



# ***Modelling and control of a solar thermal power plant***

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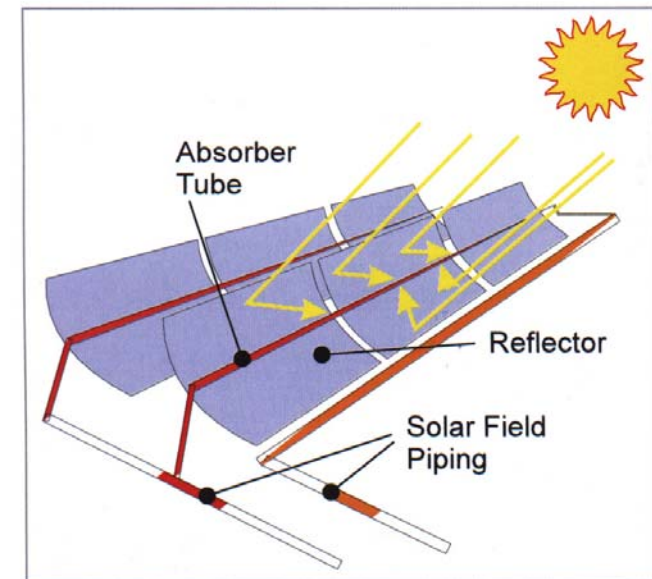
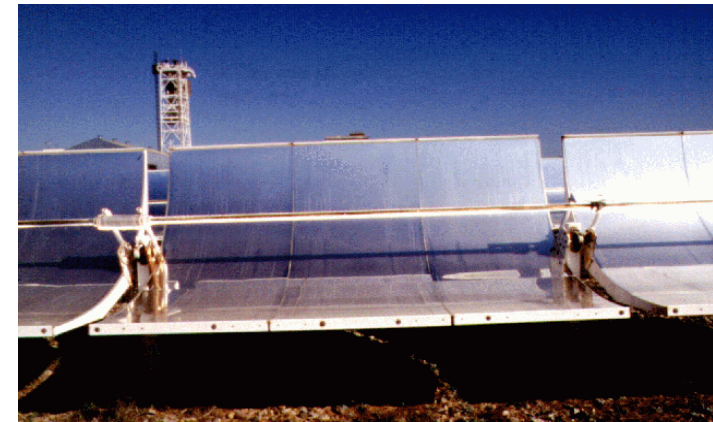
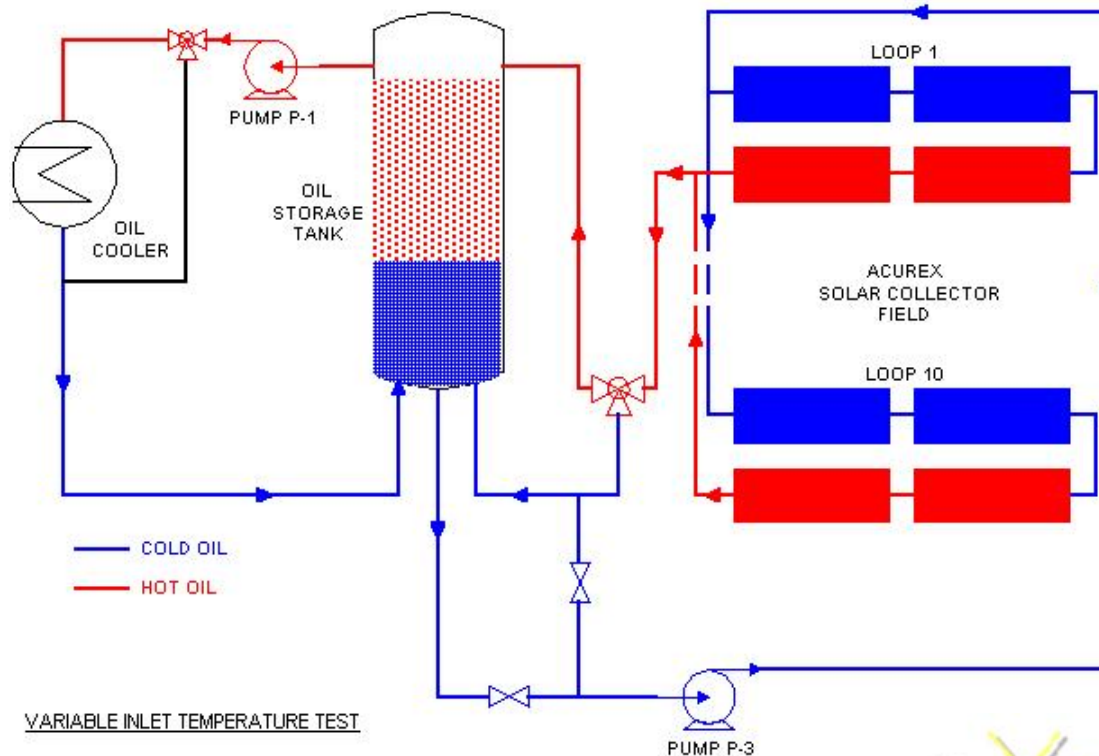
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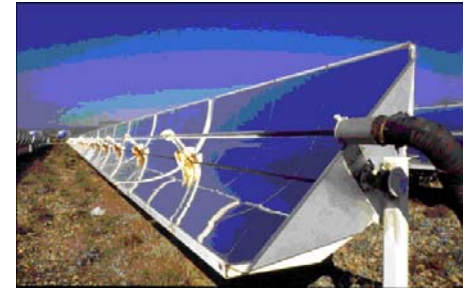


# Solar Collector Field





## Solar collector field



### Control

- Start-up
- Set point changes
- Clouds
- Load disturbances
- Local disturbances
- Malfunctioning

### Simulation

WHY?

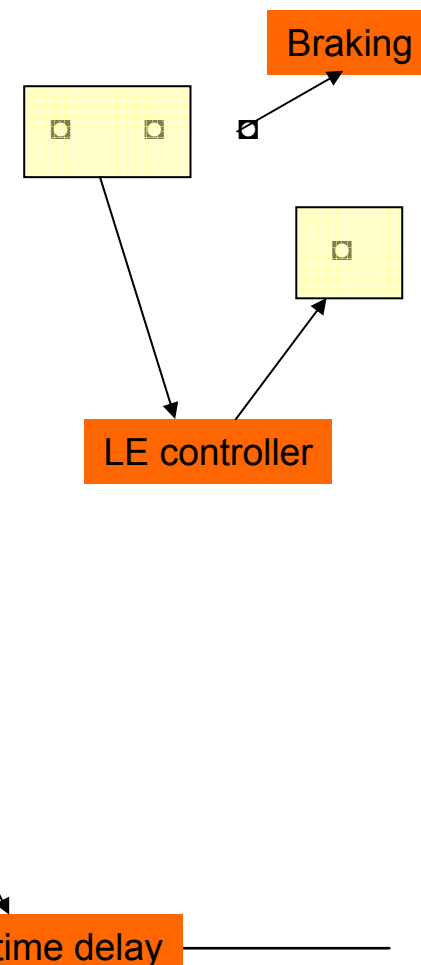
- Operating conditions cannot be reproduced
- Seasonal differences
- No time for on-line adaptation

**The model needs to be good  
in the whole operating area!!  
(Oscillations → slow operation)**



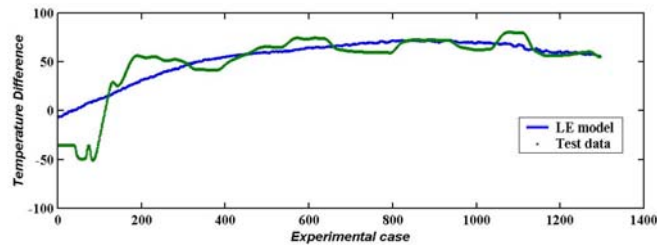
## Interaction coefficients Membership definitions

Index	Variable		Working Point	Dynamic Model	Time Delay	$e$	$\Delta e$	$Ie$	$\Delta u$
1	Inlet temperature	$T_{in}$							
2	Outlet temperature	$T_{out}$							
3	Oil flow	$F$		-0.19012					
4	Effective irradiation	$I_{eff}$	0.50176	0.31697					
5	Temperature difference	$T_{diff}(t)$	-0.77147	0.52315					
		$T_{diff} = T_{out} - T_{in}$							
		$T_{diff}(t + \Delta t)$		-0.76128					
6	Ambient temperature	$T_{amb}$	0.20493						
	Bias		0.33328	0.10073					

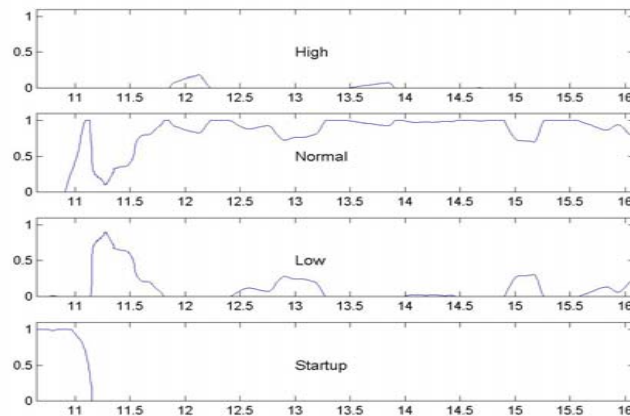


# Models

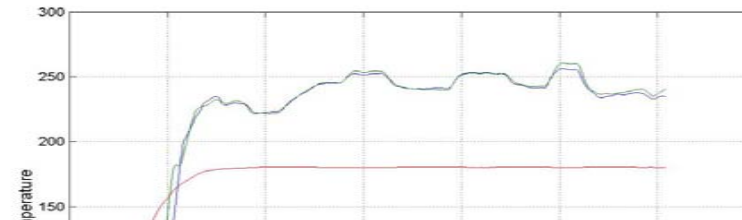
## Working point model



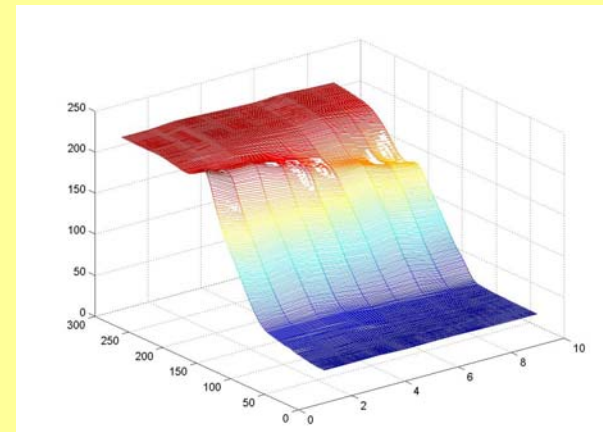
## Operating conditions



## Dynamic models



## Distributed parameter models



## Special cases with fuzzy set systems



# LE Controller: Adaptive Scaling

PI type LE controller

$$f_{6i}^{-1}(\Delta u_{ij}) = K_P(i, j) f_{4j}^{-1}(\Delta e_j) + K_I(i, j) f_{3j}^{-1}(e_j)$$

Linguistic value of the change of error

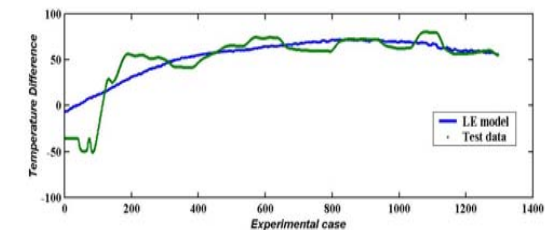
Linguistic value of the error

Working point

$$wp = f_{14}^{-1}(I_{eff}) - f_{15}^{-1}(T_{diff})$$

Linguistic value of the effective irradiation

Linguistic value of the temperature difference



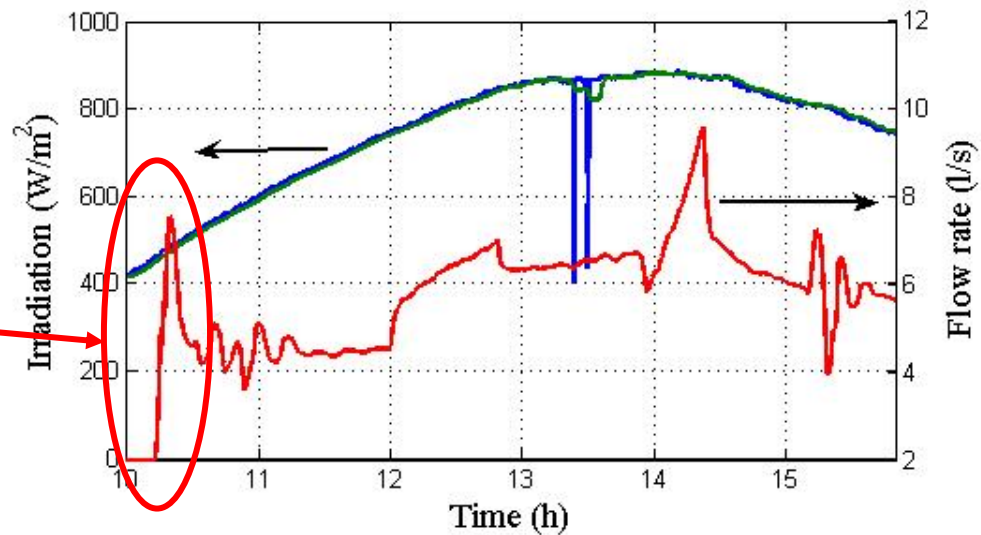
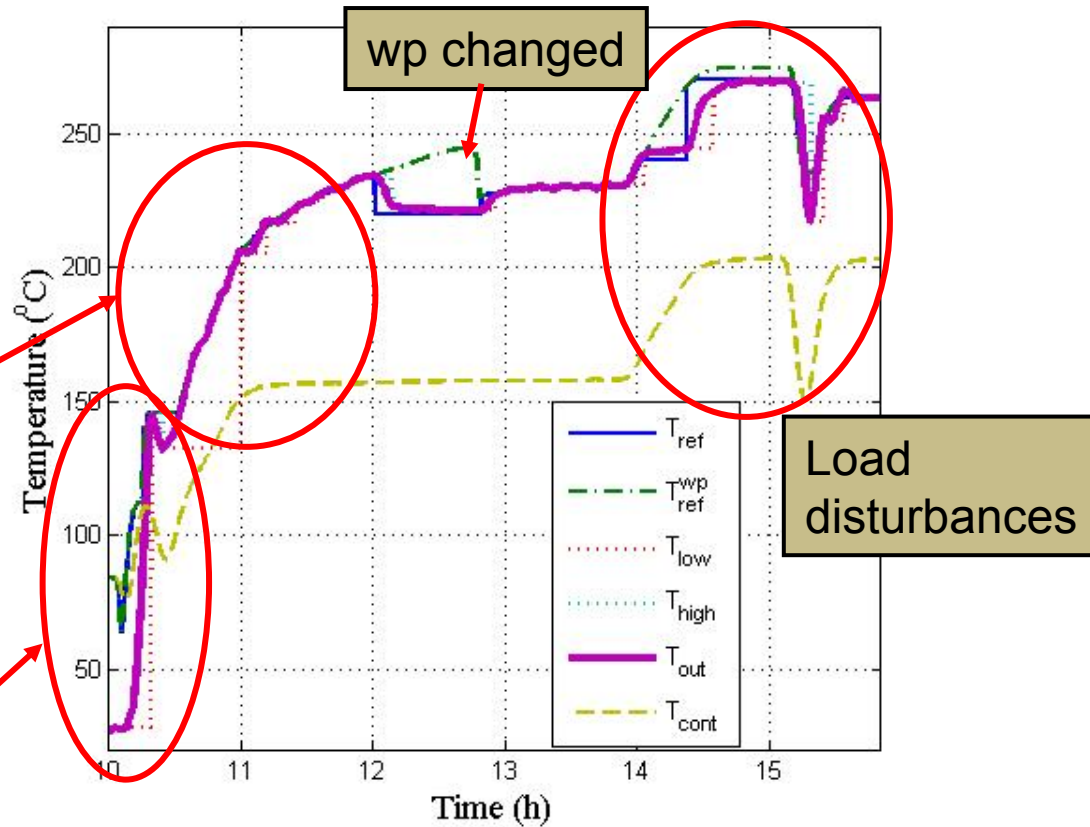
# Test results

Risk for oscillations  
→ only small  $\Delta u$   
allowed

Start-up

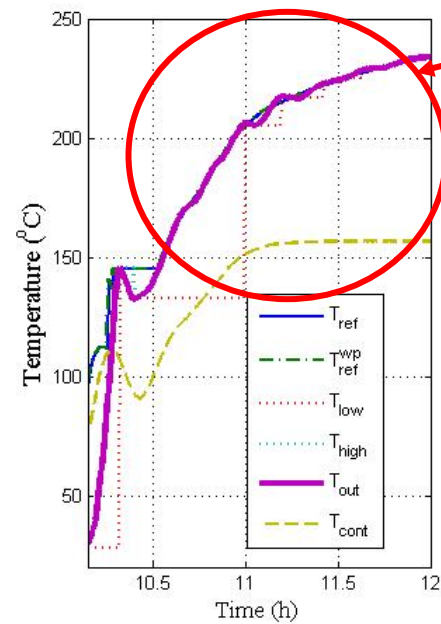
Fast start-up  
→ No time for on-line  
identification / mechanisms

Too high flow

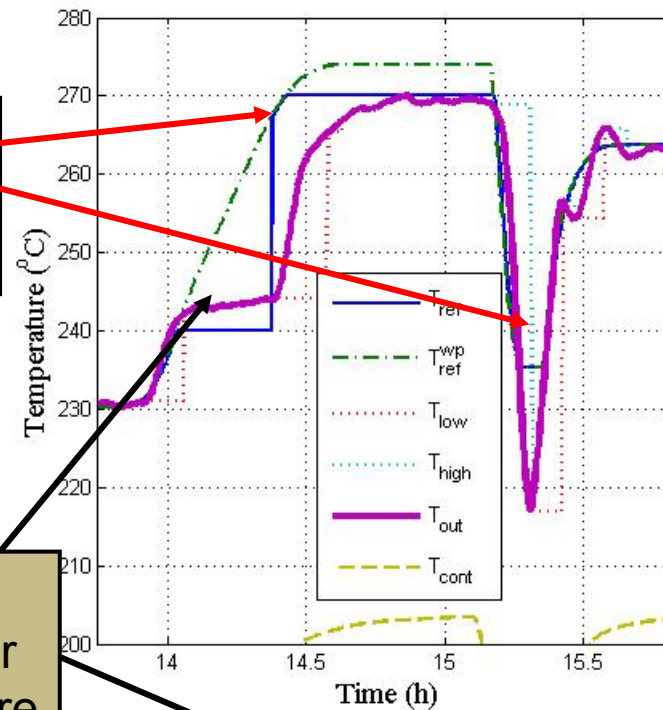




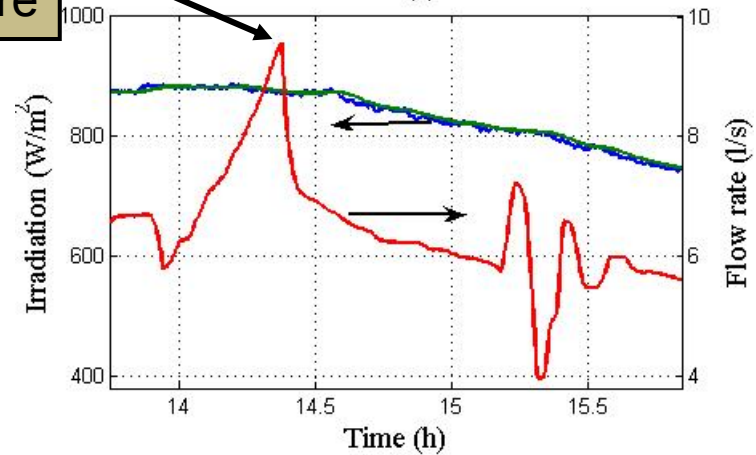
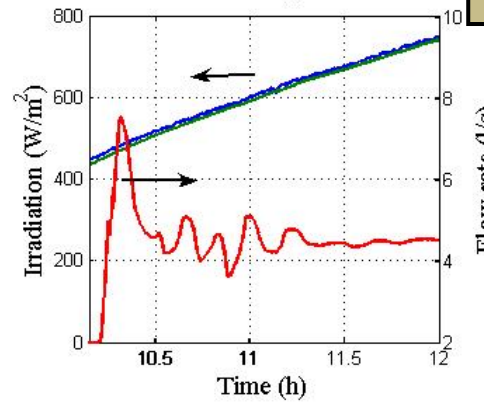
# Test results



Cascade Control (wp)

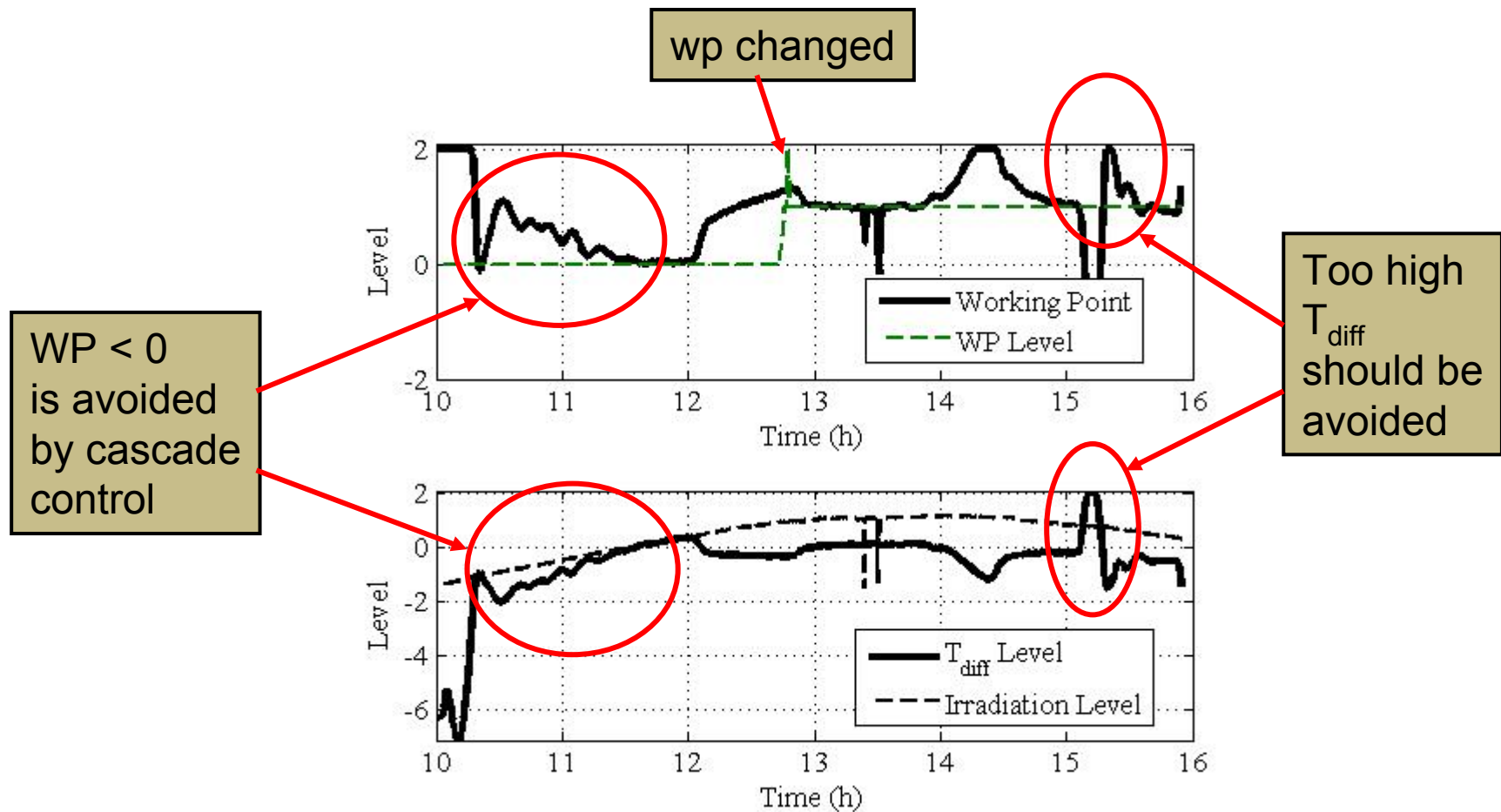


Too low setpoint for temperature

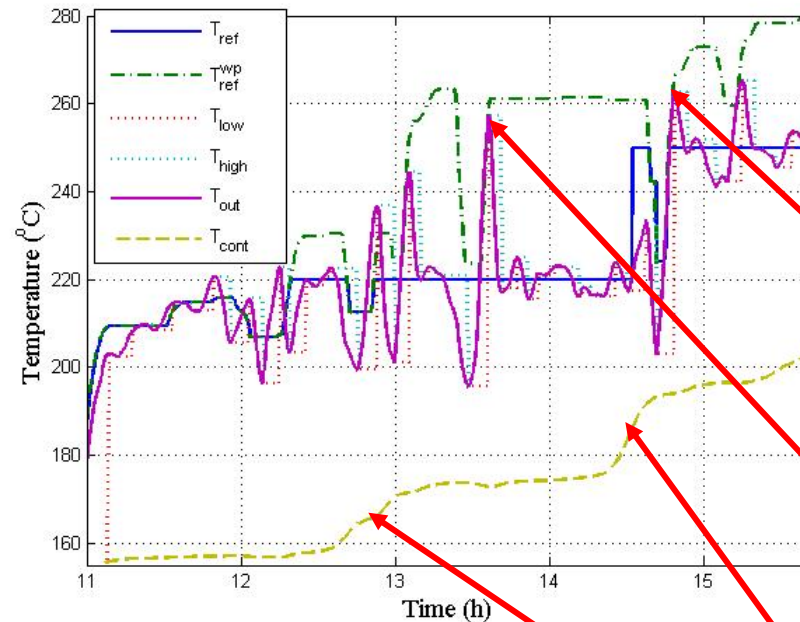
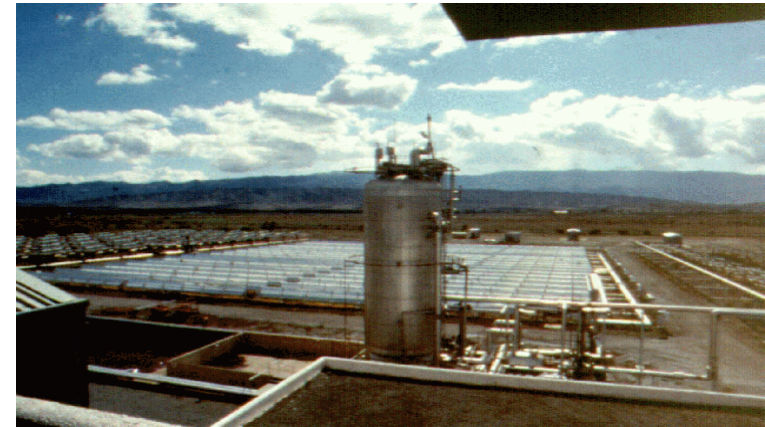




# Working point control

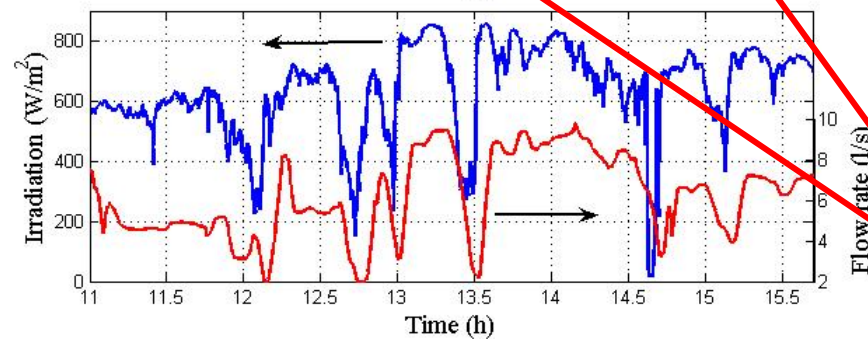


# Irradiation disturbances



Cascade control reduces overshoot efficiently.

Cascade control is not strong enough to reduce overshoot



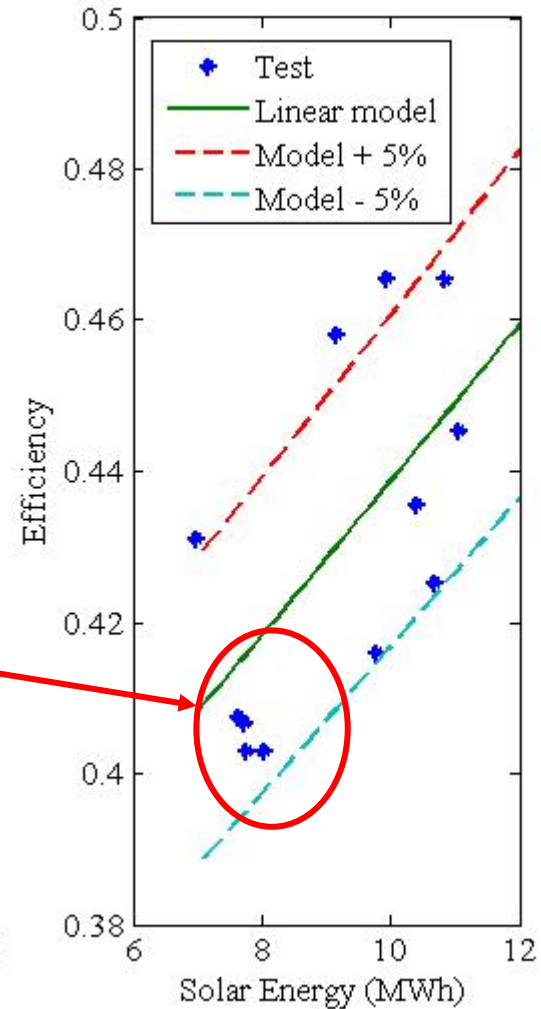
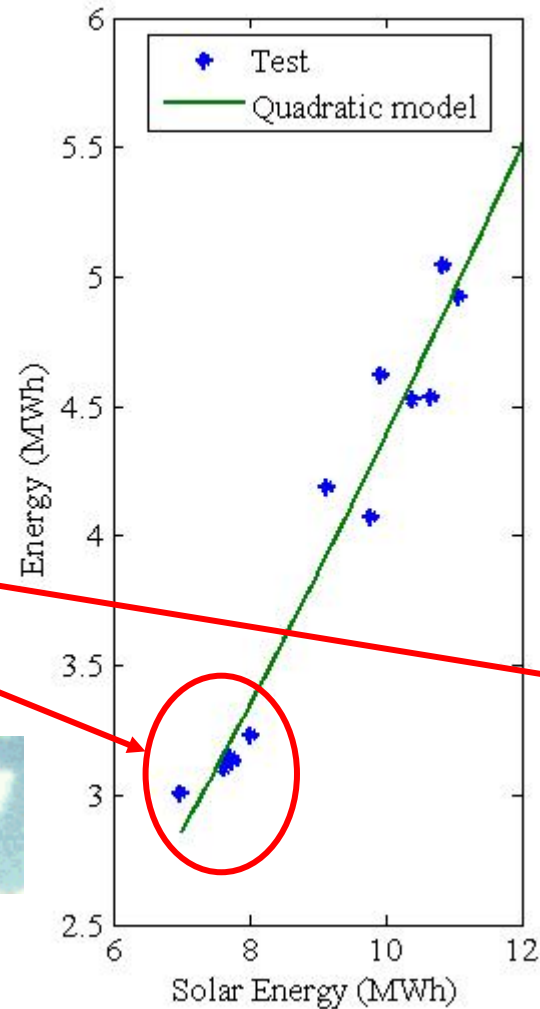
Inlet temperature changes considerably



# Energy collection

High efficiency in energy collection

High energy collection even on cloudy days





# Conclusions

## LE Simulation

- Linguistic equations and fuzzy set systems combined
- Data & expertise
- Understanding of the underlying phenomena
- Delays as smoothly changing fuzzy numbers
- Distributed parameter LE model
  - exact comparison is not possible
  - controller testing and tuning

→ ***A robust platform for controller design***



## LE Control

- Conditions leading to strong oscillations are avoided in advance
- Cascade for temperature set point
- High efficiency in energy collection
  - Normal operation
  - Cloudy conditions
  - Load disturbances
- Compact implementation
- ***Different requirements combined***

