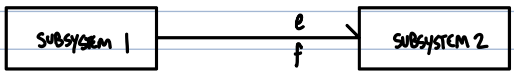
25 TIME DELAYS

THE MASTER/SLAVE ARE GREAT IF THEY'RE IN THE SAME ROOM, ON THE SAME SYSTEM

PASSIVITY THEOREM

POWER FLOW BOND NOTATION



V_1 V_2 ARE ENERGY-LIKE LYAPUNOV CANDIDATES

e = EFFORT
f = FLOW

$$\text{POWER} = e \cdot f$$

$$V = V_1 + V_2$$

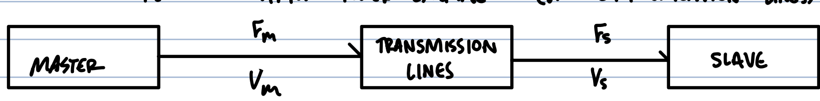
IF $\frac{dV}{dt} \leq 0 \Rightarrow$ STABLE SYSTEM

$$\frac{dV_1}{dt} = \underbrace{-e \cdot f}_{\text{POWER SENT TO 2}} \; \underbrace{-g_1 t}_{\text{POWER DISSIPATED IN 1}} \qquad \frac{dV_2}{dt} = \underbrace{e \cdot f}_{\text{POWER RECEIVED FROM 1}} \; \underbrace{-g_2(t)}_{\text{POWER DISSIPATED IN 2}}$$

$$\frac{dV}{dt} = -\left[g_1(t) + g_2(t)\right]$$

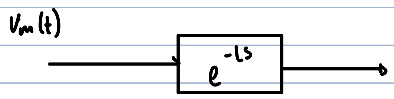
- IF BOTH $g_1(t)$ & $g_2(t)$ ARE NON-NEGATIVE, THEN THE SYSTEM IS STABLE
- WHEN V_i IS POSITIVE AND $g_i(t)$ IS NON-NEGATIVE, THEN THE SUBSYSTEM IS SAID TO BE PASSIVE

I.E "VIRTUAL" POWER EXAMPLE (VIA COMMUNICATION LINES)

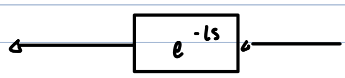


DELAY

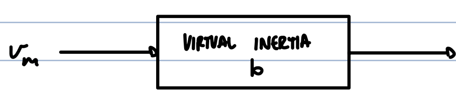
L = TIME DELAY



$V_s(t) = V_m(t-L)$

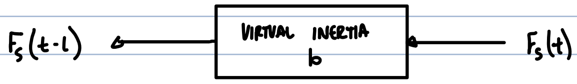


$F_s(t-L) = F_m(t)$ $\qquad$ $F_s(t)$



$V_m(t-L)$

$$V = \int_{t-L}^{t} \frac{1}{2} b \, V_m(\tau)^2 \, d\tau$$



$$V = \int_{t-l}^{t} \frac{1}{2b} F_s(\tau)^2 \, d\tau$$

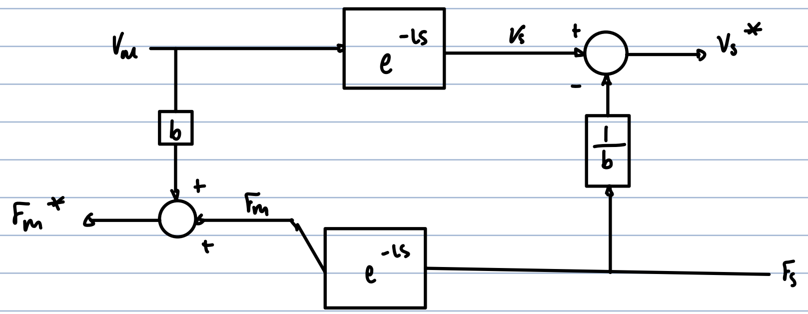
$$\frac{dV}{dt} = \frac{d}{dt}\left[\int_{t-l}^{t} \left(\frac{1}{2} b V_m(\tau)^2 + \frac{1}{2b} F_s(\tau)^2 \right) d\tau \right]$$

$$= \frac{1}{2} b V_m(t)^2 - \frac{1}{2} b V_m(t-l)^2 + \frac{1}{2b} F_s(t)^2 - \frac{1}{2b} F_s(t-l)^2$$

$$= (V_m F_m - V_s F_s) - \underbrace{\left[\frac{1}{b} F_m^2 - \frac{1}{2b}(F_m - bV_m)^2 + bV_s^2 - \frac{1}{2b}(F_s + bV_s)^2 \right]}$$

$g(t)$ IS NOT ALWAYS POSITIVE OR ZERO
(NO PASSIVITY GUARANTEE)

STABILIZATION BY ADDING DAMPING



YOU'D PROBABLY HAVE TO ADD IN MORE DAMPING b,
SO

$$F_m^* = F_m + bV_m$$

$$V_s^* = V_s - \frac{1}{b} F_s$$

$$\frac{dV}{dt} = (V_m F_m^* - V_s^* F_s) - \underbrace{\left(\frac{1}{2b} F_m^{*2} + \frac{b}{2} V_s^{*2} \right)}_{g(t) \geq 0}$$

$\Rightarrow$ OUR TRANSMISSION LINES ARE PASSIVE