Non Linear Control of a Distributed Solar Field

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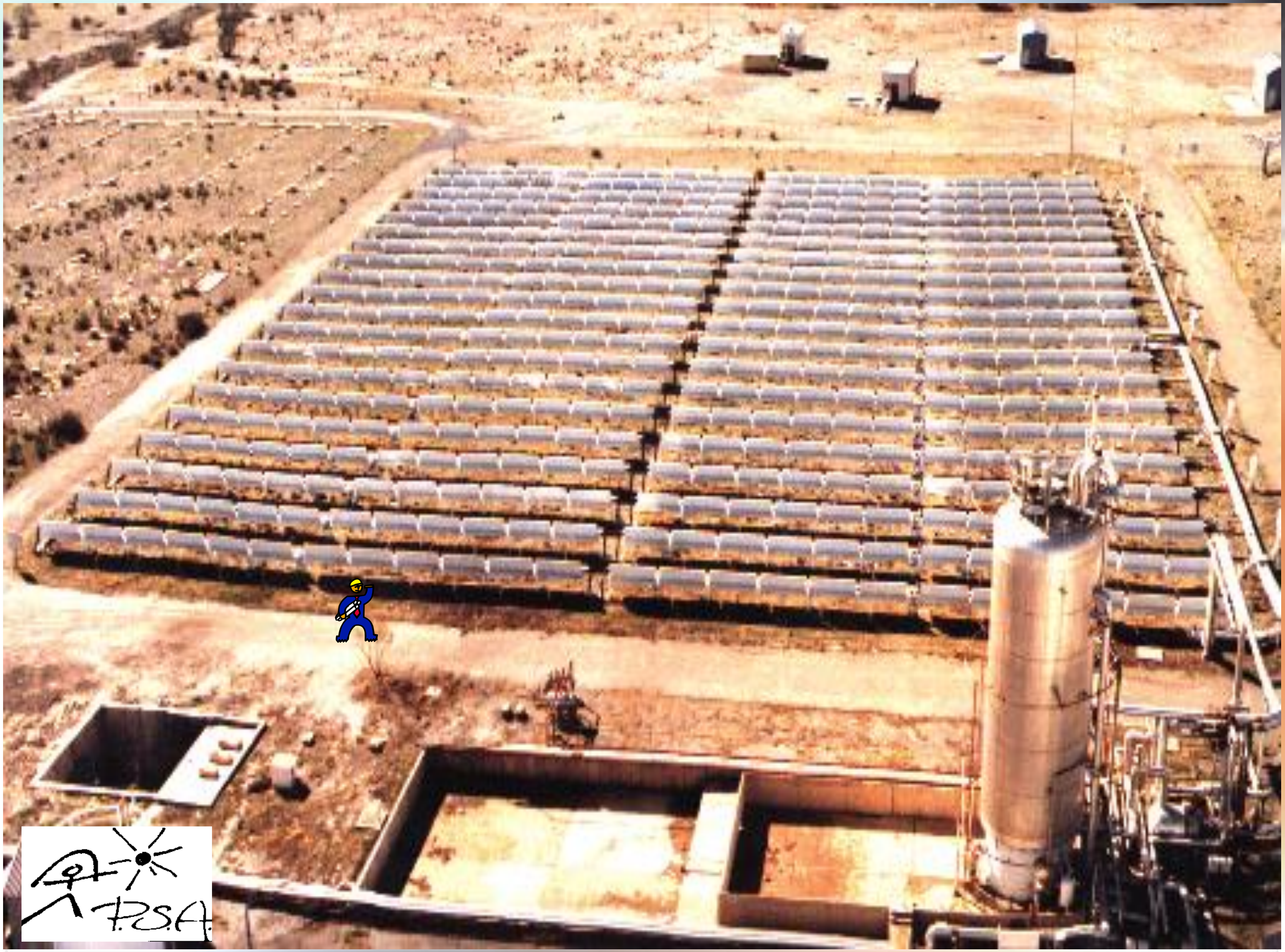
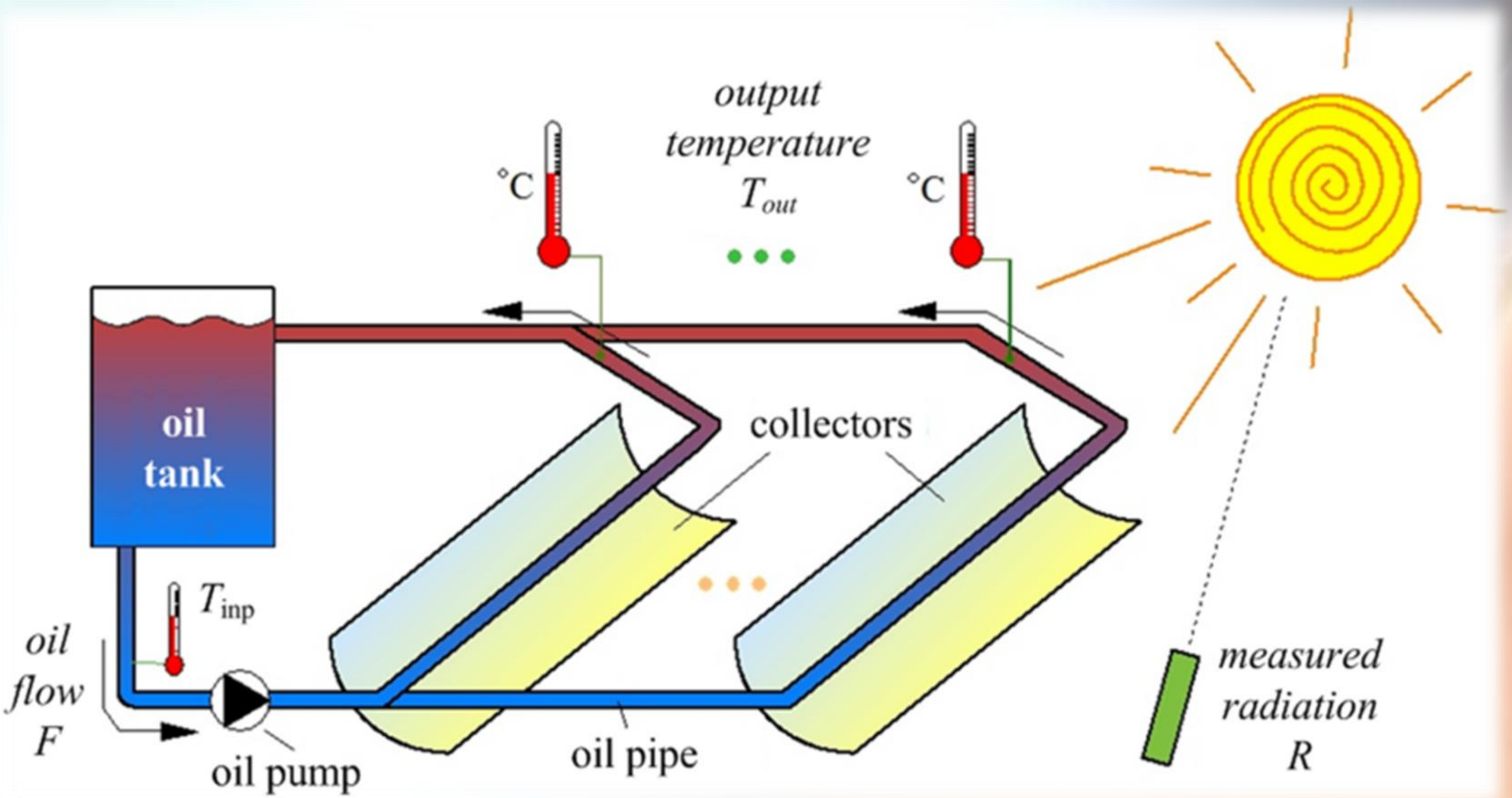
ACUREX Solar Field



Parabolic through collector

Solar plant scheme

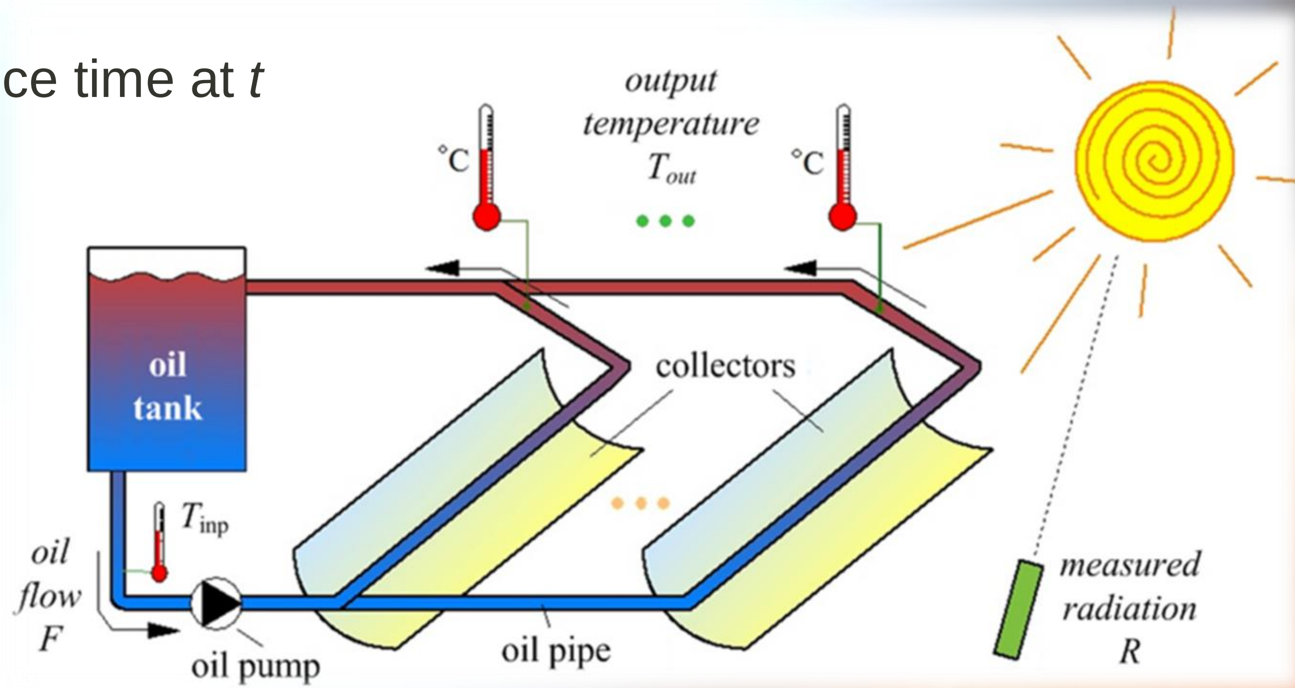


The action on the **pump's flow** changes the residence time of the oil inside the active part of the field, changing the **output temperature**.

The **solar radiation** and **input temperature** are plant **disturbances**.

Plant model (integral version)

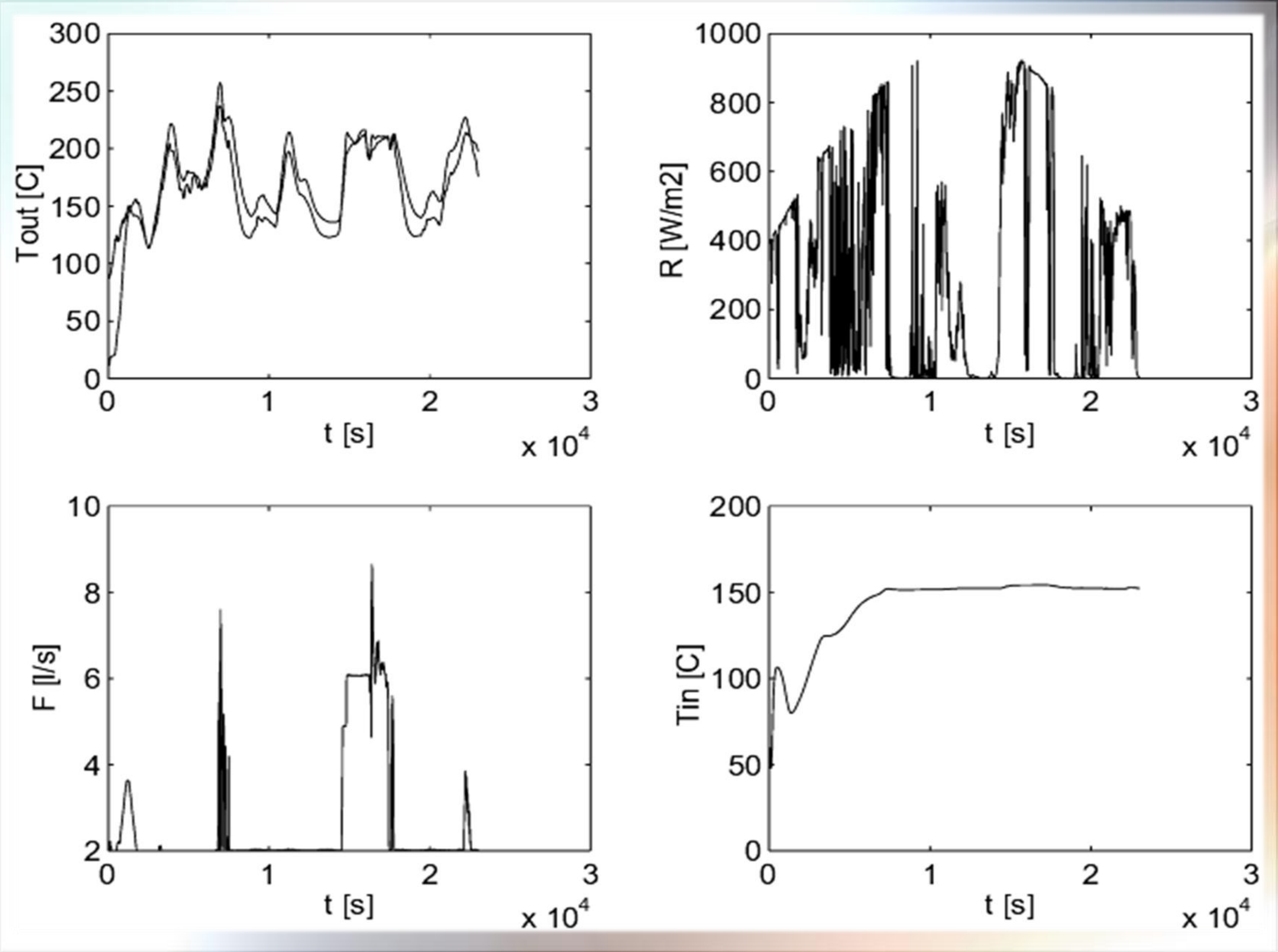
$\tau(t)$ – residence time at t



$$T_{out}(t) = T_{inp}(t - \tau(t)) + \alpha \cdot \int_{t-\tau(t)}^{t} R(\sigma)d\sigma$$

$$\int_{t-\tau(t)}^{t} F(\sigma)d\sigma = V$$ = active pipe's volume

Model validation



Steady-state analysis

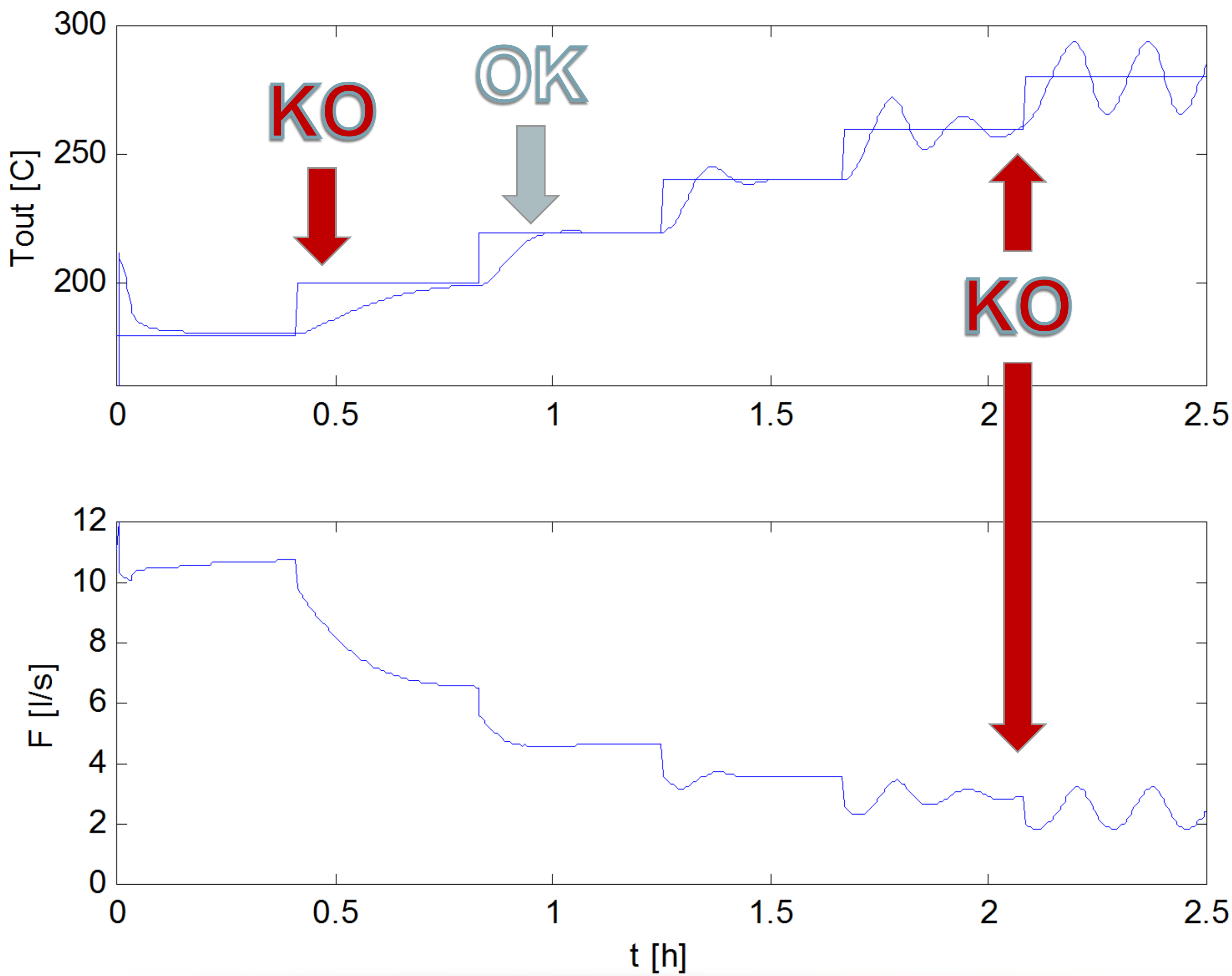
If R is constant, there is a **steady state solution** as:

$$\int_{t-\tau(t)}^{t} F(\sigma)d\sigma = \mathrm{V} \quad \Rightarrow \quad \bar{F}\cdot\bar{\tau} = \mathrm{V}$$

$$T_{\mathrm{out}}(t) - T_{\mathrm{inp}}(t-\tau) = \alpha \cdot \int_{t-\tau}^{t} R(\sigma)d\sigma$$

$$\bar{T}_{\mathrm{out}} - \bar{T}_{\mathrm{inp}} = \alpha\cdot\bar{R}\cdot\bar{\tau} = \alpha\cdot\bar{R}\cdot\frac{\mathrm{V}}{\bar{F}}$$

PID Controller…



Proposed solution

From the **steady state solution**:

$$\overline{T}_{\text{out}} - \overline{T}_{\text{inp}} = (\alpha \cdot \text{V}) \cdot \frac{\overline{R}}{\overline{F}} \qquad \textbf{\&} \qquad \overline{\tau} = \frac{\text{V}}{\overline{F}}$$

Make PID's **proportional gain K_P** proportional to

$$\times \frac{F}{R}$$

gain inversion

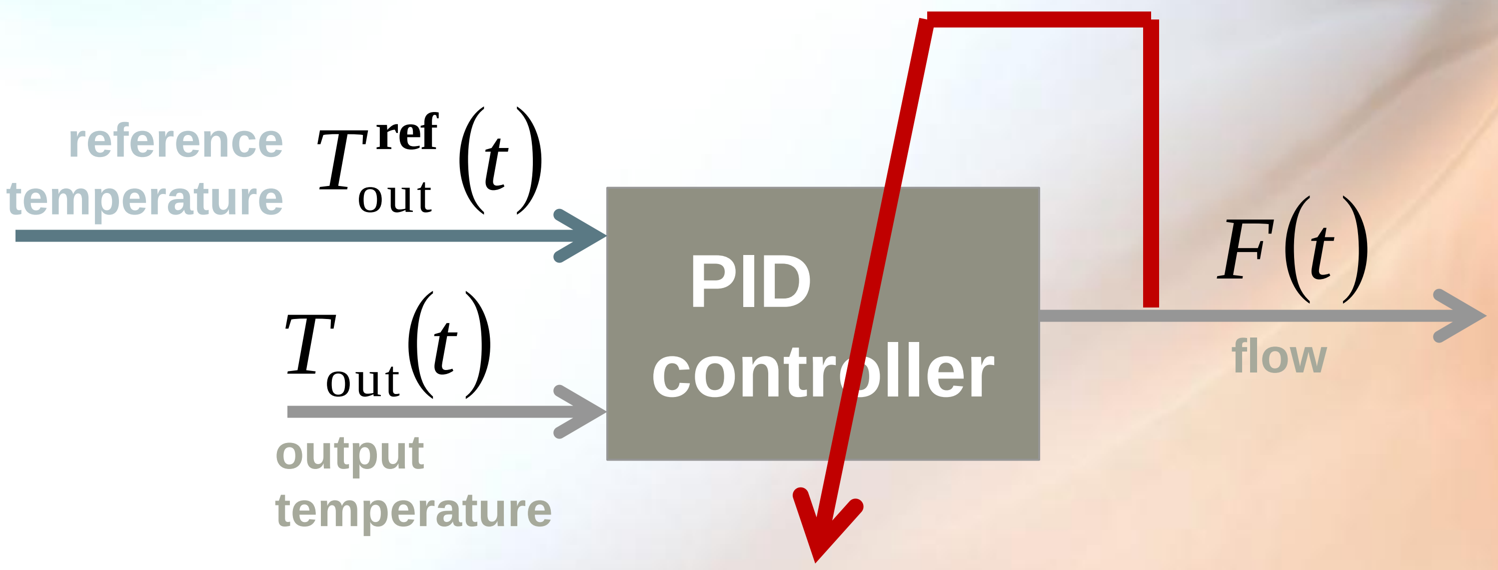
Make PID's **integral** and **derivative times,** T_I and T_D, proportional to

$$\times \frac{1}{F}$$

time compliance

But we have a problem...

We are doing **gain scheduling** using as **scheduling variable** the resulting control action:



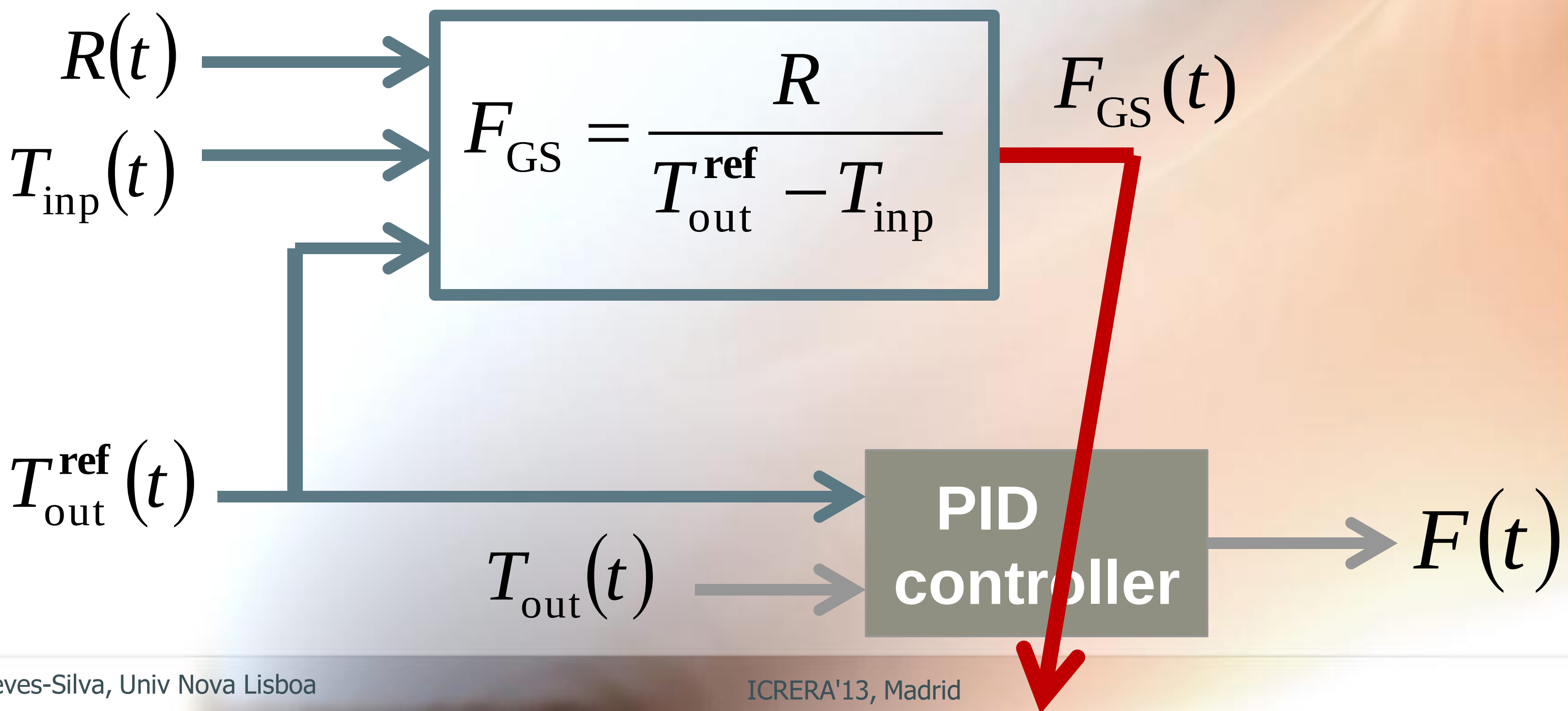
from GS literature: **potential stability problems!**

… and the solution:

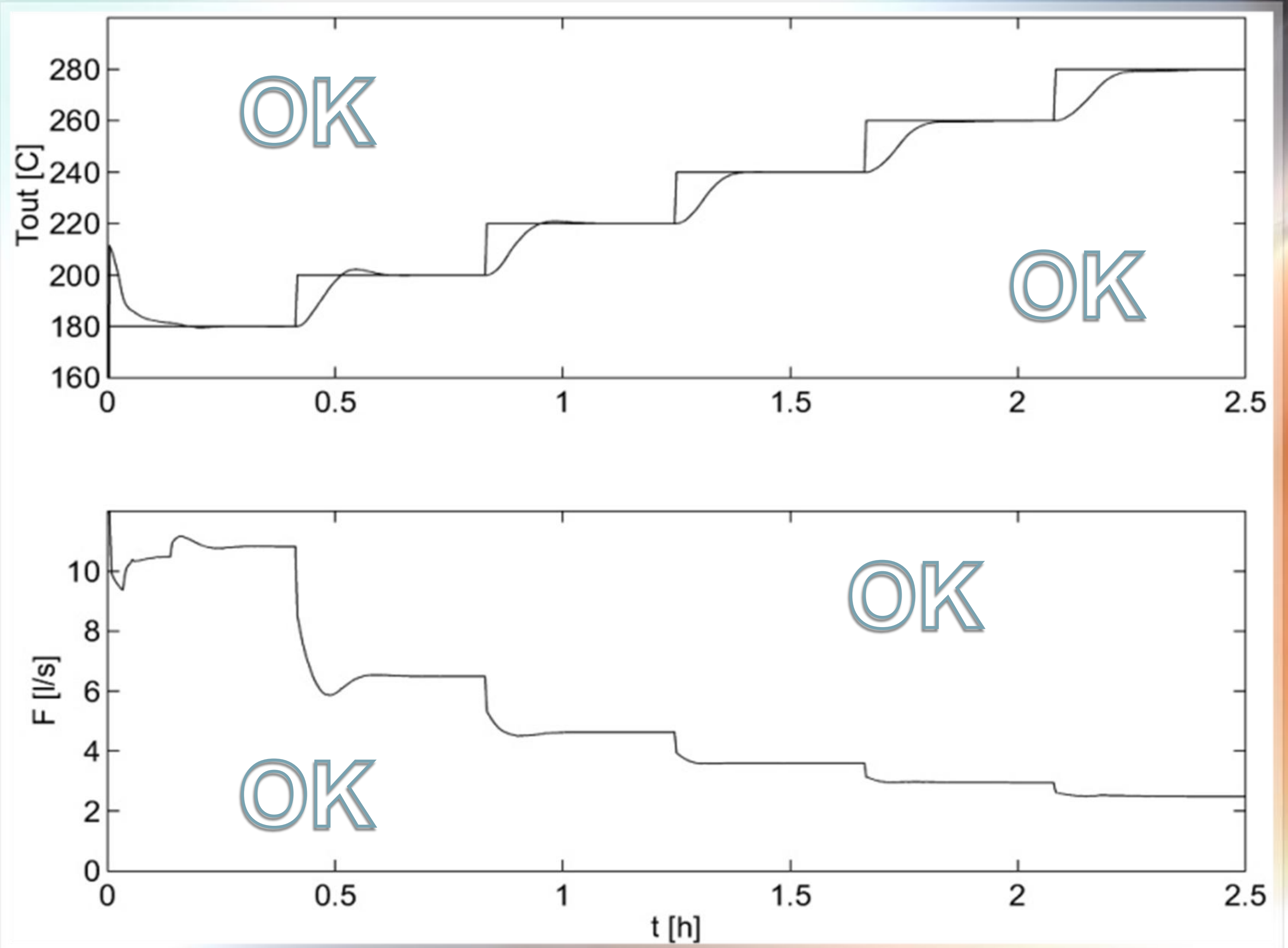
Use again the **steady-state** relationship

$$\overline{T}_{\text{out}} - \overline{T}_{\text{inp}} = (\alpha \cdot \text{V}) \cdot \frac{\overline{R}}{\overline{F}}$$

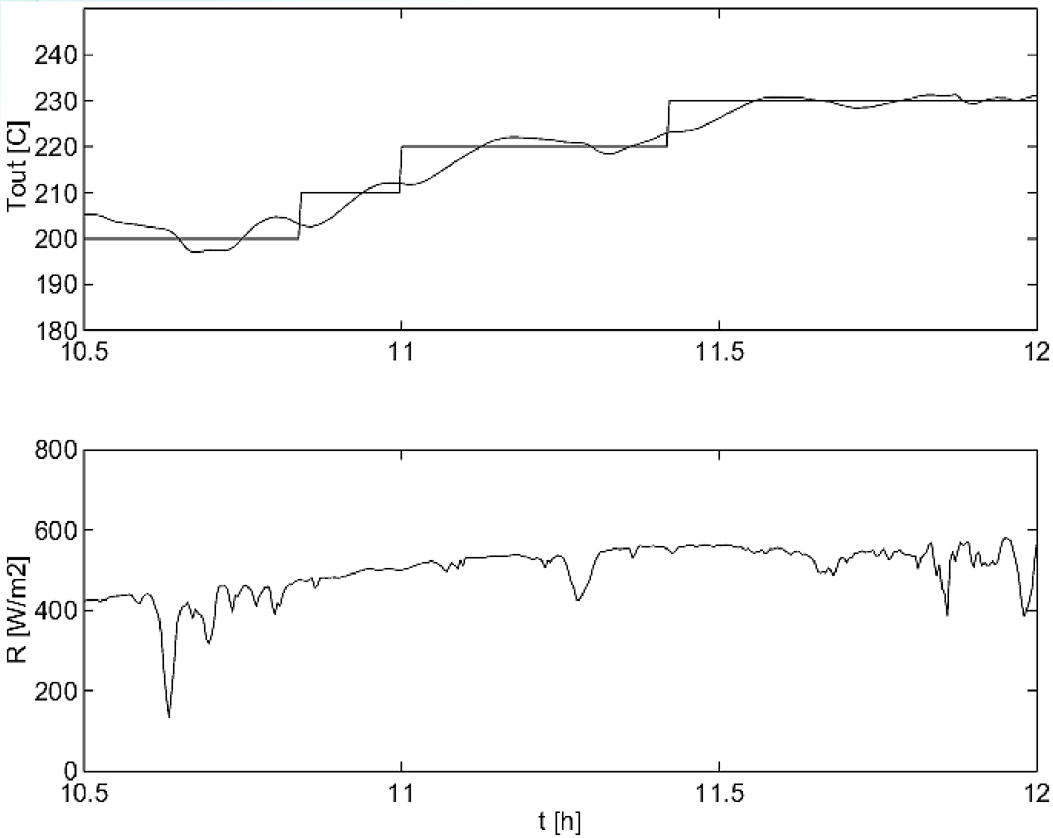
to define a **virtual steady-state flow** to be used as scheduling variable as

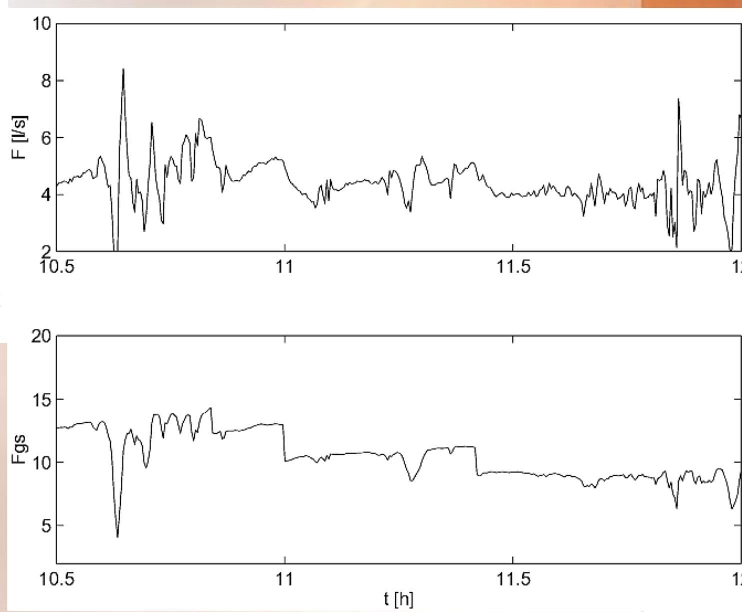


Simulation results

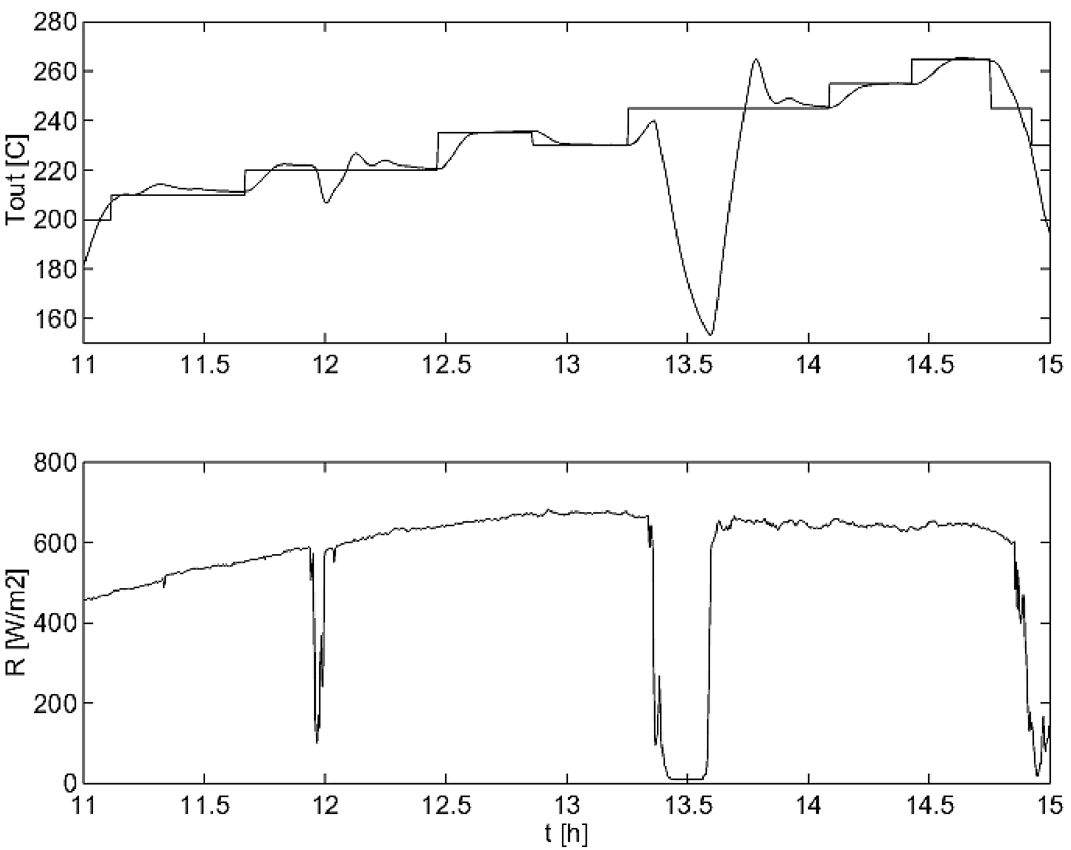


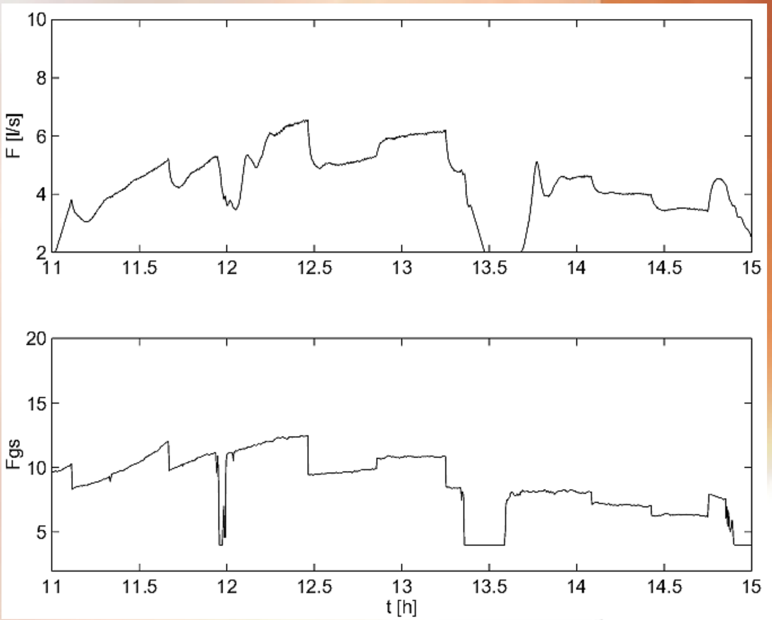
Experimental results I



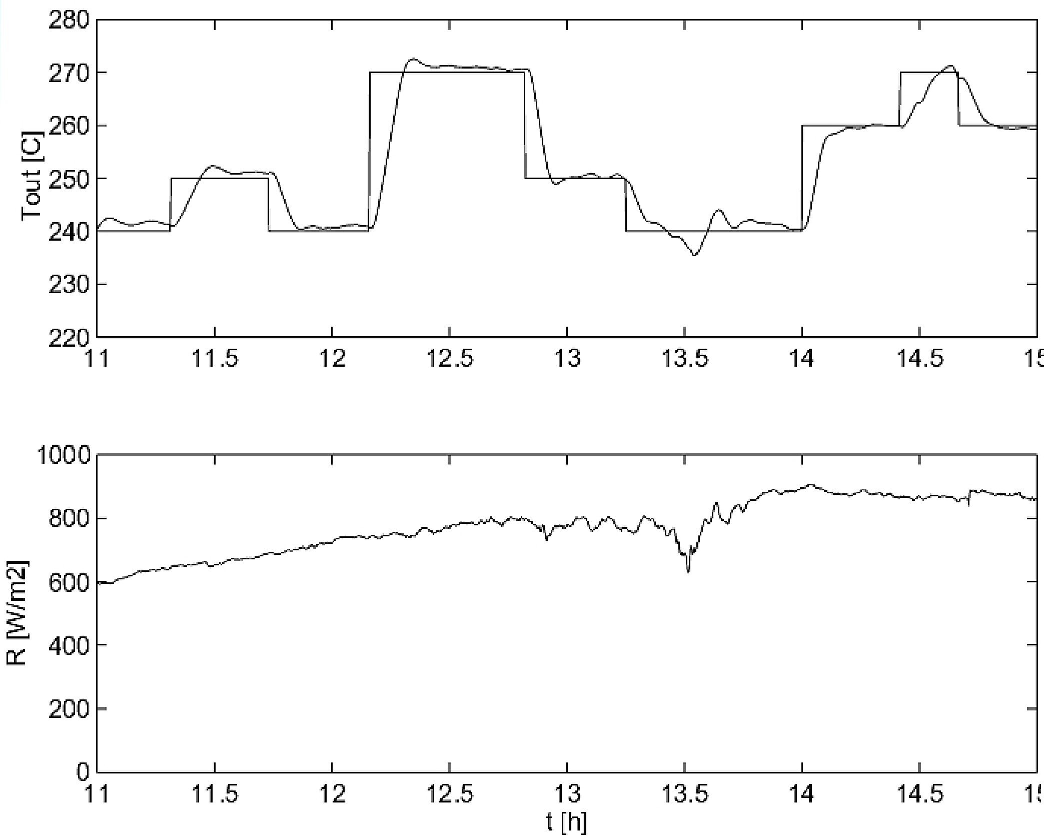


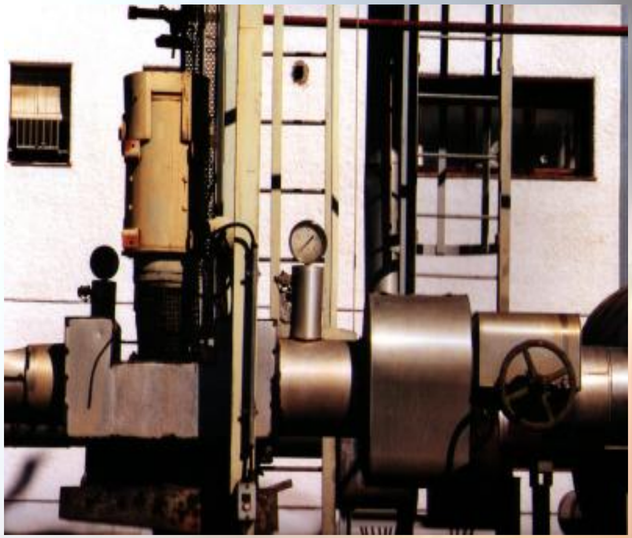
Experimental results II

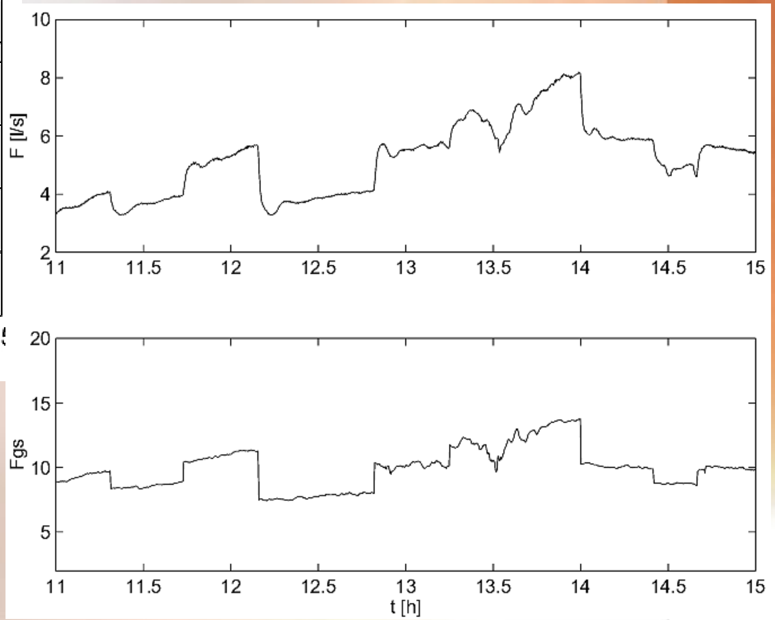




Experimental results III







Conclusions

- Parabolic through collector fields exhibit non-linear dynamic behavior, mainly due to the flow variation;
- Fixed gain PID controllers do not give satisfactory performance for all operating range;
- A solution based on the steady-state relationship between radiation, flow and temperatures is presented;
- The controller gain inverts the plant's dependency on flow; and the controller times are made compliant with the residence time;
- A virtual flow is computed from external signals to be used as scheduling variable, avoiding an additional feedback loop;
- Experimental results at the ACUREX field provide favorable evidence on the approach's performance.

...the investment continues!

Thank you!

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Some additional references

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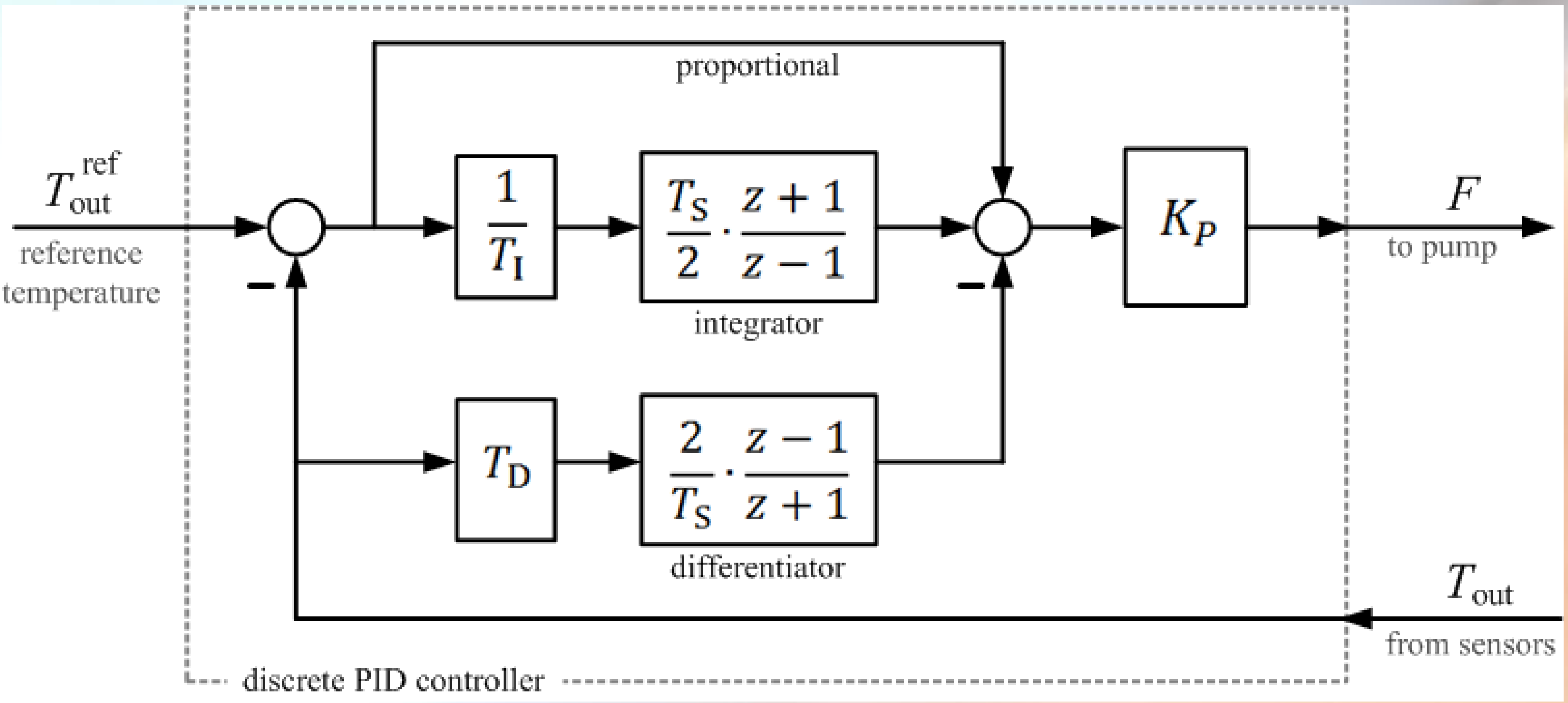
Q&A: PID controller



Q&A: Gain scheduling PID