08/05/2019

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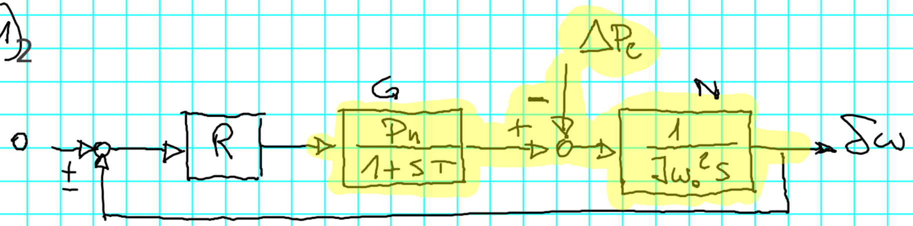
E 1

Islanded generator, $f_0 = 50\,Hz$, $P_n = 20\,MW$
First-order dynamics with a time constant of 8 s

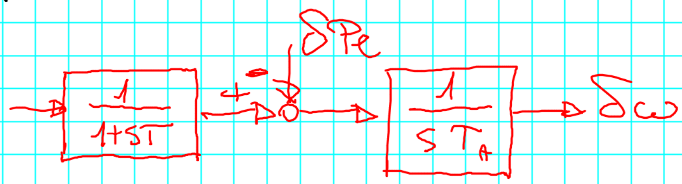
1) Draw the scheme of the generator with PRI + SEC frequency & power control in PI form (K, T_i)
2) Determine network inertia J so that the characteristic time T_A be 10 s
3) Tune a PI for a closed-loop settling time of 1 min
4) Determine steady-state normalised frequency error for a step variation of amplitude 4 MW in the electric power demand in the absence of I action

1)



$R(s) = K\left(1+\frac{1}{sT_i}\right)$ $P_n = 20\pi W$, $T = 8s$, $\omega_0 = 100\pi$

OR



nom. Factor P_n

2 3) $\frac{1}{T_A} = \frac{P_N}{J\omega_0^2}$

1 Watt $\frac{P_N}{J\omega_0^2} = \frac{1}{10} \Rightarrow J = \frac{\underset{\text{MW}}{20} \cdot \underset{\text{s}}{10}}{(100\pi)^2}$

$= 0{,}002 \ \frac{\text{MJ}}{(\text{r/s})^2}$

4)

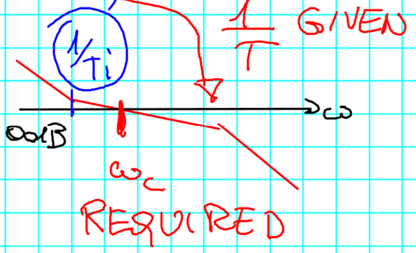
$$L(s) = K \frac{1+sT_i}{sT_i} \frac{P_u}{1+sT} \frac{1}{J\omega_0^2 s}$$

$$= K \frac{1+sT_i}{sT_i} \frac{1}{1+sT} \frac{1}{sT_A} =$$

$$= \frac{K}{s^2 T_i T_A} \frac{1+sT_i}{1+sT}$$

to be found for a "good" φ_m

Bode mag plot must be like



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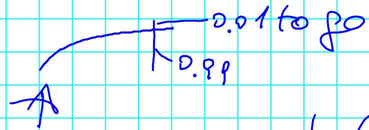
$$L = \frac{\omega_c}{s} \Rightarrow \frac{L}{1+L} = \frac{\omega_c/s}{1+\omega_c/s} = \frac{1}{1+s/\omega_c}$$

unit step response of $\frac{L}{1+L}$ (zero initial state)

$$y(t) = 1 - e^{-\omega_c t}$$



$\lim_{t \to \infty} y = 1$ & $y(t) = 0.99$ for $t = \frac{\log(100)}{\omega_c}$

$$\approx \frac{4.6}{\omega_c} \approx \frac{5}{\omega_c}$$

6 Want settling time 60 s

$\Rightarrow$ dominant closed-loop time constant $\frac{60}{5} = 12\,s$

round it 10 s for convenience

$\Rightarrow$ required cutoff $= \frac{1}{10\,s} = 0{,}1\ r/s$

Pole of generator at $\frac{1}{8} = 0{,}125\ r/s$

From log sheet we got

$$L = \frac{0,025\,(1+s/0,025)}{s^2\,(1+8s)}$$

whence

$$R = \frac{L}{GN} = \frac{0,025\,(1+40s)}{s^{\cancel{2}}\,\cancel{(1+8s)}}\,\cancel{(1+8s)}\,10\,\cancel{s} = \frac{0,25\,(1+40s)}{s}$$

$$\frac{1+sT}{P_N} \quad \frac{J\omega_0^2\,s}{1} \rightarrow (1+sT)\,T_A s$$

8 PI Form:

$$\frac{0{,}25\,(1+40s)}{s} = K\,\frac{1+sT_i}{sT_i}$$

$$T_i = 40$$

$$\frac{K}{T_i} = 0{,}25 \Rightarrow K = 0.25 \cdot 40 = 10$$

4) Set $R = K$ (no I action)

We get

$$L = K \frac{1}{1+sT} \frac{1}{sT_A}$$

$$\frac{\delta\omega(s)}{\delta P_e(s)} = \frac{-1/sT_A}{1+\frac{K}{sT_A(1+sT)}} = \frac{-(1+sT)}{(1+sT)sT_A+K}$$

$\Delta P_e = 4\,MW$

$$\Rightarrow \delta P_e = \frac{4\,MW}{20\,MW} = 0.2$$

P_n

Then by final value theorem

$$\delta\omega(\infty) = \lim_{s \to 0} s \, \frac{0.2}{s} \, \frac{-(1+sT)}{(1+sT)sT_A + K}$$

$$= -0.2/K$$

With the tuned K $\quad \delta\omega(\infty) = 0.02$

$\square$