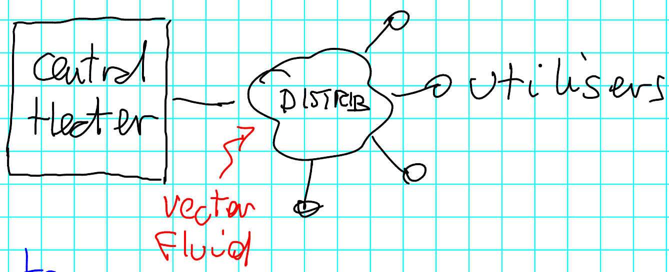
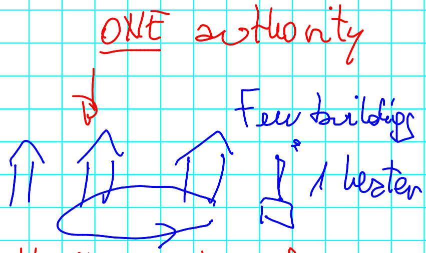
23/05/2019

• CASE STUDY 2 : heat network



contexts:

Compound network

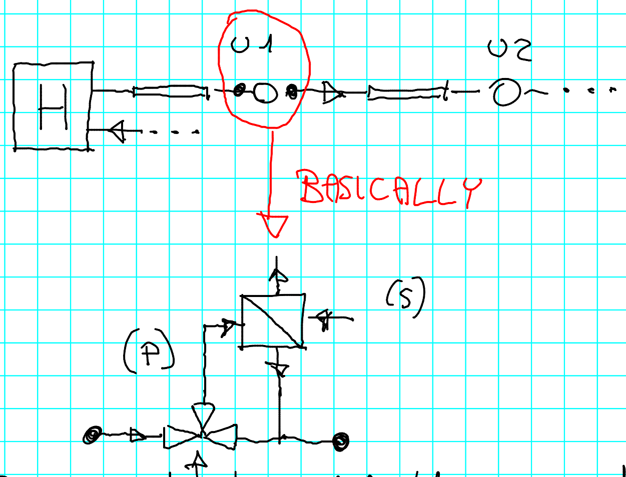


City-level network   many   authorities
properties
installers   brands
...

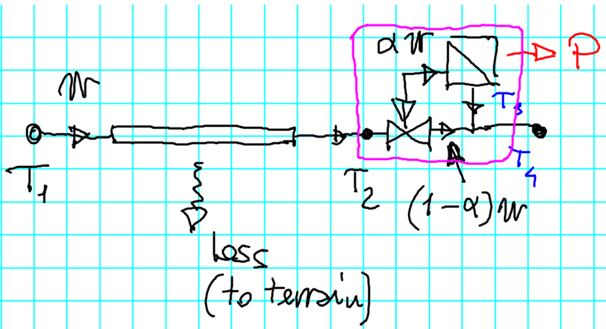
↑ parts do not talk to one another

Topologies :

1) Ring :



You act on this 3-way valve to provide the required power to the HE while maintaining acceptable temperatures



$T_2 < T_1$

$$\alpha w c (T_2 - T_3) = P \Rightarrow T_3 = T_2 - \frac{P}{\alpha w c}$$

but depends on P

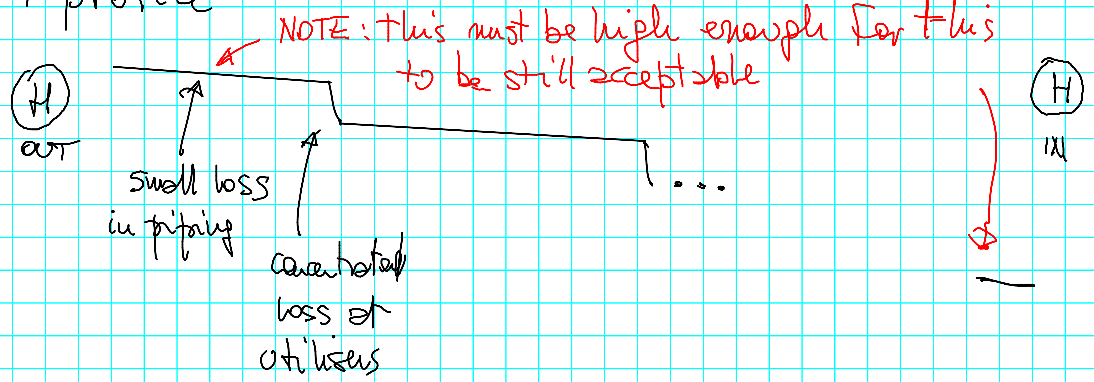
$$T_4 = (1-\alpha) T_2 + \alpha \left(T_2 - \frac{P}{\alpha w c}\right) = \underline{\underline{T_2 - \frac{P}{wc}}}$$

$\boxed{\text{independent of } \alpha}$

NOTE: need also to guarantee a certain T on the S side

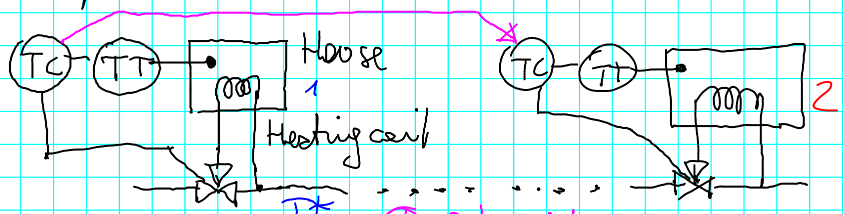
Result:

T profile



If U_n takes more power, that is disturbing U_{n+1} and all the downstream ones

Consequence (example)



(*) Note: delay

this valve opens ⇒ more P taken to room 1 ⇒ T* ↓

this valve has to open as well to keep T in room 2

⇒ we may need FF compensation (*)

Hence (ring)

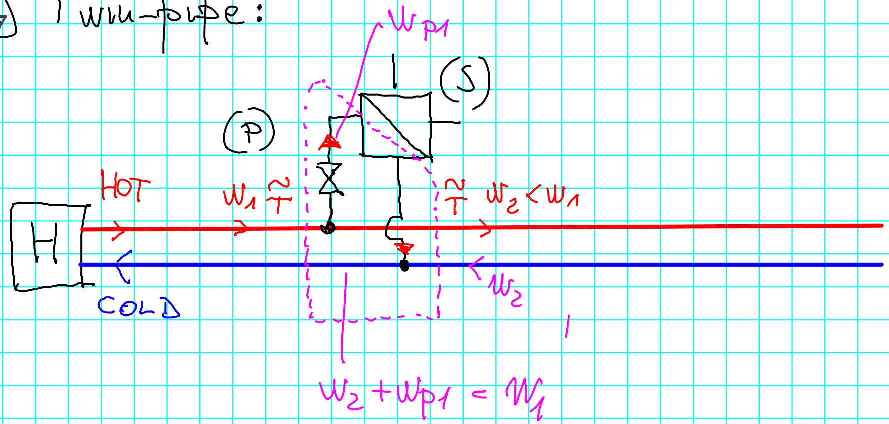
Simplest piping

=) Least surface exposed to terrain loss

BUT may need controllers to communicate with one another

Only used in quite small, single-authority compounds

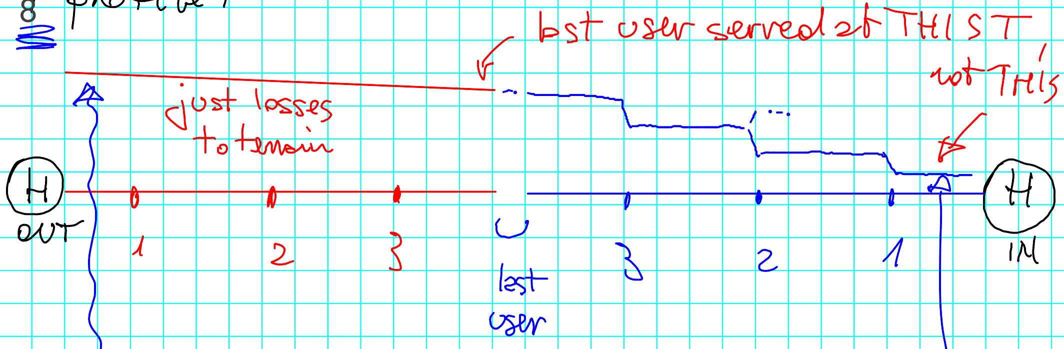
2) Twin-pipe:



main advantage: any utiliser does not disturb those downstream (in the H path)

8

T profile:



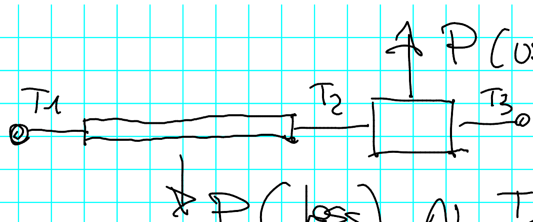
this T can drop to a level that would not be acceptable for any user, provided the heater can cope with restoring this

Trade-offs :

1) larger HE surfaces ⇒ increased cost & flowrate
less ΔT ⇒ smaller heater

2) increased flowrate ⇒ larger pump & pumping power
but need less T ⇒ less H power

3) increased T @ heater outlet ⇒ less $\dot{m}$
but more loss to terrain



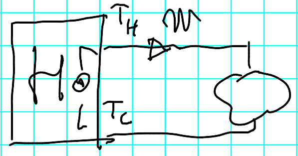
$P(\text{useful}) \sim T_2 - T_3$

$P(\text{loss}) \sim \frac{T_1 + T_2}{2}$

Useful P depends on differences } of T
Lost P depends on absolute values }

$\Rightarrow$ Another point in favour of twin pipe

Powers:



equivalent hydraulic impedance for network

$$P_{heating} = w\left(h_H - h_C\right) = w\left(cT_H + \frac{p_H}{\rho} - cT_C - \frac{p_C}{\rho}\right)$$

SI units

$c \sim 4000$ $\qquad p_H \sim 3 \cdot 10^5$ $\qquad T_H \sim 130°C$

$\rho \sim 1000$ $\qquad p_C \sim 2 \cdot 10^5$ $\qquad T_C \sim 90°C$

(?)

12 $c\,T_H + \left(\frac{p_H}{\rho}\right) - c\,T_c\left(-\frac{p_c}{\rho}\right)$

$\underbrace{4\cdot 10^{3}\cdot 1{,}3\cdot 10^{2}}_{5{,}2\cdot 10^{5}}$ $\quad \frac{3\cdot 10^{5}}{10^{3}}$ $\quad 3\cdot 10^{2}$

Same story here

300m

$P_{heating} \approx 4000\cdot 40 = 1{,}6\cdot 10^{5}\ W$

13

$$P_{pump} \simeq w \underbrace{\Delta h}_{\text{across the pump}} \simeq w \frac{p_H - p_c}{\rho} \simeq \cancel{\rho} q \frac{p_H - p_c}{\cancel{\rho}}$$

But $\frac{\Delta p}{\rho} = K w^2 = K q^2 \rho^2 \Rightarrow \Delta p = K \rho^3 q^2$

K: impedance

q: volume Flowrate

Hence $P_{pump} = q \Delta p = K \rho^3 q^3$

Suming up

$P_{heating} \sim q\,\Delta T$

$P_{pumping} \sim q^3$ $\Rightarrow$ optimum point

(+ losses to tension) $(\Delta T, q)$

Thoot because

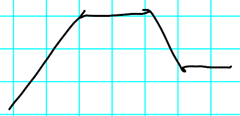
ΔT depends on this

15 Overall, the energy management system architecture is

$$\begin{array}{ccccc} \text{Ambient conditions \& User requirements (FORECAST)} & \Rightarrow & \text{determine optimum } T_{flow} \text{ and Flowrate set points} & \Rightarrow & \text{Flow control loop } \underbrace{T_{flow} \;\; \text{"} \;\; \text{"}}_{\text{PIs}} \end{array}$$

$\Uparrow$ by optimisation OR by what-if simulation ⊗

(*) 16 Very often one has to compute the energy consumption on a certain time span (e.g. day) based on time-varying inputs



— expected P taken by users . . .

The cost function is often the result not of a computation but rather of a simulation.

Average practice

Take a simulation model

optimise for various ambient conditions: T_{amb}, ($P_{ST,ten}$)

$T_{ambient}$ (Forecast of $P_{ST,ten}$) $\Big\}$ $\xrightarrow[\text{interpolation of simulation results}]{}$ optimal T_{HO} & w set points.

$\square$