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Instituto de Desenvolvimento de Novas Tecnologias

ADVANCED AUTOMATED ALGORITHM GENERATION SOFTWARE IN THE CONTROL OF A SOLAR POWER PLANT

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ACODUASIS IST-2001-42068

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Contents

- Introduction
- Eicas Methodology
- Test Case Description
- Control Using EicasLab
- Simulation Results
- Conclusion

Introduction

- Methodology developed along 20 years
- Notions:
  - Plant
  - Dynamic system
  - Model
- ACUREX (PSA)
  - Static gain and time constants dependent on operating point

Eicas Methodology

- Models only five approximate description: uncertainty!
- If uncertainty norm-bounded: $\|y - y_m\| < E\|y_m\| + D$
- As well as: $\|y_m - y_0\| < E_0\|y_m\| + D_0$
- ***Theorem:*** if state controller exists, and attenuates the effect of disturbance on y_o then the same controller attenuates the closed-loop plant-model uncertainty effects, so that eo(t) satisfies:

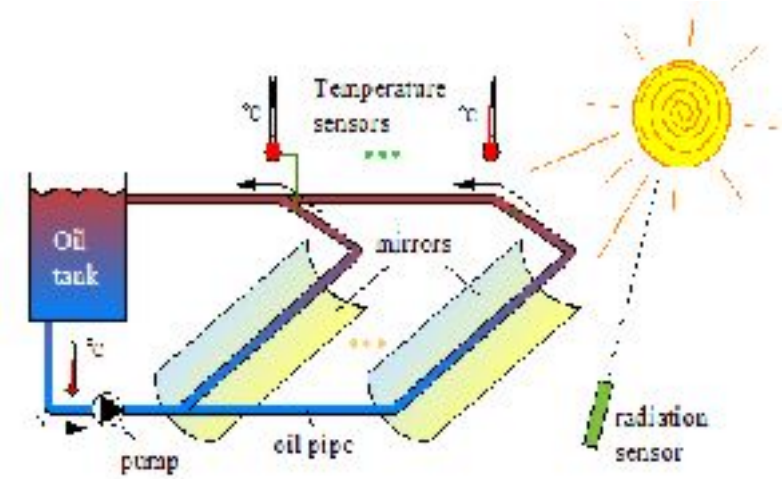
$$\|e_o\| < Q^*(E_0\|y_d\| + D_o) \text{ being } Q^* < Q/(1 - E_0(1+Q))$$

Test Case Description: ACUREX Field

Plataforma Solar de Almeria (PSA): south of Spain

- *Characteristics:*
  - static gain and time constants directly dependent on the operating point
  - 480 distributed solar collectors, arranged in 10 loops along an east-west axis

Test Case Description: Plant



- Oil is pumped from the bottom of a tank through the collectors, where it acquires solar energy.
- Manipulating the oil flow (pump) it is possible to control the output temperature of the oil.

Test Case Description: Plant

- The collector has a reflective cylindrical parabolic surface, to concentrate the incident solar radiation on a pipe located on the surface focal line.
- Tracking system by which the mirrors can rotate parallel to the axis of the tube, in order to follow the sun in height throughout the day.
- Sensor at the input, measuring the temperature of the oil entering the active part.

Test Case Description: Fine Model

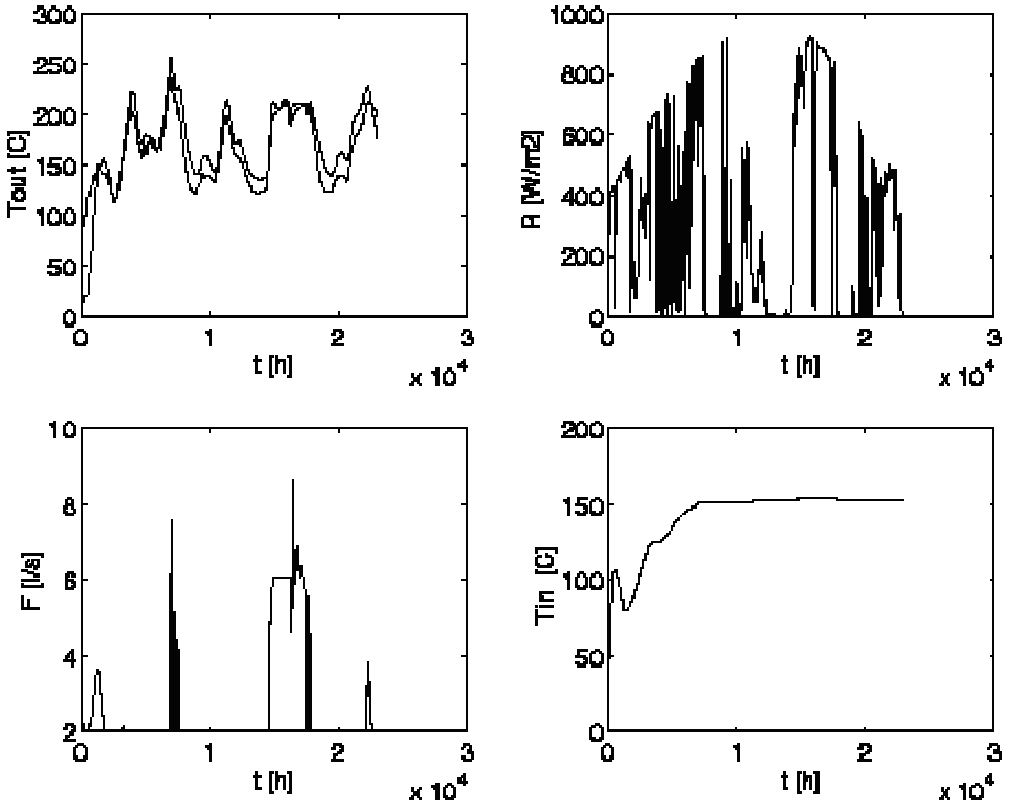
- Distributed system
  - Transport effect
    - Modelled by hyperbolic equation

Hyperbolic equation: $$\frac{\partial y(z,t)}{\partial t} + \frac{f(t)}{A}\frac{\partial y(z,t)}{\partial z} = \Gamma w(t)$$

- It is possible to establish a steady-state relation among input/output temperature gain, *?T*, the solar radiation *W* and the flow *F*

Steady-state: $$\Delta T = (\Gamma \cdot V)\cdot\frac{W}{F}$$

Test Case Description: Validation Results

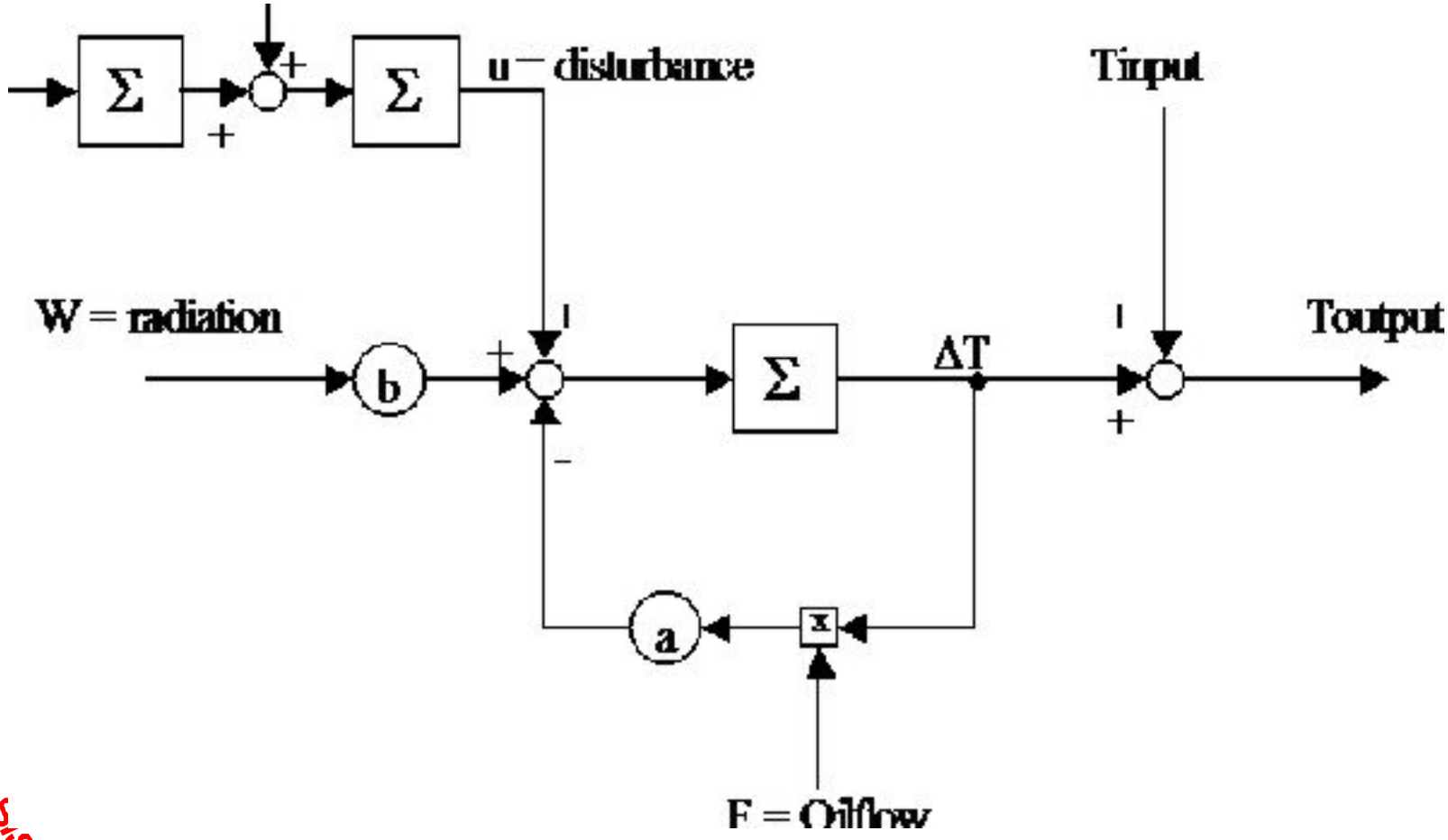


Test Case Description: Characteristics

- Output Variables:
  - Average of the temperature at the output of each loop, Tout;
- Manipulated variable:
  - Oil flow command to the pump controller;
- Accessible Disturbances:
  - Direct solar radiation, W;
  - Temperature at the input of the field, Tinp;
- Non-accessible Disturbances:
  - Loss of tracking of the solar collectors;
  - Difference between measured and incident solar radiation;
- Control goal:
  - follow a reference value together with a good disturbance rejection;

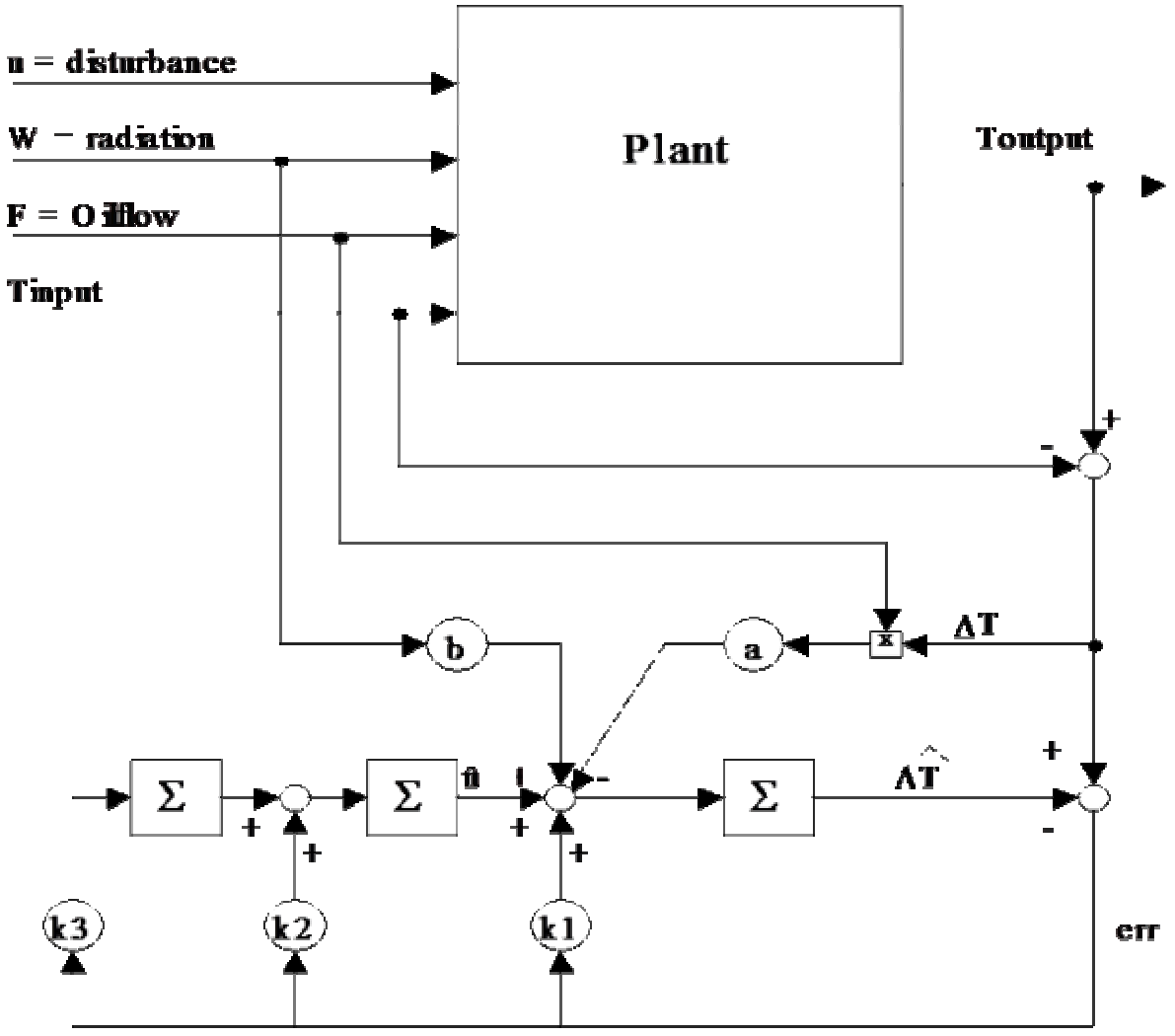
Control Design using EicasLab: Simplified model

Simplified Model: $\frac{d\Delta T}{dt} = u + bW - a \cdot \Delta T \cdot F$



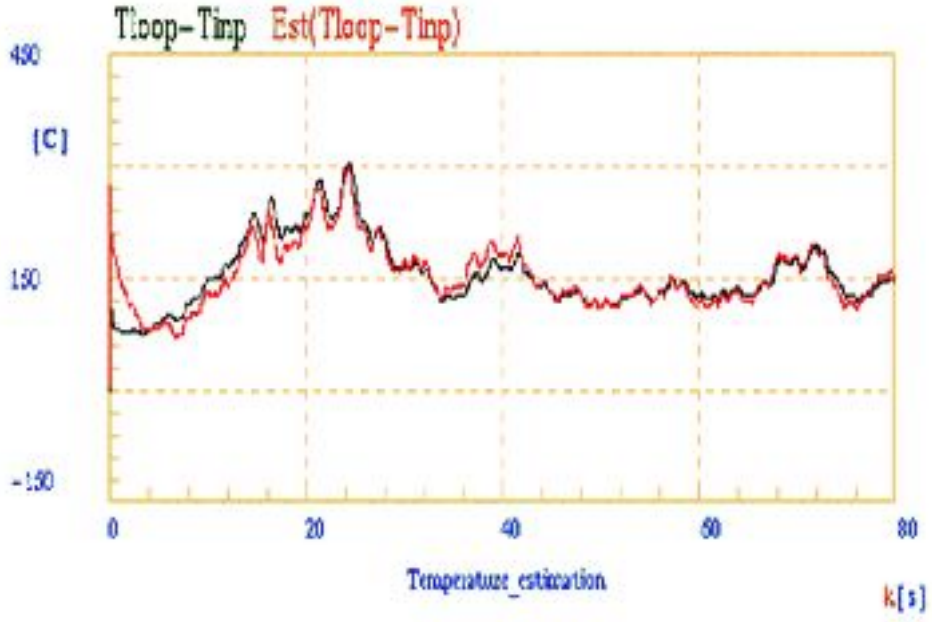
Control Design using EicasLab: State observer

Observer:



Control Design using EicasLab: Identification

- The condition of almost linear plant has been verified!



  - Comparison between the output of the identified system during this simulation and the output of the system to identify

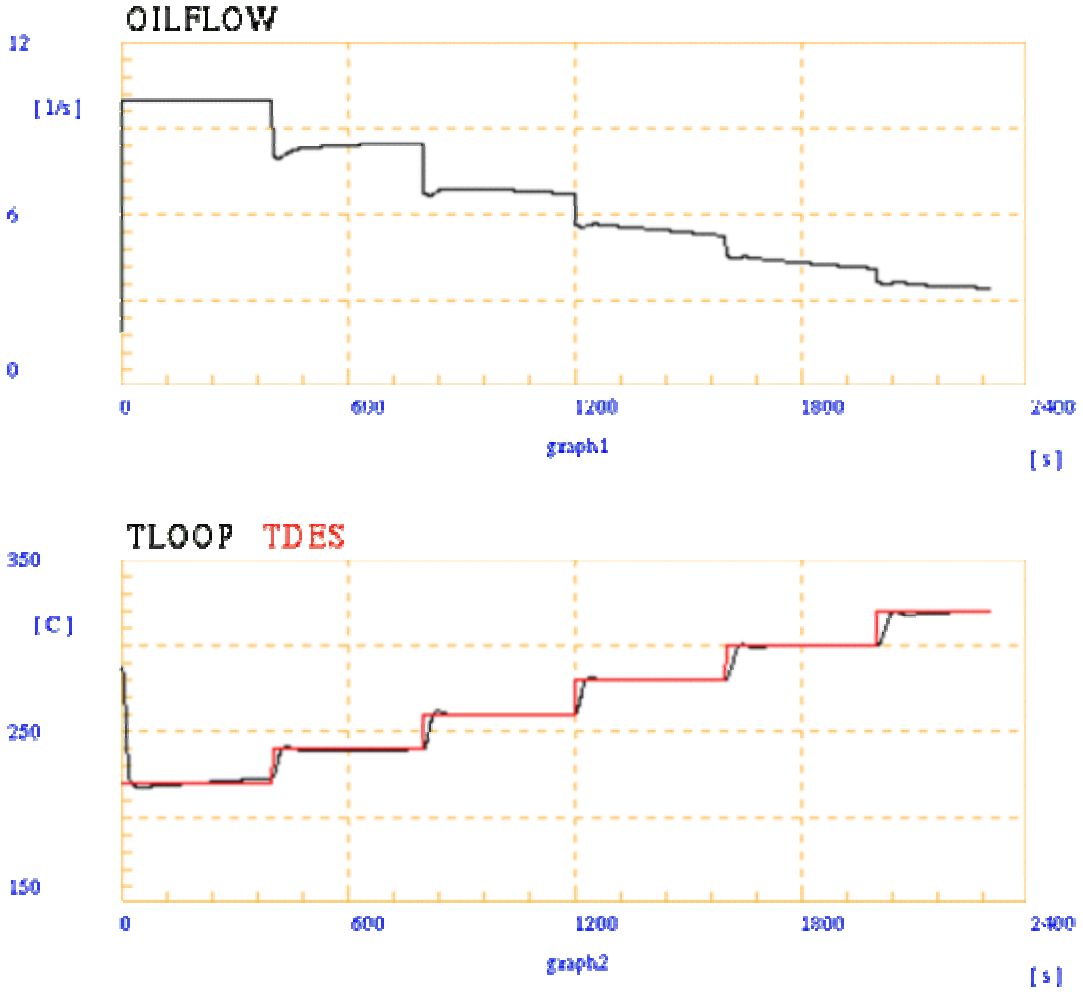
Control Design using EicasLab: Implementation

- Control contains:
  - Observer
  - Estimation of the disturbances to set flow, *F*

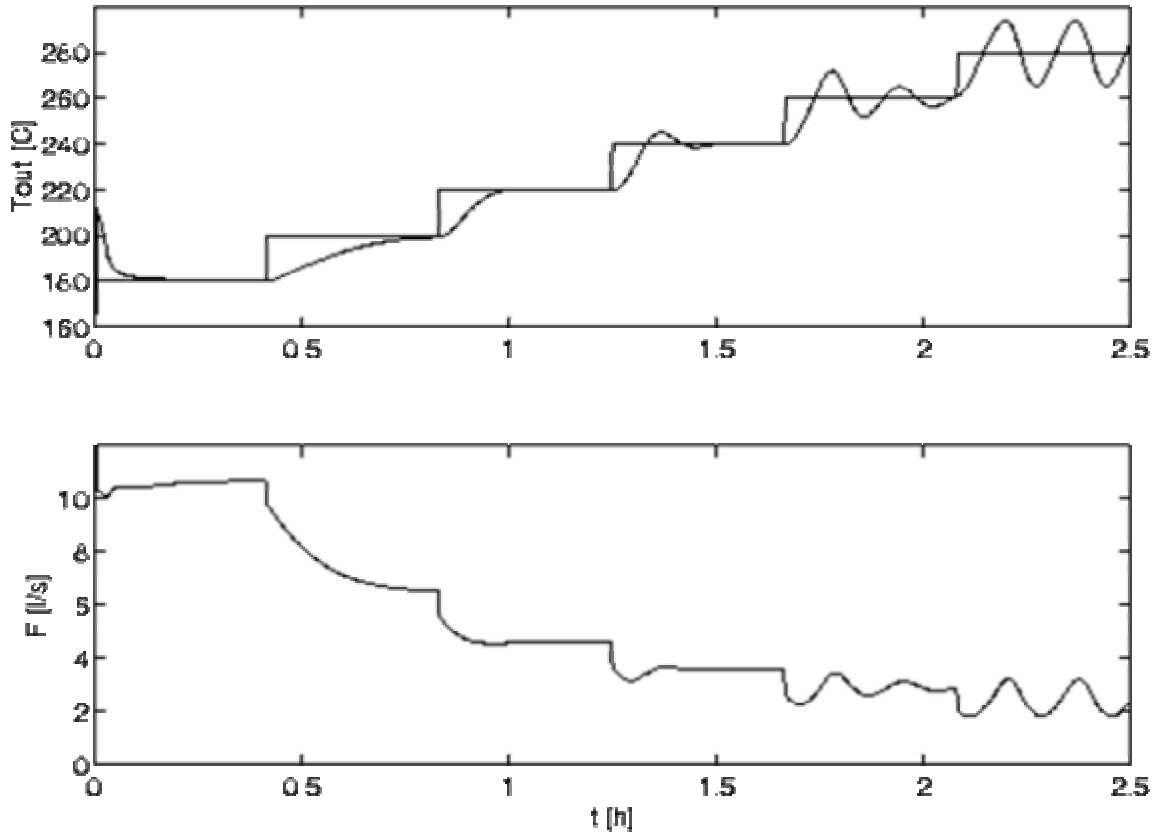
$$F = \frac{b \cdot W + \hat{d}}{a(T_{ref} - T_{inp})}$$

  - *Where:*
    - *a and b are the identified parameters*
    - T_{ref} *is the desired temperature*
    - T_{inp} *is the temperature of the oil at the beginning of the loop*
    - *W is the sun radiation*

Simulation Results: Eicas methodology



Simulation results: Linear PID controller



Conclusions

- An application of the Eicas methodology is here presented
- The control of a solar plant as been implemented through the use of EicasLab software tool
- Simulation results have been presented