Løsningsslag 12 des 2007

BIE240 Reguleringsteknikk

1) a)
$$\frac{dm_1(t)}{dt} = w_{inn}(t) - w_{ut}(t)$$
$$= w_{PA001}(t) - w_{LV001}(t)$$

1) b)
$$\boxed{\frac{dm_2(t)}{dt} = w_{inn}(t) - w_{ut}(t) = w_{LV001}(t) - w_{LV002}(t)}$$

1a) har at $m_1(t) = V_1(t) \cdot \rho(t) = A_1 \cdot h_1(t) \cdot \rho(t)$

antar A_1 og ρ konstant

slik at $m_1(t) = A \cdot \rho \cdot h_1(t)$

$$w_{LV001}(t) = \rho \cdot q_{LV001}(t)$$
$$= \rho \cdot Kv_{LV001} \cdot u_{LV001}(t) \cdot \sqrt{\Delta p(t)}$$

hvor $\Delta p(t) = p_{atm} + \rho \cdot g \cdot h_1(t) - p_{atm}$

Dette fordi røret etter LV001 er åpent.

$$w_{LV001}(t) = \rho \cdot K_{v_{LV001}} \cdot u_{LV001}(t) \cdot \sqrt{\rho g h_1(t)}$$

$$w_{PA001}(t) = \rho \cdot q_{PA001}(t)$$

$$= \rho \cdot u_{PA001}(t) \cdot 0.01 .$$

På samme måte som for $w_{LV001}(t)$ finner vi

$$w_{LV002}(t) = \rho \cdot K_{v_{LV002}} \cdot u_{LV002}(t) \cdot \sqrt{\rho g h_2(t)} .$$

Får da:

$$\cancel{\rho} \cdot A_1 \cdot \frac{dh_1(t)}{dt} = \cancel{\rho}\, 0.01 \cdot u_{PA001}(t) - \cancel{\rho}\, K_{v_{LV001}} u_{LV001}(t) \cdot \sqrt{\rho g h_1(t)}$$

$$\frac{dh_1(t)}{dt} = \frac{1}{A_1}\left(0{,}01 \cdot u_{PA001}(t) - K_{v_{LV001}} \cdot u_{LV001}(t) \cdot \sqrt{\rho g h_1(t)}\right)$$

Tank 2:

$$m_2(t) = V_2(t)\cdot\rho = V_2(h_2(t))\cdot\rho$$

da blir

$$\frac{dm_2(t)}{dt} = \frac{\partial V_2}{\partial h_2(t)}\cdot\frac{\partial h_2(t)}{\partial t}\cdot\rho$$

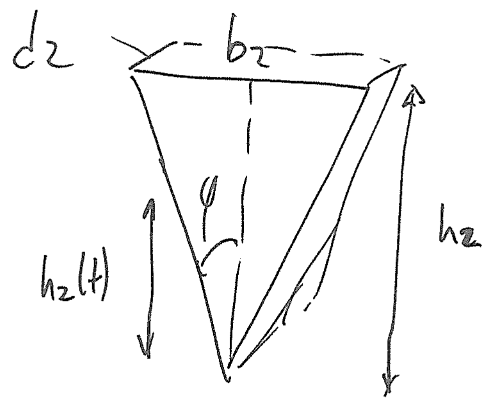
hvor $\frac{dV_2}{dh_2} = A_2(h_2(t))$

Får da:

$$\cancel{\rho}\cdot A_2(h_2(t))\cdot\frac{dh_2(t)}{dt} = \cancel{\rho}\, K_{V_{LV001}}\cdot u_{LV001}(t)\cdot\sqrt{\rho g h_1(t)} - \cancel{\rho}\, K_{V_{LV002}}\cdot u_{LV002}(t)\cdot\sqrt{\rho g h_2(t)}$$

$$\frac{dh_2(t)}{dt} = \frac{1}{A_2(h_2(t))}\cdot\left(K_{V_{LV001}}\cdot u_{LV001}(t)\cdot\sqrt{\rho g h_1(t)} - K_{V_{LV002}}\cdot u_{LV002}(t)\cdot\sqrt{\rho g h_2(t)}\right)$$

c) Dette er en 2.ordens ulineær modell



$$\tan\varphi = \cancel{\frac{d_2/2}{h_2}} \quad \frac{b_2/2}{h_2}$$

Volumet opp til $h_2(t)$ er:

$$V(h_2(t)) = \tan\varphi \cdot 2 \cdot d_2 \cdot h_2(t)$$

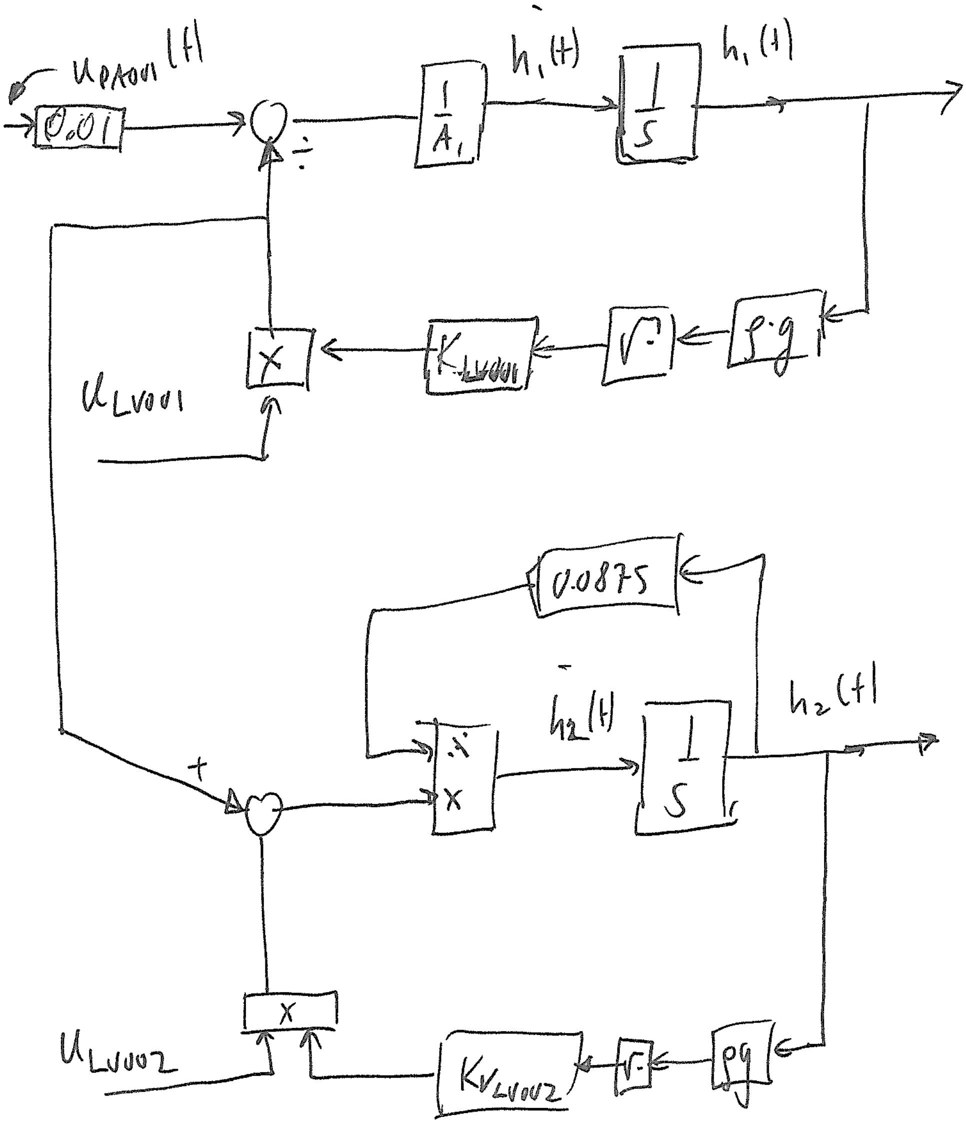
$$= \frac{b_2/2}{h_2} \cdot 2 \cdot d_2 \cdot h_2(t)$$

$$= \frac{b_2 \cdot d_2}{h_2} \cdot h_2(t)$$

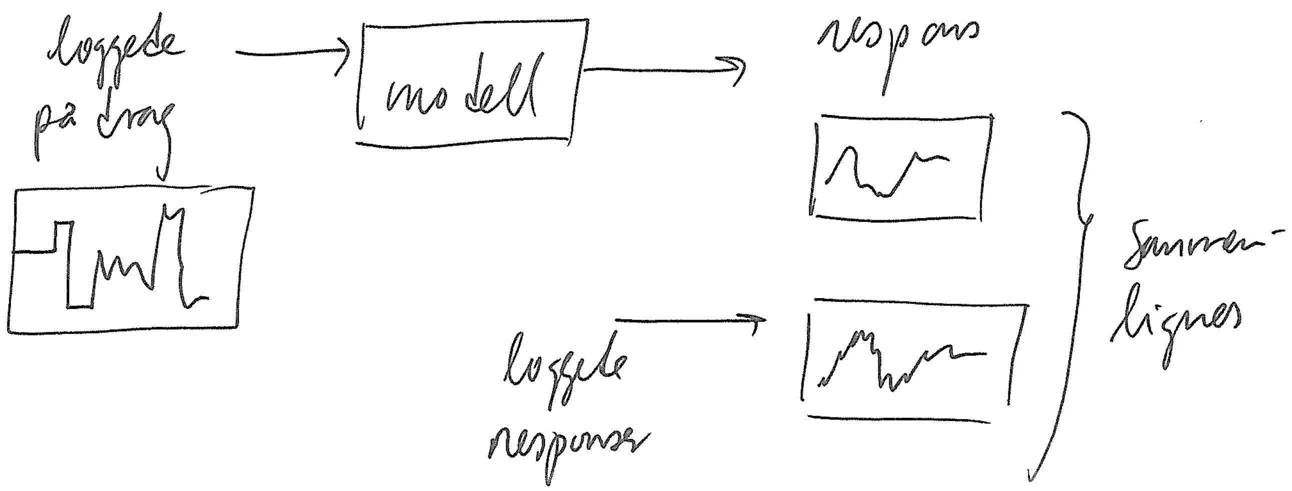
$$= \frac{0.35 \cdot 0.1}{0.4} \cdot h_2(t)$$

$$= 0.0875\, h_2(t)$$

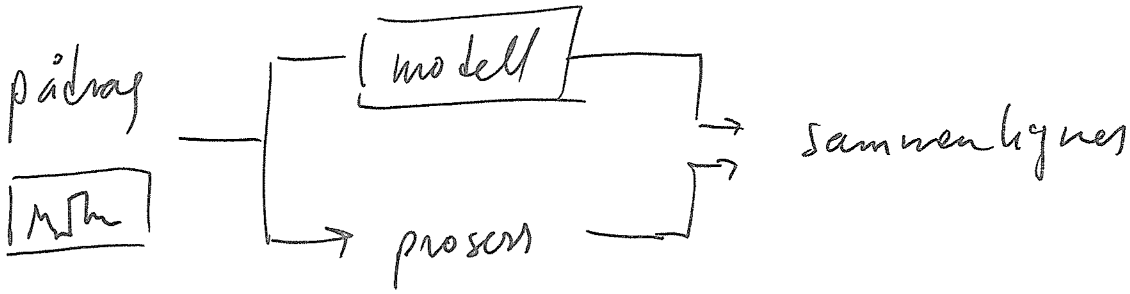
d)


u_PA001 (t)
0.01
1/A_1
ḣ_1 (t)
1/s
h_1 (t)
ρ·g
√·
K_LV001
×
u_LV001
0.0875
÷
×
ḣ_2 (t)
1/s
h_2 (t)
+
×
u_LV002
Kv_LV002
√·
ρg

e) Offline verifisering: Da samles pådragsdata og responsdata i en fil som du kan kjøre på PC-offline. Pådragsdata går inn til modellen, og modellens respons sammenlignes med loggede responsdata.



e) Online verifisering: Da kjøres modellen i parallell med prosessen i samme tid.



Dette tar selvfølgelig lenger tid.

f) Setter ligning 3) og 4) = 0

$$0 = \frac{1}{A_1}\left(\cdots\cdots \right)$$

$$0 = \frac{1}{A_2(h_2(f))}\left(\cdots \right)$$

Dette gir :

$$u_{LV001,A} = \frac{u_{PA001,A} \cdot 0.01}{K_{VLV001} \cdot \sqrt{\rho g\, h_{1,A}}}$$

$$= \frac{0.007}{0.0002\sqrt{10 \cdot 1000 \cdot 0.6}}$$

$$= 0.4518$$

Videre får vi

$$u_{LV002,A} = \frac{K_{VLV001} \cdot u_{LV001,A} \cdot \sqrt{\cancel{\rho g}\, h_{1,A}}}{K_{VLV002} \cdot \sqrt{\cancel{\rho g}\, h_{2,A}}}$$

$$= \frac{0.0002 \cdot 0.4518 \cdot \sqrt{0.6}}{0.0003 \cdot \sqrt{0.25}} = 0.4666$$

9) Har at

$$\frac{dh_1(t)}{dt} = f_1\left(u_{PA001}(t),\ u_{LV001}(t),\ h_1(t)\right)$$

Har da $\left.\frac{\partial f_1}{\partial u_{PA001}}\right|_A = \frac{1}{A_1}$

$$\left.\frac{\partial f_1}{\partial u_{LV001}}\right|_A = \div \frac{K_{v_{LV001}}}{A_1} \cdot \sqrt{\rho g h_{1,A}}$$

$$\left.\frac{\partial f_1}{\partial h_1}\right|_A = \div \frac{K_{v_{LV001}}}{A_1} \cdot u_{LV001,A} \cdot \sqrt{\rho g} \cdot \frac{1}{2\sqrt{h_{1,A}}}$$

som gir:

$$\Delta \dot{h}_1(t) = \left.\frac{\partial f_1}{\partial u_{PA001}}\right|_A \cdot \Delta u_{PA001}(t) + \left.\frac{\partial f_1}{\partial u_{LV001}}\right|_A \Delta u_{LV001}(t)$$

$$+ \left.\frac{\partial f_1}{\partial h_1}\right|_A \cdot \Delta h_1(t)$$

h)

$$\Delta \dot{h}_1(t) = 50\,\Delta u_{PA001}(t) - 0.7746\,\Delta u_{LV001}(t)$$

$$- 0.2916\,\Delta h_1(t)$$

Laplace gir

$$s \cdot \Delta h_1(s) + 0.2916\,\Delta h_1(s) = 50\,\Delta u_{PA001}(s)$$
$$- 0.7746\,\Delta u_{LV001}(s)$$

Setter $\Delta u_{PA001}(s) = 0$, dividerer på 0.2916

$$\Delta h_1(s) = \div \frac{2.656}{3.43s+1} \cdot \Delta u_{LV001}(s)$$

$$H_{p,1}(s) = \frac{\Delta h_1(s)}{\Delta u_{LV001}(s)} = \frac{-2.65}{3.43s+1}$$

i) $\Delta u_{LV002} = 0.01 \cdot 0.4666$

$= 0.004666$

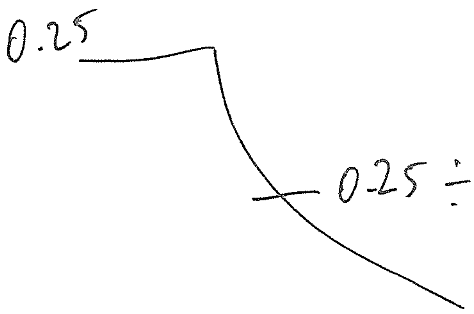
endring i høyden $h_2(t)$ er avlest

$\Delta h_2 = 0.2451 - 0.25 = -0.0049$

$$K = \frac{\Delta h_2}{\Delta u_{LV002}} = \div 1.05$$

<u>Tidskonstanten</u>: 63% av Δh_2 er

$0.63 \cdot 0.0049 = 0.003087$



$0.25 \div 0.003087 = \underline{0.2469}$

Avleser 0.2469 ved tidspunkt ved ca 3.5 sek.

Spranget gikk ved $t = 2$, slik at $\underline{T = 1.5 \text{ sek}}$.

$$H_{p2}(s) = \frac{\div 1.05}{1.5s + 1}$$

2 Regulering

a) Har at

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

Laplace gir

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

rydde:

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

$$H_r(s) = \frac{K_p(T_i s + 1)}{T_i s}$$

$$\boxed{H_m(s) = \frac{1}{0.5s + 1}}$$ for begge

b) Har at $H_{p,1}(s) = \dfrac{-2.65}{3.43s+1}$ (13)

Benytt pol-nullpkt kansellering med

$T_M = \dfrac{3.43}{2} \approx 1.7$. Det er naturlig

å velge halvparten tidskonstant, dobbel båndbredde, på reg. system i forhold til prosess.

Dette gir: $K_p = \dfrac{T}{T_M \cdot K} = \dfrac{3.43}{1.7 \cdot (-2.65)} \doteq 0.76$

$T_i = T = 3.43$

c) $H_0(s) = H_r(s) \cdot H_{p,2}(s) \cdot H_m(s)$

$$= \frac{K_p(T_i s+1)}{T_i s} \cdot \frac{(\div 1.05)}{1.5s+1} \cdot \frac{1}{2s+1}$$

Forsterkningsmarginen $\Delta K = \infty$, men

fasemarginen er ca $\psi = 45°$. ved $\omega = 0.7$.

d) For å få $\psi = 30°$, må vi inn på

$\omega = 1.03$ rad/s

Ved denne frekvensen må $|H_0(j\omega)|$

løftes med ca 6dB.

Det betyr at K_p må dobles,

dvs $\underline{\underline{K_{p,ny} = \div 4}}$