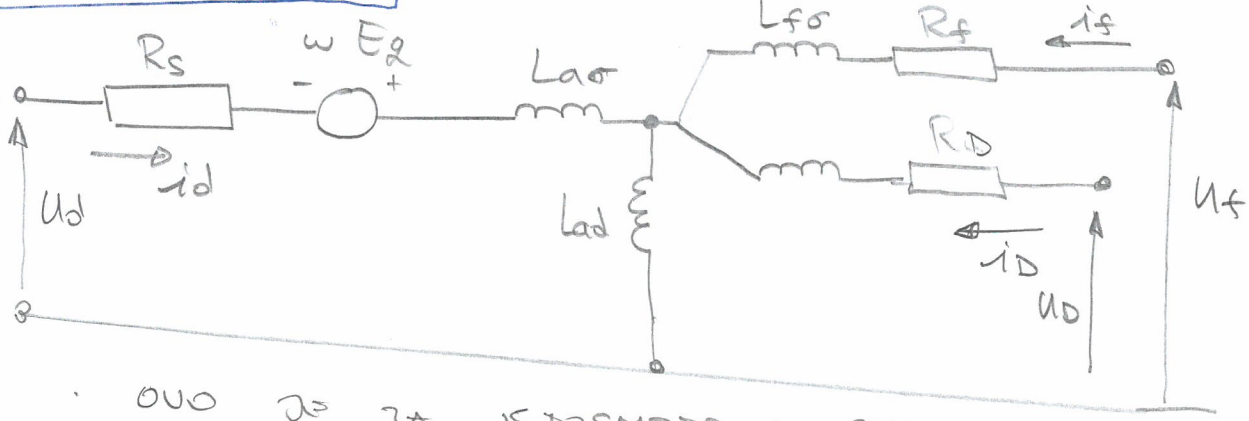
$$X_2 = \frac{X_d'' + X_q''}{2} \Rightarrow X_q'' = 2X_2 - X_d'' = 7.25\% - 21\%$$

$X_q'' = 29\%$.

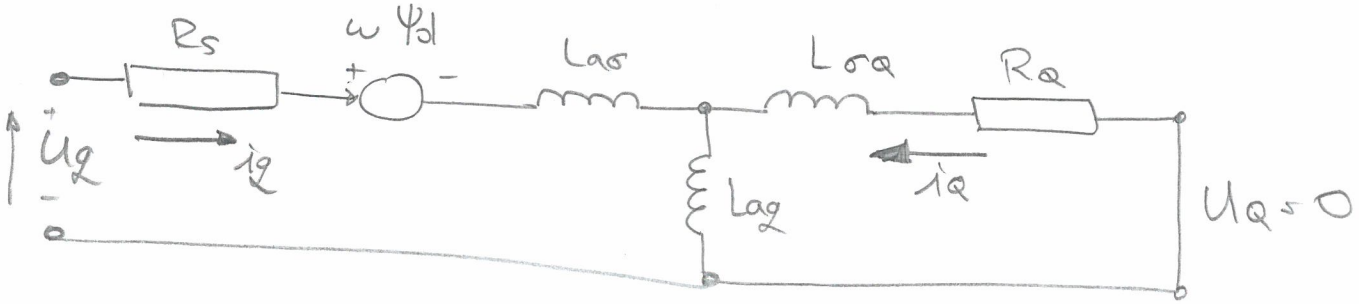
$$L_q'' = L_\sigma + \frac{1}{\frac{1}{L_{aq}} + \frac{1}{L_{Q\sigma}}} \Rightarrow L_{Q\sigma} = \left(\frac{1}{L_q'' - L_\sigma} - \frac{1}{L_{aq}}\right)^{-1} = 0.2174.$$

$L_{Q\sigma} = 21.74\%$

$L_Q = L_{a\sigma} + L_{aq} = 0.2174 + 0.78 = 0.9974 = 99.74\%$



· OVO JE U ISTOSMJERNU STRUJU d-OSI



DIS - Auditorne   Zalet asinhronih strojeva   1.4.2014

1) Ventilator se zalijeće preko AS motora, podaci motora su $75 kW$, $1460 rpm$, $50 Hz$ koji se napaja iz pretvarača (FC). Pretvarač je parametriran tako da do nazivne brzine pretvarač na osovini daje nazivni moment, a iznad nazivne je u području slabljenja polja $\frac{1}{\omega}$. M. kar. ventilatora se može opisati $M(\omega)=k\omega^2$, $k=25.91 \cdot 10^{-3}\ Nms^2/rad^2$. Ukupni m. inerc. iznosi $12.3\ kgm^2$ i potrebno je:

a) izračunat brzinu u s.s.; b) skicirat mom. karakteristike motora i ventilatora na istom grafu i naznačit S.R.T.

c) naći analitički izraz za zalet ventilatora

d) koliko je vrijeme potrebno da se vent. zaleti na $0.95\,\omega_n$

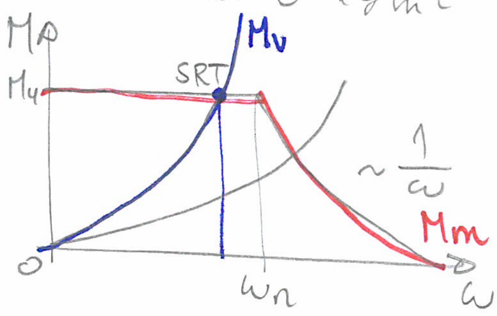
Rješenje:

·Ventilator $M(\omega)=k\cdot\omega^2$, $k=25.91 \cdot 10^{-3}\ Nms^2/rad^2$

AM: $75 kW$, $1460 rpm$; $50 Hz$

·napaja se iz FC

$J_{uk}=12.3\ kgm^2$



b) skicirat ↑

a) $\omega_{st}=?$

$$M_n=\frac{P_n}{\omega_n}=\frac{75\cdot 10^3}{1460\cdot\frac{\pi}{30}}=490.55\ Nm$$

$$M(\omega)=M_n=k\cdot\omega_{st}^2$$

$$\omega_{st}=\sqrt{\frac{M_n}{k}}=137.6\ \frac{rad}{s}$$

$$\omega_{st}=1314\ min^{-1}$$

→ ako ispadne manje od ω_n onda smo na M_n-u

→ u protivnom smo na $\sim\frac{1}{\omega}$

c) $J\frac{d\omega}{dt} = M_m - M_v$, $\omega(0) = 0$, $\omega(t) = ?$

$$J\frac{d\omega}{dt} = M_n - k\cdot\omega^2$$

$$J\frac{d\omega}{M_n - k\omega^2} = dt \quad / \int$$

$$J\frac{\operatorname{arctgh}\left(\sqrt{\frac{k}{M_n}}\cdot\omega\right)}{\sqrt{\frac{k}{M_n}}} = t + \overset{0}{C} \Rightarrow \boxed{\omega(t) = \sqrt{\frac{M_n}{k}}\cdot \operatorname{tgh}\left(\frac{\sqrt{k\cdot M_n}}{J}\cdot t\right)}$$

d) t_z od 0 do $0.95\,\omega_{st\to STACIONARNO}$

$$t = J\cdot\frac{\operatorname{arctgh}\left(\sqrt{\frac{k}{M_n}}\,0.95\,\omega_{st}\right)}{\sqrt{\frac{k}{M_n}}} = 6.32\ s$$

SIMPOWER SYSTEM TOOLBOX

↳ SIMULIRANJE DINAMIČKIH MODELA MOTORA

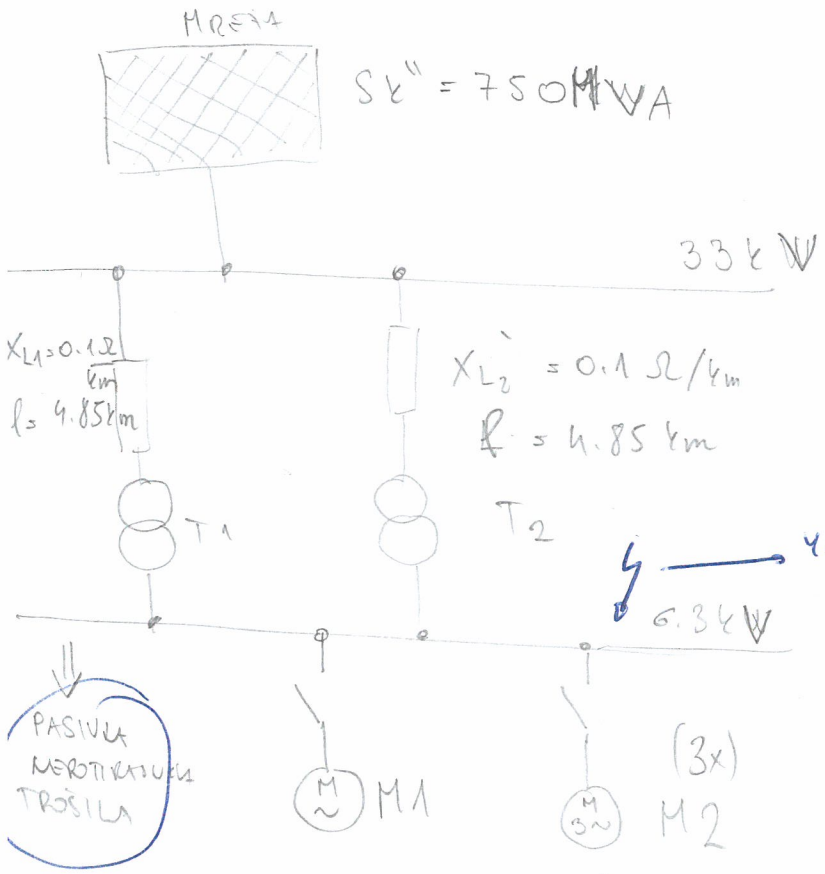
DIS - AUDITORNE

08.04.2014

1. IZRAČUNATI STRUJU TROPOLNOG K.S. U POČ TRENUTKU, BEZ i SA AS MOTORIMA.

k_3 - OZNAKA ZA 3p K.S., BEZ i SA AM

S_k'', I_b - RASKLOPNA STRUJA



$T_1: S_{t1} = 15$ MVA

$u_{k\%T1,T2} = 15\%$

K.S. ANALIZIRAMO NA SABIRNICI: 6.3 kV

M_1

$P_{AM1} = 5$ MW

6.3 kV

$\cos\varphi_n = 0.86$

$\eta = 0.97$

$\frac{I_{LR}}{I_n} = 4$ / $p = 2$

NE UZIMAMO U OBZIR JER NE DOLAZI DO PREKIDA STRUJE K.S.

NADOMJEŠTENO 3 MOTORA

$P_n = 1$ MW

6.3 kV

$\cos\varphi_n = 0.88$

$\eta = 0.94$

$\frac{I_{LR}}{I_N} = 5.5$

$p = 1$

MREŽA: $X_m = \frac{c\,U_n^2}{S_k''} \cdot \frac{1}{t_r^2}$

↳ REAKTANCIJA MREŽE

$c = (1 \div 1.1)$

; KOD NAS JE $c = 1.1$

$$X_m = \frac{c\,U_n^2}{S_k''} = \frac{1}{\left(\frac{U_n}{U_k}\right)^2} = \frac{1.1 \cdot (33\,kV)^2}{750\,MVA} \cdot \frac{1}{\left(\frac{33}{6.3}\right)^2} = 0.0582\,\Omega$$

· U SLUČAJU DA POSTOJI GENERATOR

$$X_g = k_g \cdot X_d''$$

$$k_g = \frac{U_k}{U_{nG}} \cdot \frac{c_{min}}{1 + X_d'' \cdot \sin\varphi_G}$$

· KABELI: $X_{L1} = X_{L2} = 0.1\,\frac{\Omega}{km} \cdot 4.85 \cdot \frac{1}{t_r^2}$

t_r - FAKTOR PRORAČUNATE - STAVIMO NA NAPON K.S.

- TO JE OMJER KVADRATA NAPONA

$$X_{L1} = X_{L2} = 0.1\,\frac{\Omega}{km} \cdot 4.85 \cdot \frac{1}{\left(\frac{33}{6.3}\right)^2} = 0.0177\,\Omega$$

TRAFO: - PROIZVOLJNO ODABRAT PRIMAR I SEKUNDAR ZA t_r

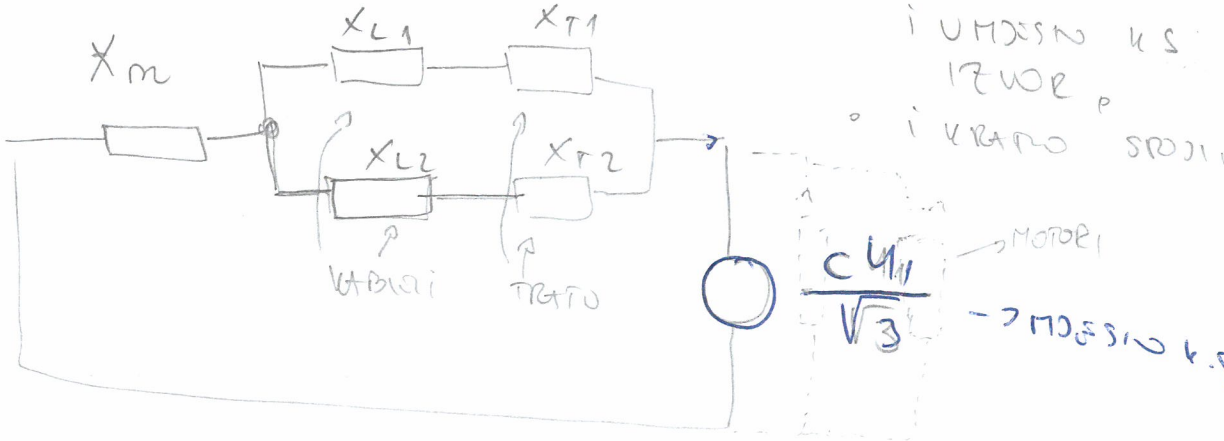
$$X_{T1} = X_{T2} = \frac{U_{k\%}}{100\%} \cdot \frac{U_n^2}{S_n} \cdot \frac{1}{t_r^2} = \frac{15}{100} \cdot \frac{6300^2}{15\,MVA} = 0.3969\,\Omega$$

$$\frac{U_n^2}{t_L^2} = \frac{U_n^2}{\left(\frac{U_k}{U_k}\right)^2} = U_k^2$$

- ZA 3P K.S. BITAN JE SAMO DIREKTNI SUSTAV

ZA k3 → $I_{k3} = \frac{c\,U_n}{\sqrt{3}\,Z_1}$

MNN1 - METODA NADOMJ. NAPON. IZVORA - MAKNEMO IZVOR KOJE NEMA U MJESTU K.S. SMANJIMO IZVOR P I KRATIMO SPOJNI LO



$X''_t = X''_M + (X_{L1} + X_{L2}) \,||\, (X_{L2} + X_{T2}) = 0.2655\,\Omega$

→ OSCILOGRAM STRUJE K.S.

→ 3 REAKTANCE - SUPRANAZIVNA "
- TRANZIJENTNA '
- STACIONARNA

- MI RAČUNAMO POČETNU I_{KS} PA KAD MISLIMO SUPTRANZIJENTNA

- REAKTANCIJE SE MJERENJU KAKO SE MJERI STRUJA K.S.

$$I''_{k3} = \frac{c\,U_n^2}{\sqrt{3}\,X''_t} = \frac{1.1 \cdot 6.3\,kV}{\sqrt{3} \cdot 0.2655\,\Omega} = 15.07\,kA$$

$$X_{MOT} = \frac{1}{n} \cdot \frac{1}{\frac{I_{LR}}{I_n}} \cdot \frac{U_n^2}{S_n} \cdot \frac{1}{t_r^2}$$

n - BROJ PARALELNO SPOJENIH MOTORA

S_n - EL. SNAGA - PRIVIDNA

$$S_n = \frac{P_n}{\cos\varphi \cdot \eta}$$

$S_{n1} = \frac{5\,MW}{0.86 \cdot 0.97} = 6\,MVA$ $S_{n2} = 1.2\,MVA$

$$X_{M1} = \frac{1}{1} \cdot \frac{1}{4} \cdot \frac{(6.3\,kV)^2}{6\,MVA} = 1.6537\,\Omega$$

tr je u ovom slučaju 1

$$X_{M2} = \frac{1}{3} \cdot \frac{1}{5.5} \cdot \frac{(6.3\,kV)^2}{1.2\,MVA} = 2.0045\,\Omega$$

• jer su motori spojeni na mrežni k.s.

$$I''_{kM1} = \frac{c\,U_n}{\sqrt{3}\,X_{M1}} = 2.419\,kA \qquad I''_{kM2} = 1.996\,kA$$

$$I''_{k4} = I_{k3} + I''_{kM1} + I''_{kM2} = 19.485\,kA$$

• SNAGA K.S.

$$S''_k = \sqrt{3} \cdot U_n \cdot I''_k = \sqrt{3} \cdot 6300 \cdot 19.485 \cdot 10^3 = 212.618\,MVA$$

• ŠTO JE VEĆA SNAGA K.S., TO ZNAČI DA JE MREŽA TVRĐA, MANJI PROPADI NAPONA MOTORA I STABILNIJI.

• RASKLOPNA STRUJA – ODABIRU SE SKLOPKE PREMA TOME.
– OVISI O VREMENU ZATEZANJA, ODNOSNO KOLIKO DUGO STRUJA MOŽE BITI TAKO
* DA SKLOPKA NE OPALI

$$I_b = \mu \cdot I''_k \cdot q$$

$$q = 0.57 + 0.12 \cdot \ln m$$

$$m = \frac{P_{mech}}{P}$$

$t_{min} = 0.1\,s$ – VR. ZATEZANJA

$$\mu = 0.62 + 0.72 \cdot \exp\left(0.32 \cdot \frac{I''_{kM}}{I_{nM}}\right)$$

$q_1 = 0.68 \qquad q_2 = 0.57$

$\frac{I_{kM1}''}{I_{mn1}} = 4.4$ $\frac{I_{kM2}''}{3 \cdot I_{nM2}} = 6.05$

n

FORMULE ZA Q i M ĆE PISATI NA TESTU

$\mu_1 = 0.62 + 0.72 \cdot \exp(-0.32 \cdot 4.4) = 0.9$

$\mu_2 = 0.62 + 0.72 \cdot \exp(-0.32 \cdot 6.05) = 0.72$

$I_{B1} = 0.8 \cdot 0.68 \cdot 2.419\ kA = 1.315 kA$

$I_{B2} = 0.72 \cdot 0.57 \cdot 1.995 kA = 0.819 kA$

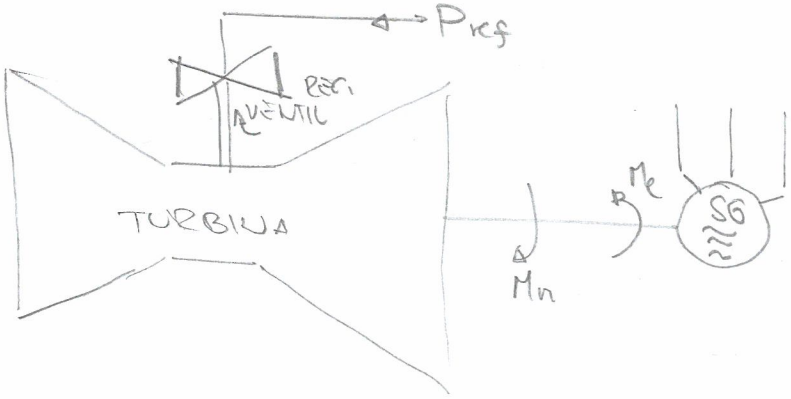
- OČEKIVATI LAKŠI PRIMJER OVOGA U ISPITU
- TREBAT ĆEMO PROMOVIRATI REAKTANCIJE I K.S.

2 - 3 ZADATKA OSMO RAZINA

DIS - AUDITORNE

15.04.2014

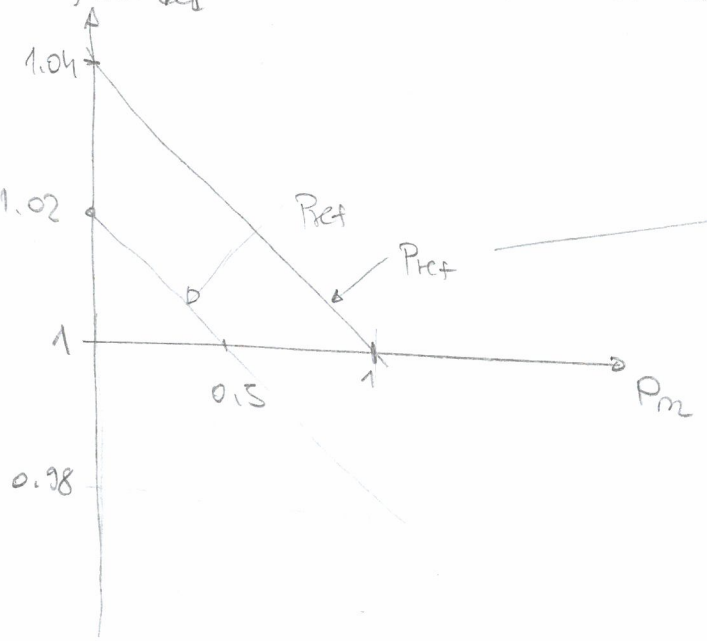
1. PARNA TURBINA I MJERNO VLADANJE



$$\Delta P_m = \Delta P_{ref} - \frac{1}{R}\Delta f$$

REGULACIJSKA KONSTANTA $\left[\frac{Hz}{MW}\right]$

AKO NAM EES ZATRAŽI VIŠE SNAGE, ONDA ĆE SE f SMANJITI



→ ZA 1 PU. SNAGE IMAMO 1. PU. FREKVENCIJE

1. GENERATOR 1 MVA, 50 Hz, NAPAJA INDUSTRIJSKU MREŽU.

AGREGAT IMA REGULACIJSKU KONSTANTU $R = 0{,}05$ pu, U ZA BAZNU SNAGU S_n. AKO SE FREKVENCIJA INDUSTRIJSKE MREŽE POVEĆA ZA 0,1 Hz, KOLIKO SE PROMIJENILA SNAGA TURBINE. SNAGA NA REGULAC. VENTILU OSTALA JE NEPROMIJENJENA. (REFERENCA)

Rj:

$$\Delta f = \frac{0{,}1\,\text{Hz}}{f_{BAZNO}} = \frac{0{,}1\,\text{Hz}}{50\,\text{Hz}} = 2 \cdot 10^{-3}\ \text{p.u.}$$

$$\Delta P_{ref} = 0$$

$$\Delta P_{meh} = \Delta P_{ref}^{\,0} - \frac{R}{\Delta R} = -\frac{1}{0{,}05}\ \text{p.u.} \cdot 2 \cdot 10^{-3}\ \text{pu.}$$

$$= -0{,}04\ \text{p.u.} \rightarrow \text{SMANJI TURBINU}$$

$$\Delta P_{meh} = \Delta P_{meh\,p.u.} \cdot S_B = -0{,}04\ \text{p.u.} \cdot 1 \cdot 10^6\ \text{W} = -40\,\text{kW}$$

SMANJUJE SE SNAGA TURBINE ZA 40 kW.

2. VIŠE AGREGATA – FREKVENCIJA JE KONSTANTNA

n – BROJ AGREGATA

$$\Delta P_{mehuk} = \sum_{i=1}^{n} \Delta P_{mi}$$

$$\Delta P_{ref\,uk} = \sum_{i=1}^{n} \Delta P_{ref\,i}$$

$$\Delta P_{muk} = \sum_{i=1}^{n} \Delta P_{mi} = \sum_{i=1}^{n} \Delta P_{ref} + \left(\sum_{i=1}^{n} \left(\frac{1}{R_i}\right)\right) \cdot \Delta f$$

$$\Delta P_{mehuk} = \Delta P_{ref} - \beta \cdot \Delta f$$

β – REGULACIJSKA ENERGIJA $\left[\frac{MW}{Hz}\right]$

2. U 50 Hz INDUSTRIJSKOJ MREŽI POSTOJE 3 AGREGATA: $G_1 \Rightarrow 2$ MVA, $G_2 \Rightarrow 1$ MVA, $G_3 \Rightarrow 750$ kVA. REG. KOLST. ZA SVAKI GENERATOR IZNOSI $R = 0.1$ p.u. S OBZIROM NA NAZIVNU SNAGU POJEDINOG GENERATORA. U NEKOM TRENUTKU, OPTEREĆENJE U IND. MREŽI PORASTE ZA $\Delta P_{mech} = 500$ kW. ODREDITE:

a) REGULACIJSKU ENERGIJU β ZA $S_B = 1$ MVA

b) PROMJENU FREKVENCIJE Δf

c) PROMJENU SNAGE SVAKOG POJEDINOG AGREGATA ΔP_{mi}

Rj:

a) R - ZADAN ZA VLASTITU BAZNU SNAGU ODGOVARA NAZIVNOJ SNAZI GENERATORA.

$$R_{NOVI} = R_{STARI} \cdot \frac{S_{BNOVI}}{S_{BSTARI}}$$

$$R_1 = 0.1 \text{ p.u.} \cdot \frac{1}{2} = 0.05 \text{ p.u.}$$

$$R_2 = 0.1 \cdot \frac{1}{1} = 0.1 \text{ p.u.}$$

$$R_3 = 0.1 \cdot \frac{1}{0.750} = 0.133 \text{ p.u.}$$

$$\beta = \frac{1}{0.05} + \frac{1}{0.1} + \frac{1}{0.133}$$

$\beta = 37.5$ p.u. // → UVJEK ISPADNE VELIKI BROJ

b) REFERENCE SNAGE SU OSTALE NEPROMIJENJENE - $\Delta P_{ref} = 0$

$$\Delta P_m = -\beta \Delta f$$

$$\Delta f = \frac{\Delta P_m}{\beta} = \frac{\frac{0.5 \text{ MVA}}{1 \text{ MVA}}}{37.5}$$

$\Delta f = -0.013$ p.u.

$f = f_B + \Delta f f_B = 50 - 0.013 \cdot 50 = 49.3$ Hz //

c) RASPODJELA SNAGE PO AGREGATIMA

$$\Delta P_{m1} = -\frac{1}{R_1}\Delta f = 0.2667 \text{ p.u.} = \underline{266.67 \text{ kW}} //$$

$$\Delta P_{m2} = -\frac{1}{R_2}\cdot\Delta f = -\frac{1}{0.1}(-0.013) = 0.1333 \text{ p.u.}$$
$$= 133.3 \text{ kW}$$

$$\Delta P_{m3} = -\frac{1}{R_3}\cdot\Delta f = 0.1 \text{ p.u.} = \underline{100 \text{ kW}} //$$