9. des 2009

Løsningsforslag
BIE 240 Regtek

1) a) orden 2 for vannkoker (varmeelement + vann)

orden 1 for stekertermometer (stålkapsling)

$K_m = 1$ fordi ~~viser~~ stekertermometeret

viser jo temperatur

$$H_m(s) = \frac{T_{målt}(s)}{T_{vann}(s)}$$

Vannet er tydelig varmet opp til 25.5 °C

$\Delta T = 25.5 - 18 = 7.5\,°C$

63% av $7.5\,°C = 4.72\,°C$

~~Leser~~ Leser av tiden ved $18 + 4.72 = 22.7\,°C$

$T = 9$ sek $- 4$ sek $= 5$ sek (sprang gikk ved $t = 4$ sek)

a) $H_m(s) = \dfrac{1}{5s+1}$ ②

b) $\dfrac{dE(t)}{dt} = Q_i(t) - Q_{ut}(t)$

$E(t) = m \cdot c_p \cdot T(t)$ (antar masse m og c_p konst.

$$m \cdot c_p \cdot \frac{dT(t)}{dt} = P(t) - h \cdot A\left(T(t) - T_{omg}(t)\right)$$

$$\frac{dT(t)}{dt} = \frac{1}{mc_p} \cdot \left(P(t) - hA\left(T(t) - T_{omg}(t)\right)\right)$$

Laplace

$$s \cdot T(s) = \frac{1}{mc_p}\left(P(s) - hA\left(T(s) - T_{omg}(s)\right)\right)$$

$$\left(s + \frac{hA}{mc_p}\right) T(s) = {}^1\!/_{mc_p}\, P(s)$$

$= K$

$$H_p(s) = \frac{T(s)}{P(s)} = \frac{{}^1\!/_{mc_p}}{s + \frac{hA}{mc_p}} = \frac{{}^1\!/_{hA}}{\frac{mc_p}{hA} s + 1}$$

$T =$

c) $m = 0.1$

$C_p = 4200$

T_r avlest $: \approx 23°C - 18°C = 5°C$

63% av 5 = 3.15 °C

$18 + 3.15 = 21.15$ °C avleses ved

$\underline{t = 35 \text{ sek}}$ spranget gikk ved $t = 10$

$T_r \approx 35 - 10 = 25$ sek.

$T_r \approx T_m + T$

$$25 \approx 5 + \frac{m \cdot c_p}{hA}$$

$$hA = \frac{m \cdot c_p}{20} = \frac{0.1 \cdot 4200}{20} = 21$$

$$K = \frac{1}{21} = 0.05$$

$T = 20$ sek

$$H_p = \frac{T(s)}{P(s)} = \frac{0.05}{20s + 1}$$

d)

$$H_{sys}(s) = \frac{1}{5s+1} \cdot \frac{0.05}{20s+1}$$

$$|H_{sys}(j\omega)| = \left| \frac{1}{1+j\omega 5} \cdot \frac{0.05}{1+j\omega 20} \right|$$

$$= \frac{0.05}{\sqrt{1+\omega^2 5^2} \cdot \sqrt{1+\omega^2 20^2}}$$

$$\angle H_{sys}(j\omega) = -\operatorname{atan}(\omega 5) - \operatorname{atan}(\omega 20)$$

e) $\omega = 0.01$

$$|H_{sys}(j0.01)| = \frac{0.05}{\sqrt{1+0.01^2 \cdot 5^2} \cdot \sqrt{1+0.01^2 \cdot 20^2}} = \underline{\underline{0.049}}$$

$$\angle H_{sys}(j0.01) = -\text{atan}(0.01 \cdot 5) - \text{atan}(0.01 \cdot 20)$$

$$= -\underline{\underline{14.17^\circ}}$$

$$|H_{sys}(j0.1)| = \frac{0.05}{\sqrt{1+0.1^2 \cdot 5^2} \sqrt{1+0.1^2 \cdot 20^2}} = \underline{\underline{0.02}}$$

$$\angle H_{sys}(j0.1) = -\text{atan}(0.1 \cdot 5) - \text{atan}(0.1 \cdot 20)$$

$$= \underline{\underline{-90^\circ}}$$

$$|H_{sys}(j \cdot 1)| = \frac{0.05}{\sqrt{1+5^2} \sqrt{1+20^2}} = 4.9 \cdot 10^{-4}$$

$$\angle H_{sys}(j \cdot 1) = -\text{atan}(5) - \text{atan}(20)$$

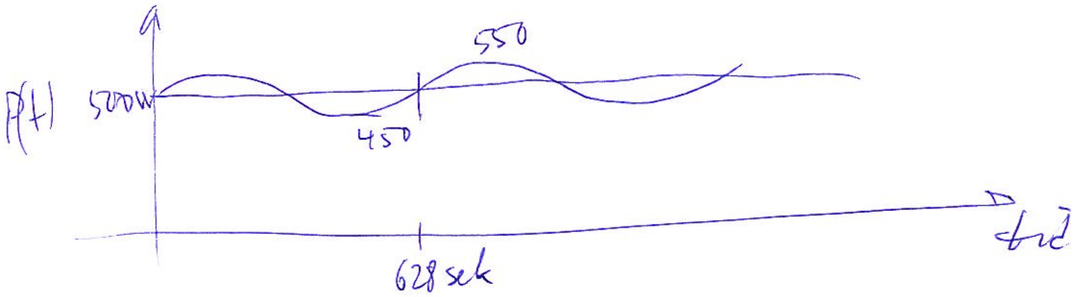
$$= -165^\circ$$

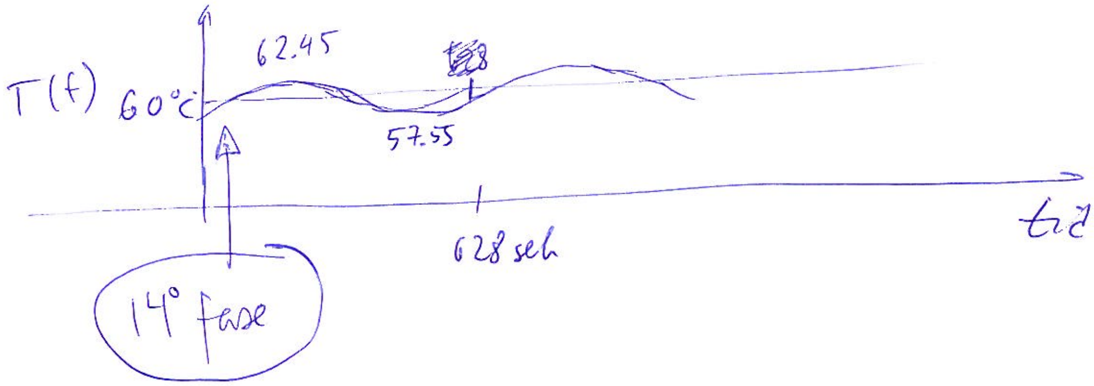
f) $w = 0.01$ rad/sek

$$T_p = \frac{2\pi}{\omega} = \frac{6.28}{0.01} = 628 \text{ sek}$$

Amplitude i temp. sinus:

$50W \cdot 0.049 = \underline{2.45^\circ}$



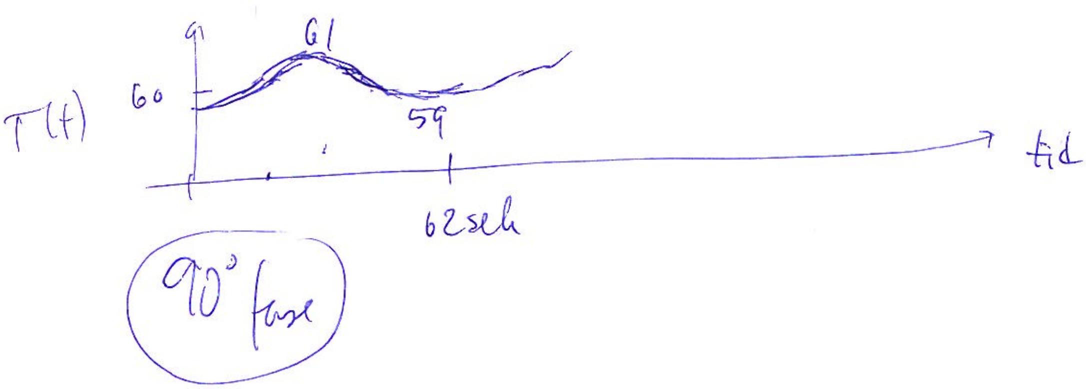


$\omega = 0.1$ rad/sek

$$T_p = \frac{2\pi}{\omega} = 62.8 \text{ sek}$$

Amplitude i temp. sinus

$50\,W \times 0.02 = 1^\circ$

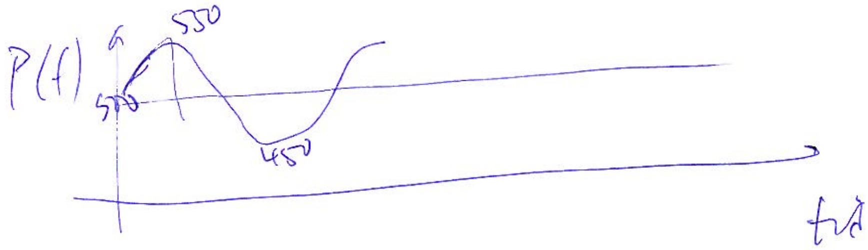


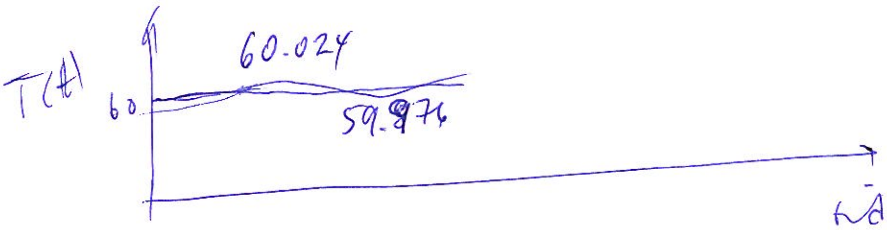
f) $\omega = 1.0$ $T_p = \frac{2\pi}{1} = 6.28$ sek

Amplitude i sinus:

$50\,W \times 4.9 \cdot 10^{-4}$

$= \underline{0.024\,°C}$





2 Regulering

(8)

a) $H_p(s) = \frac{0.2}{15s+1} e^{-2s}$

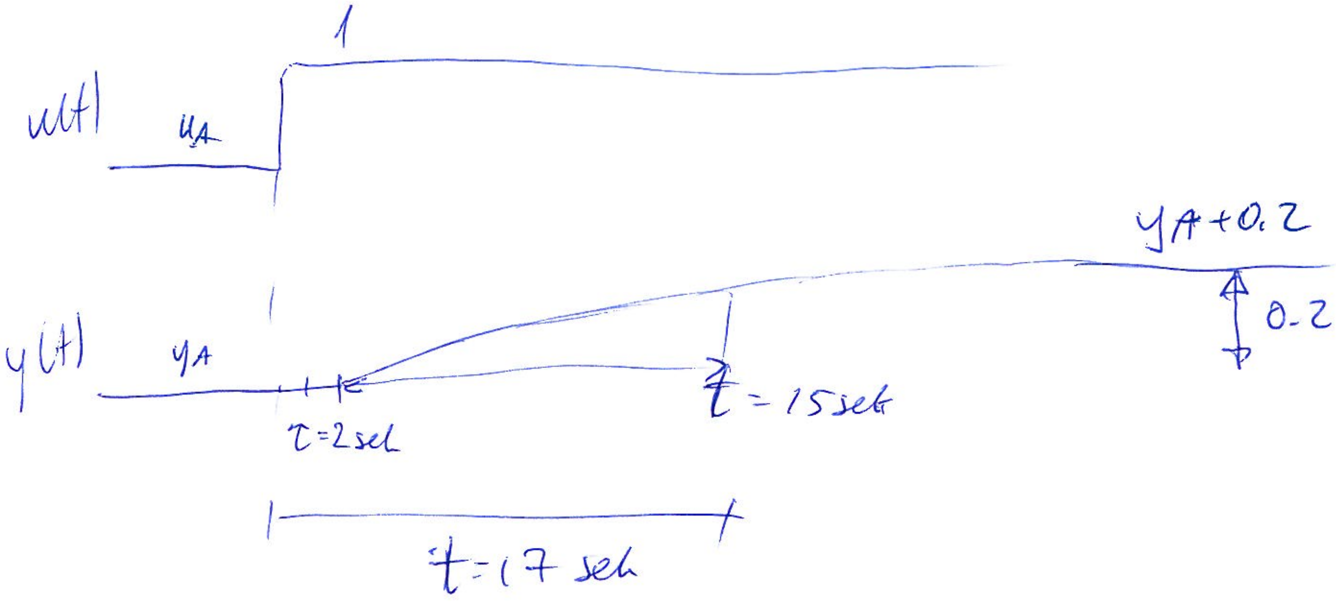
$p = -\frac{1}{T} = -\frac{1}{15}$

asymptotisk stabilt

$\mathcal{L}\left\{u(t) = K_p \cdot e(t) + \frac{K_p}{T_i}\int_0^t e(\tau)\,d\tau\right\}$

$u(s) = K_p\, e(s) + \frac{K_p}{T_i} \cdot e(s) \cdot \frac{1}{s}$

$H_r(s) = \frac{u(s)}{e(s)} = K_p + \frac{K_p}{T_i s} = \frac{K_p T_i s + K_p}{T_i s}$



b) $K_p = \frac{0.9 \cdot V}{L \cdot R} = \frac{0.9 \cdot \upsilon}{\tau \cdot \frac{K \cdot \upsilon}{T}} = \frac{0.9\,T}{\tau K}$ (10)

$T_i = 3.3 \cdot L = 3.3 \cdot \tau$

$$K_p = \frac{0.9 \cdot 15}{2 \cdot 0.2} = 33.75$$

$$T_i = 3.3 \times 2 = 6.6$$

c) $H_p(s) = \frac{0.2}{15s+1}$

1) Polplassering: $\zeta = 0.6 \Rightarrow \delta = 0.1$ 10% oversving

$$\omega_0 \approx \frac{1.5}{T_r} \approx \frac{1.5}{T/2} = 0.2$$

Velger å la reg. systemet ~~bare~~ være dobbel så rask som prosessen

$$K_p = \frac{2 \cdot 0.6 \cdot 0.2 \cdot 15 - 1}{0.2} = 13$$

$$T_i = \frac{2 \cdot 0.6 \cdot 0.2 \cdot 15 \cdot 1}{0.2^2 \cdot 15} = 4.33$$

2) Pol/nullpkt kansellering

$T_M = \frac{T}{2}$ $K_p = \frac{T}{T_m K} = \frac{15}{7.5 \cdot 0.2} = 10$

$$T_i = T = 15$$

d) Når prosessen har dødtid, må reg.para være slakkere. Dette ser vi faktisk er tilfelle i b) og c).

Grunnen til at reg.para må være slakkere er at dødtiden gjør at stabilitetsegenskapene blir dårligere

e) $$H_p(s) = \frac{0.2}{15s+1} e^{-2s}$$

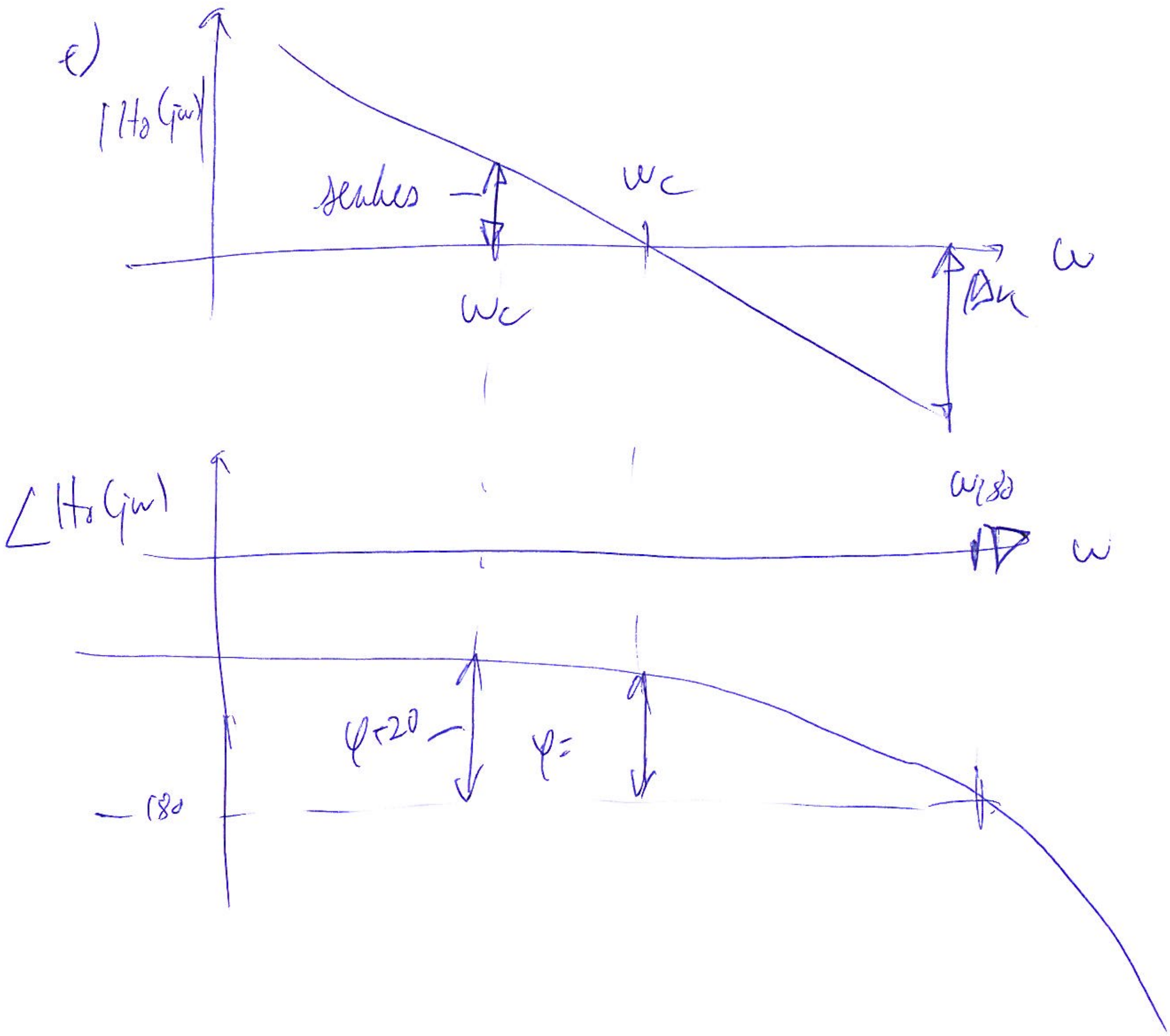
$$H_r(s) = \frac{K_p T_i s + K_p}{T_i s} = \frac{33.75 \times 6.6 \cdot s + 33.75}{6.6 s}$$

$$= \frac{222.75 \cdot s + 33.75}{6.6 \cdot s}$$

$$H_o(s) = H_m(s) H_p(s) \cdot H_r(s)$$

$$= 1 \cdot \frac{0.2}{15s+1} \cdot e^{-2s} \cdot \frac{222.75 s + 33.75}{6.6 s}$$

e)



f) For å øke fasemargin, ser du etter den nye frekvensen ω_c som gir $\varphi + 20$. For å få ω_c til å flytte seg mot venstre, må du senke $|H_0(j\omega)|$ så mye som indikert over. Hvis denne er f.eks 10dB, må du redusere K_p med 10dB, dvs $\frac{K_p}{10dB} = \frac{K_p}{3.16} = K_{p,ny}$

Økt fasemargin $\Rightarrow$ ~~større~~ mindre oversving i sprangresponsen