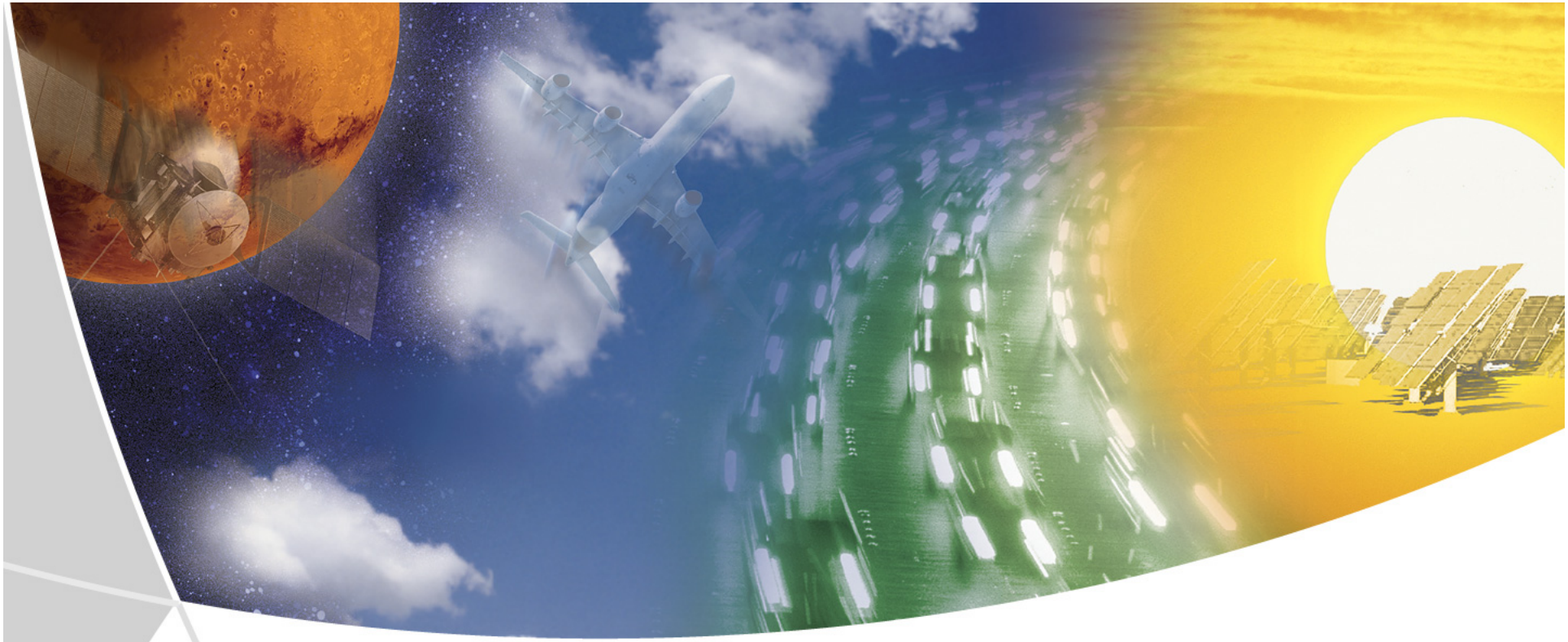

Direct Solar Steam in Parabolic Troughs – Simulation of dynamic behaviour

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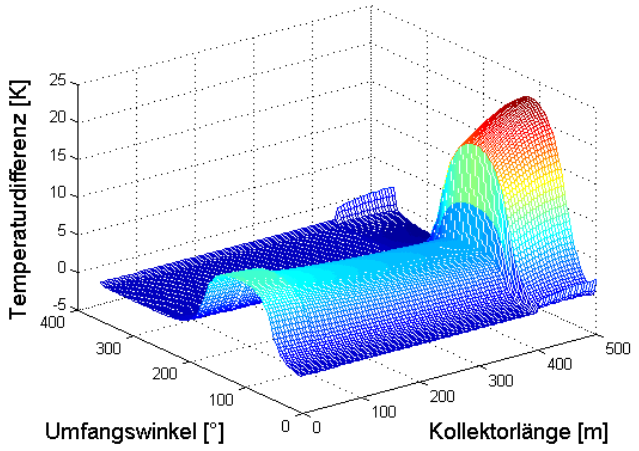
Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

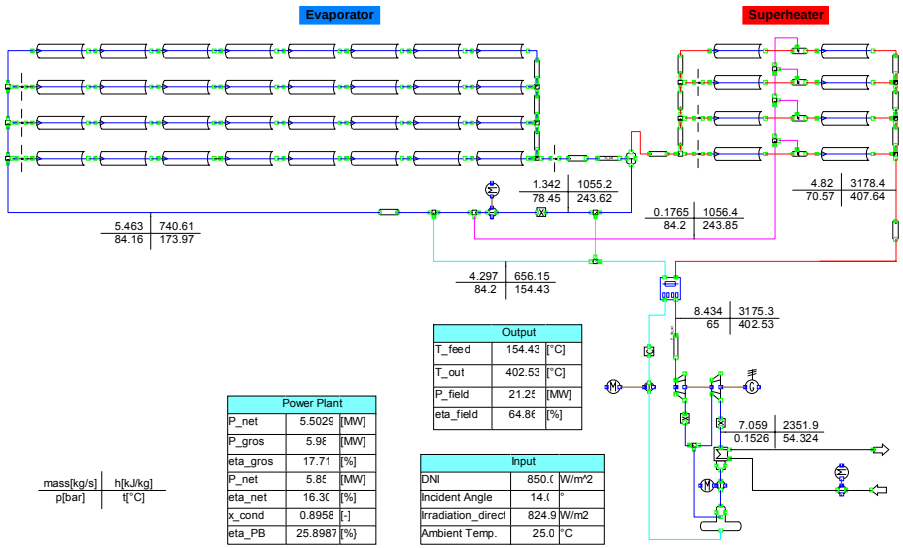
Content

- Introduction
- Solar field under changing conditions
- Measures to smoothen solar field output
- Economic Analysis

Introduction – Status Quo (Summary)

- Operation of a DSG collector loop is feasible
- LEC reduction of 8 % expected (Flagsol 2003, *T* = 420°C)
- Recirculation mode is preferred
- Absorber tubes available for 400°C
- Validated design tools available
- Storage concept not yet demonstrated





Introduction – Target

- DSG as a commercial option

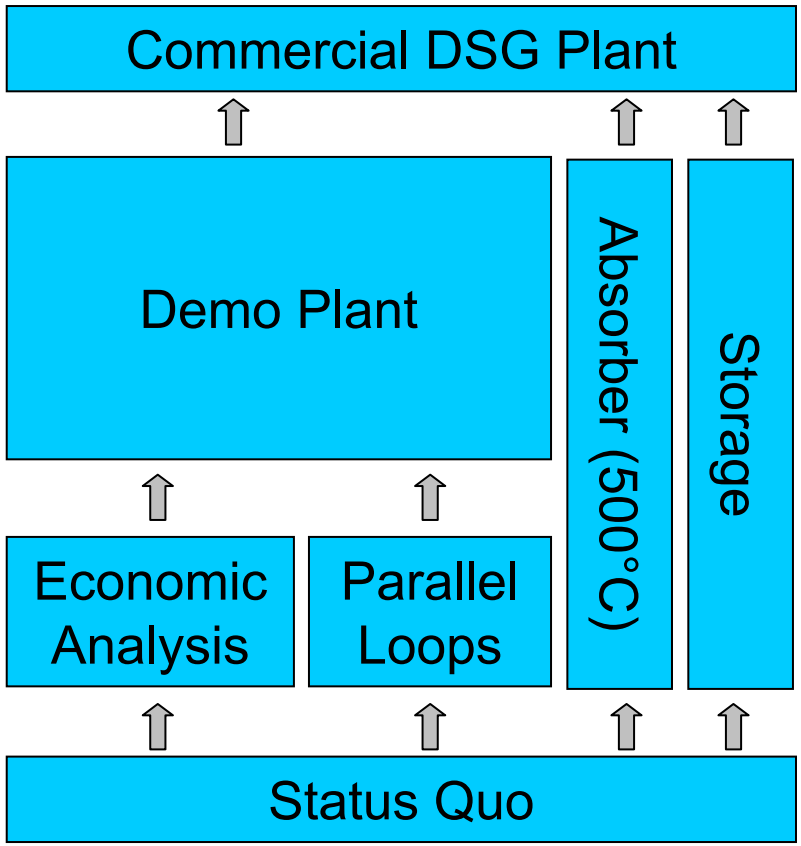
  → Detailed Economic Analysis

  → Investigation of parallel loops

  → Design, erection and operation of a demo plant

  → Development of high temperature absorber tubes (Dr. N. Benz)

  → Development of storage concept (D. Laing)

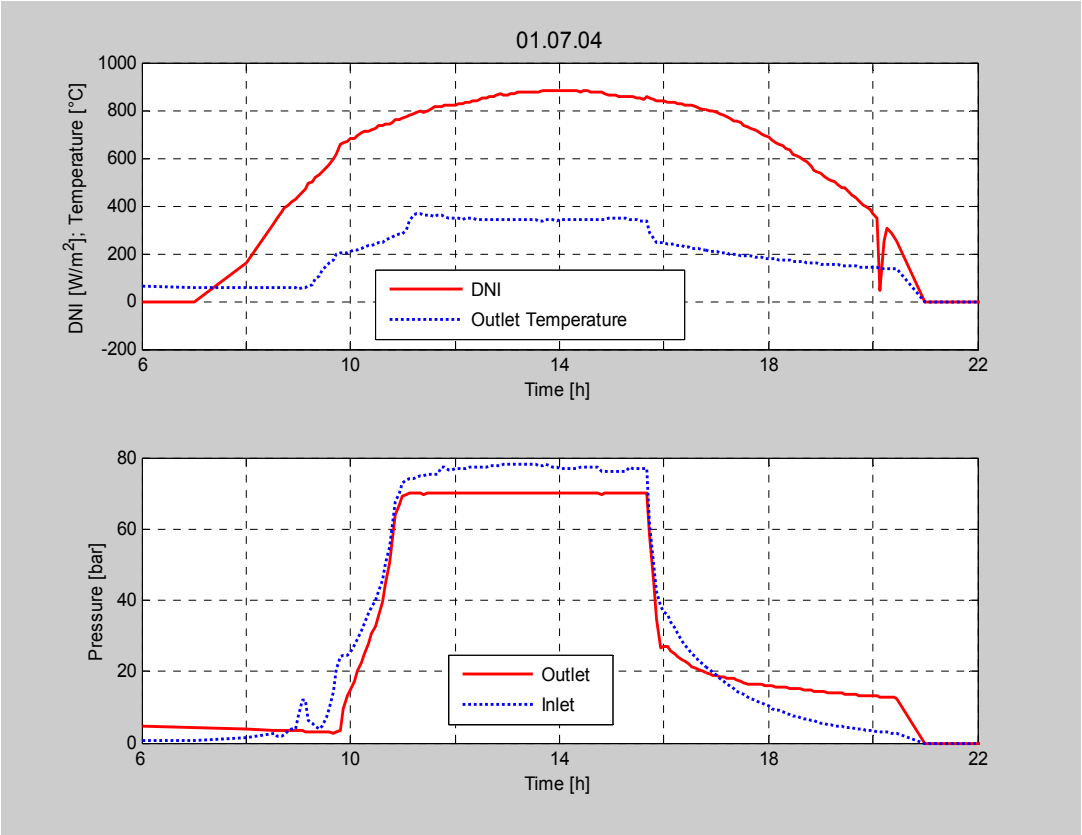


Solar field under changing conditions – Irradiation Level

Irradiation level depends on:

- Time
- Season
- Site
- Atmosphere

➢ Uniform
➢ Slow changes
➢ Predictable

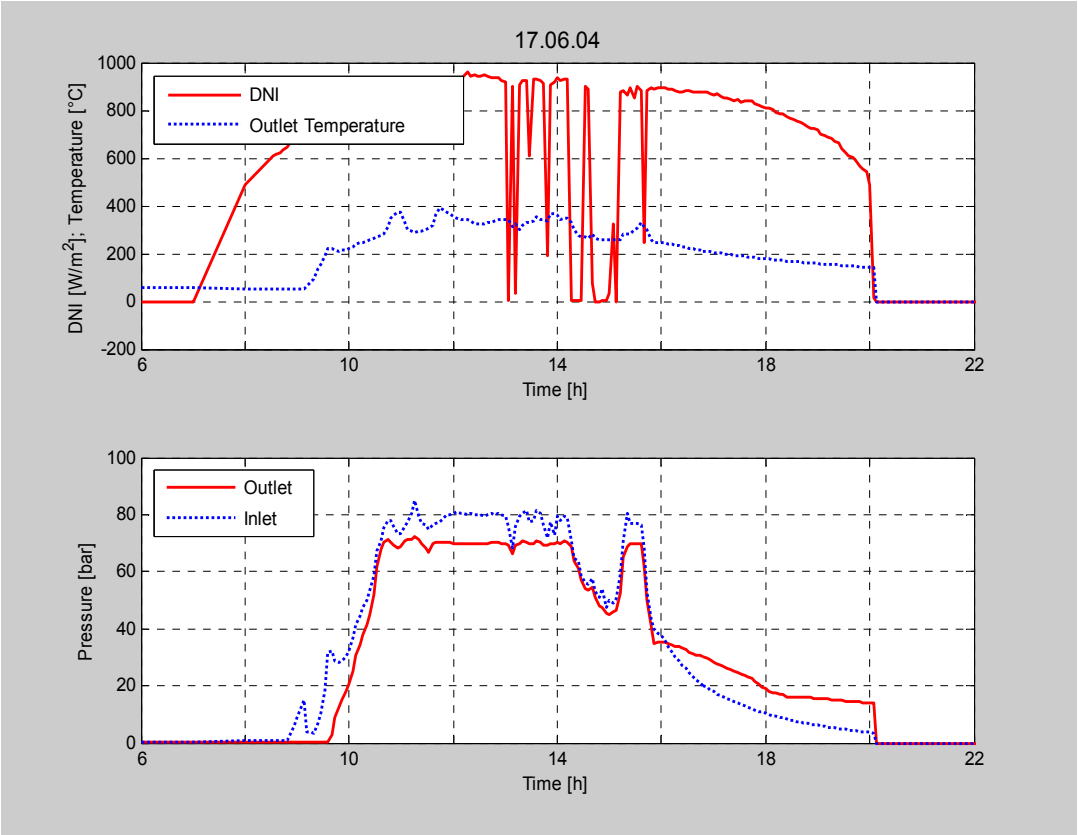


Solar field under changing conditions – Transients

Transients depend on:

- clouds

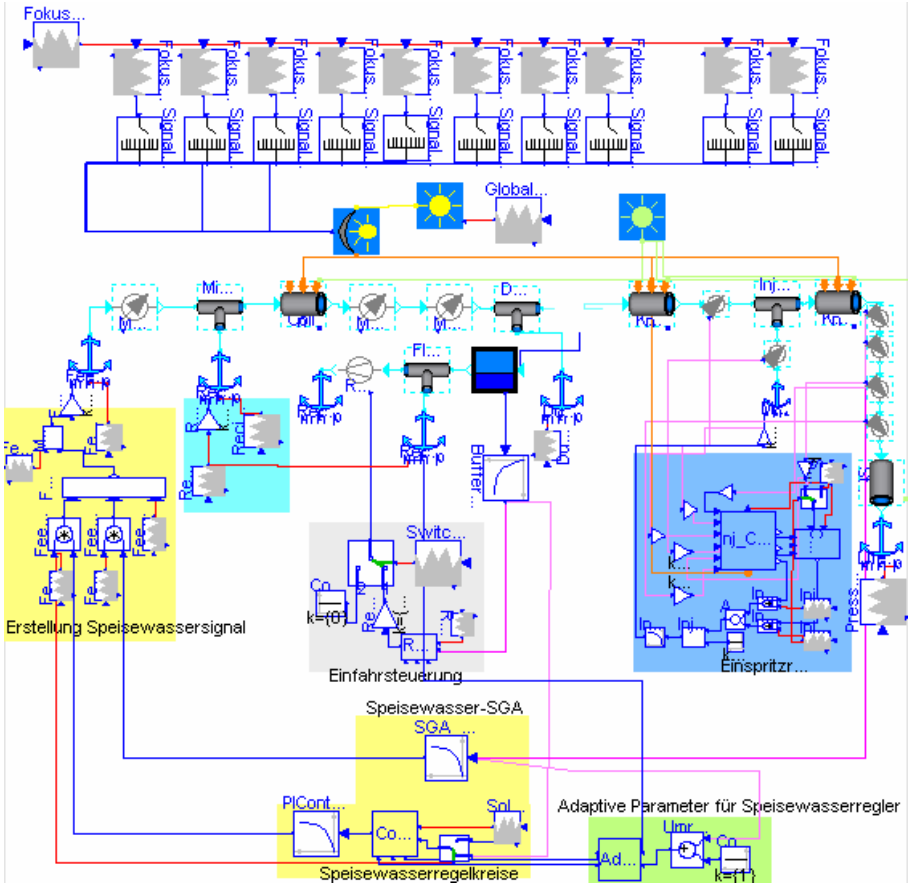
- ➢ local
- ➢ fast changes
- ➢ many disturbance scenarios
- ➢ limited predictability



Solar field under changing conditions – Simulation tool

Modelica/DYMOLA

- modular
- especially suited for transient simulation
- different model libraries available
- DLR libraries:
  - TechThermo
  - DissDyn
  - TTStorage



Solar field under changing conditions – Simulation tool

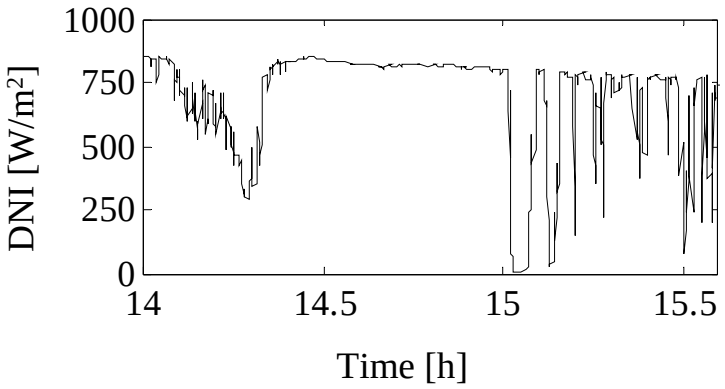
Validation at DISS test facility

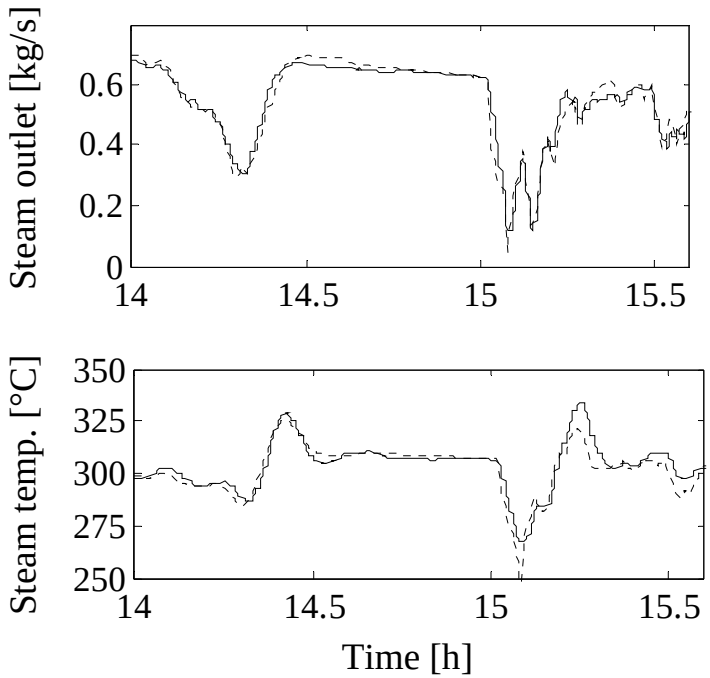
Input:

- DNI
- feed water mass flux

Output:

- steam mass flux
- steam temperature



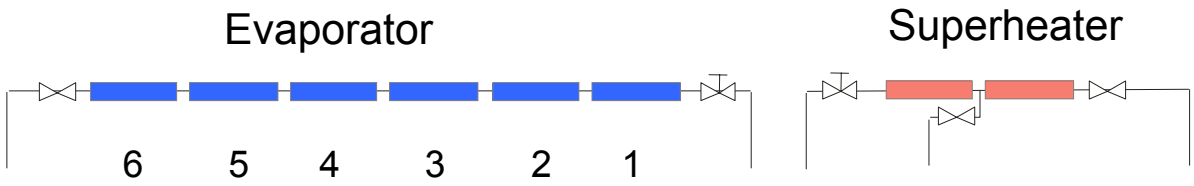


measured
simulated

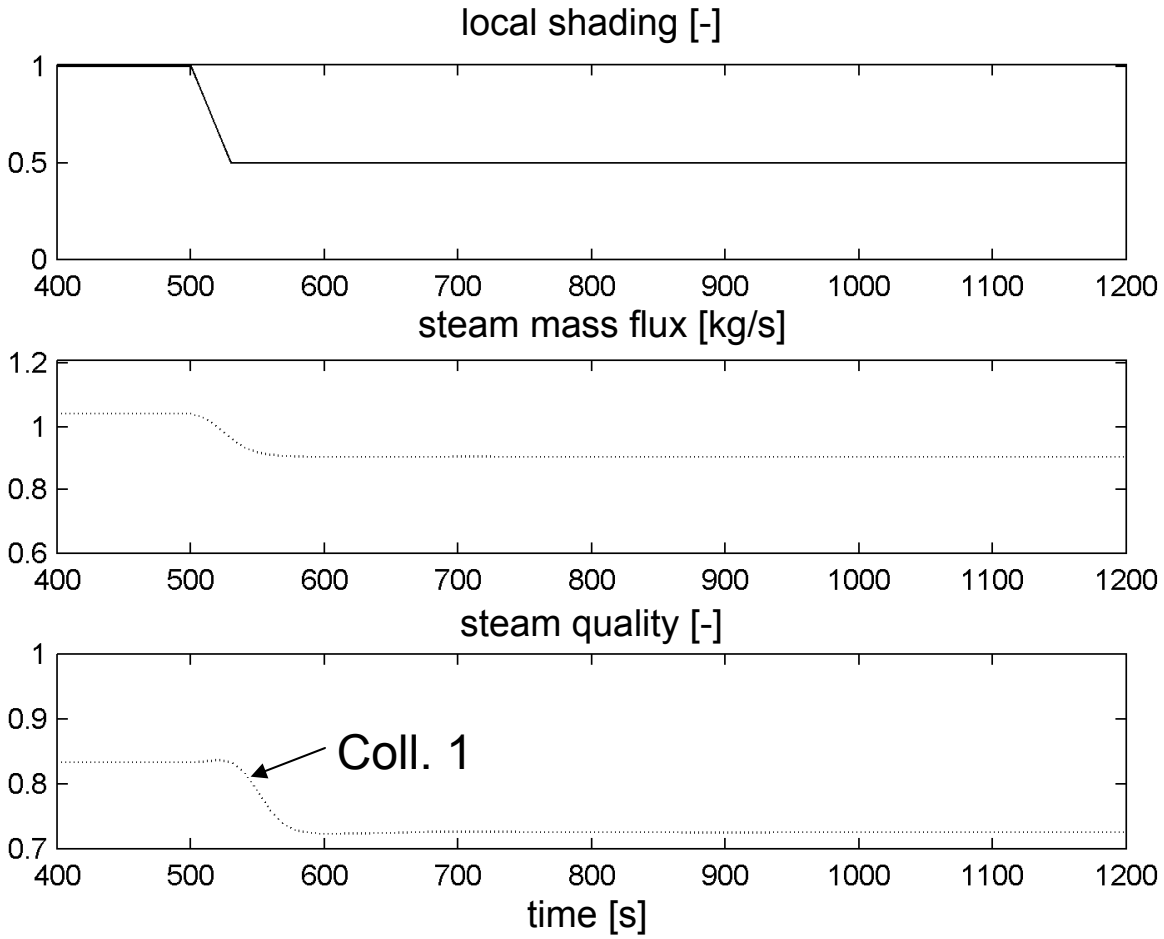
Solar field under changing conditions – Local Shading

Reaction to local shading of single evaporation collector

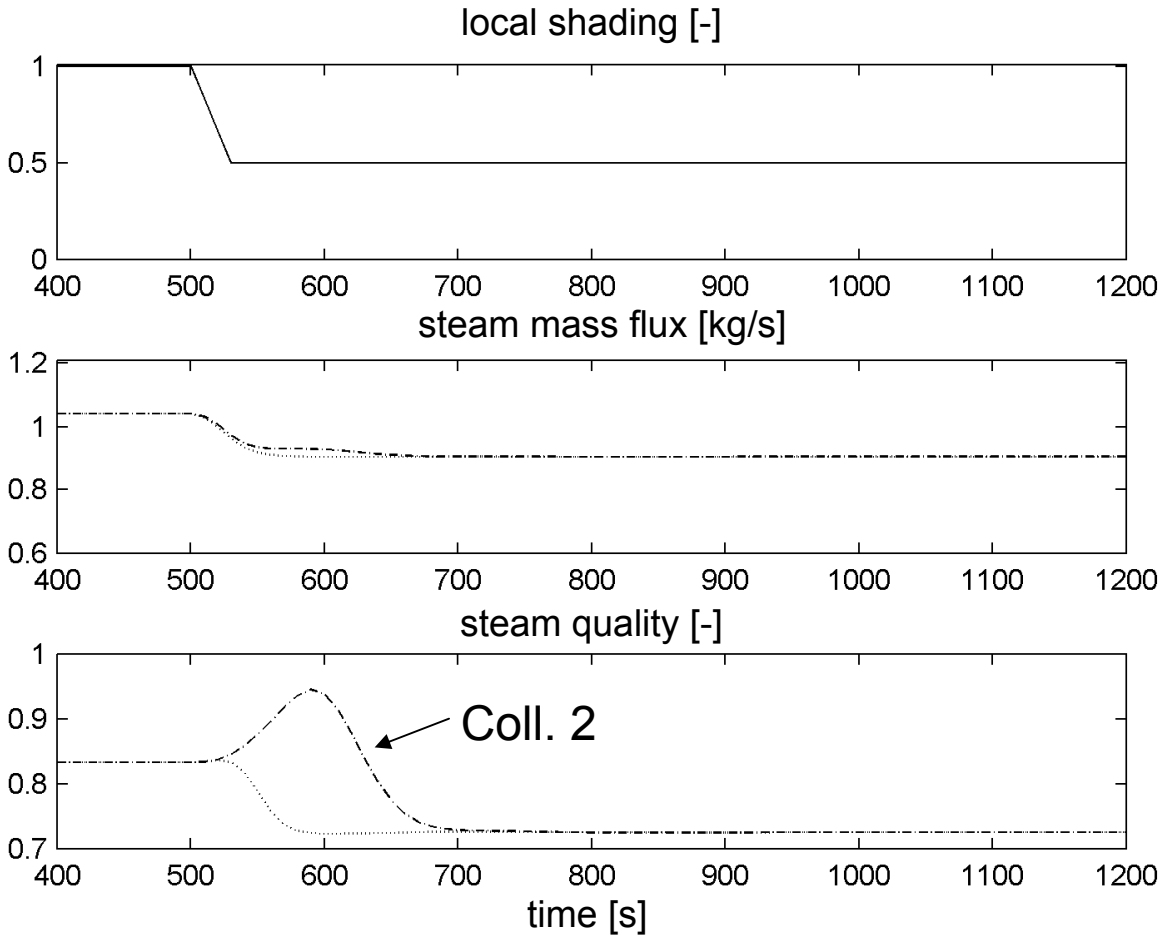
- six collectors in series
- evaporator and superheater subdivided by separator



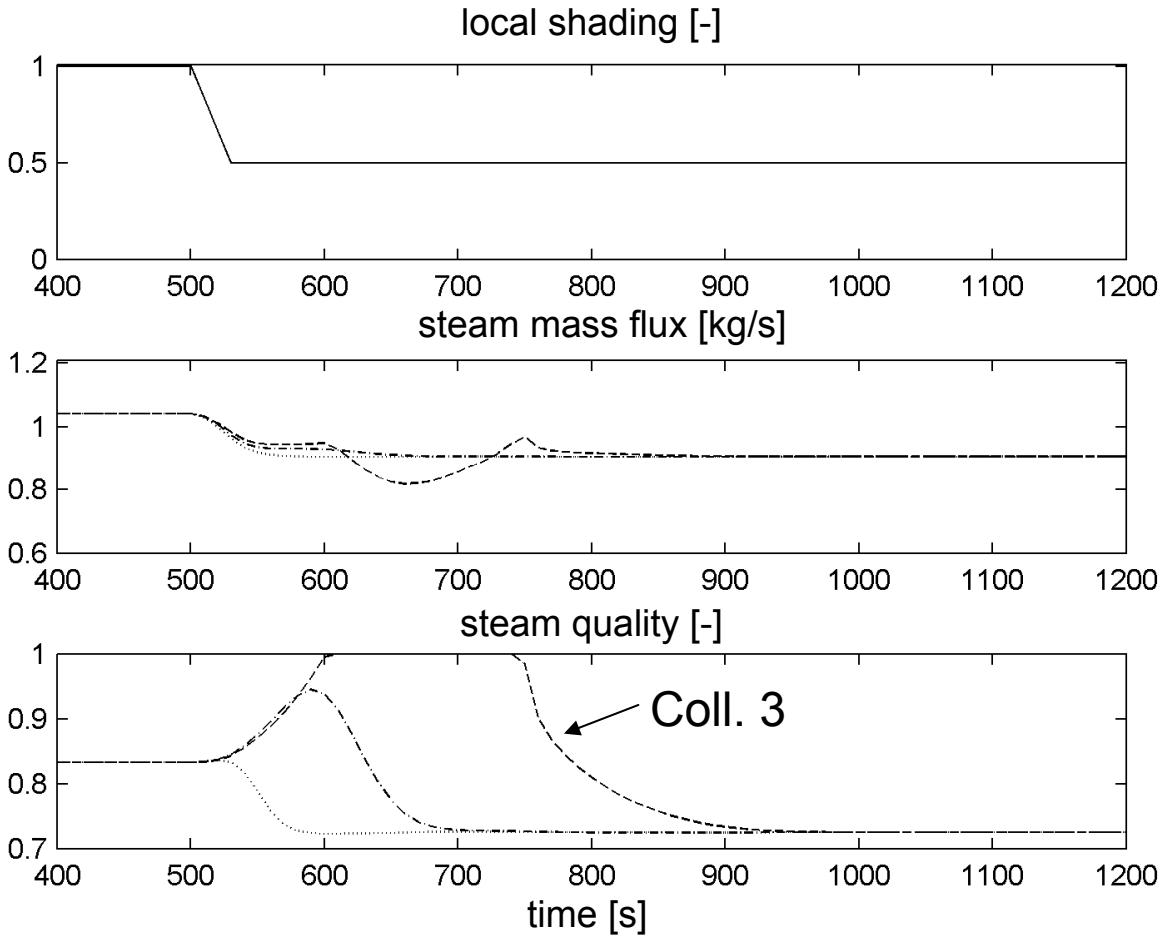
Solar field under changing conditions – Local Shading



Solar field under changing conditions – Local Shading



Solar field under changing conditions – Local Shading



complex situation
in evaporator

spatiotemporal
dependencies

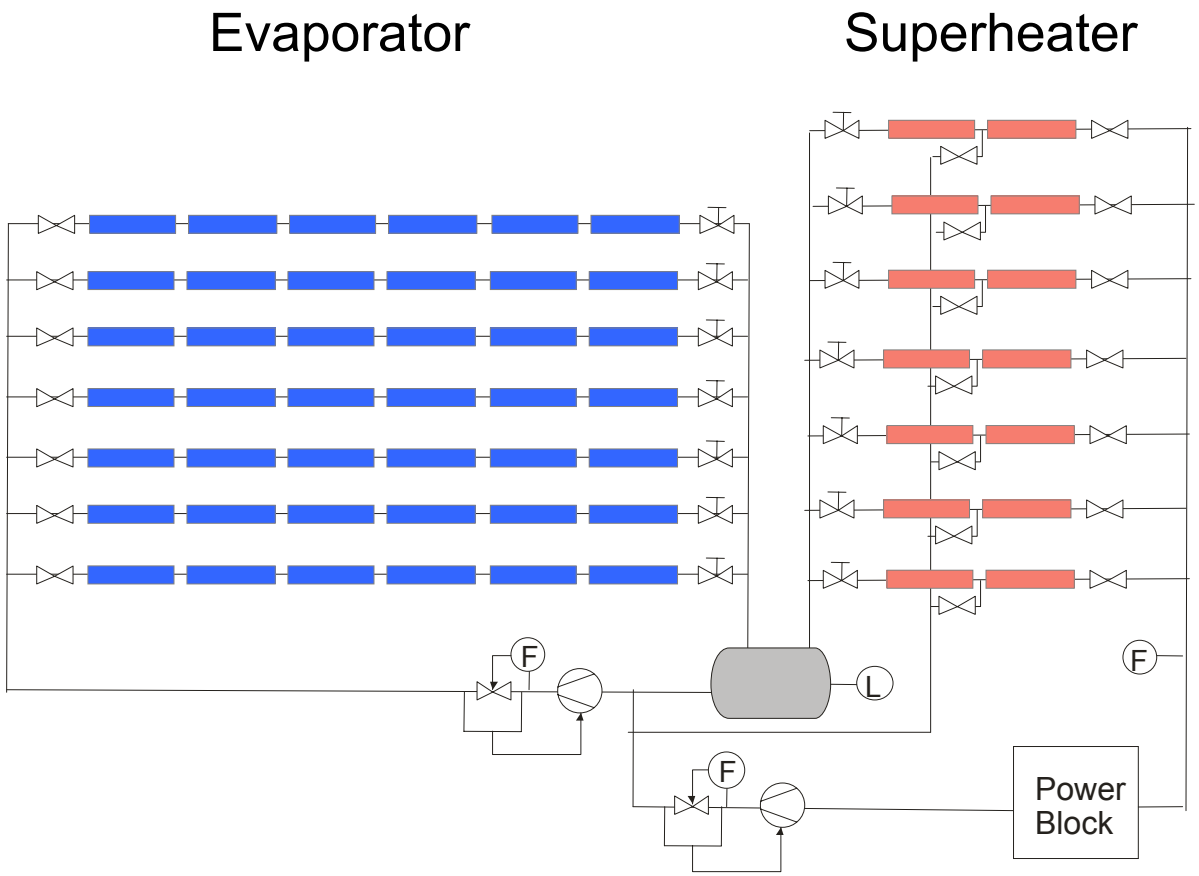
Measures to smoothen field output

Possibilities

- local averaging in collector fields
- control
- utilization of thermal inertia
- thermal storage / fossil backup

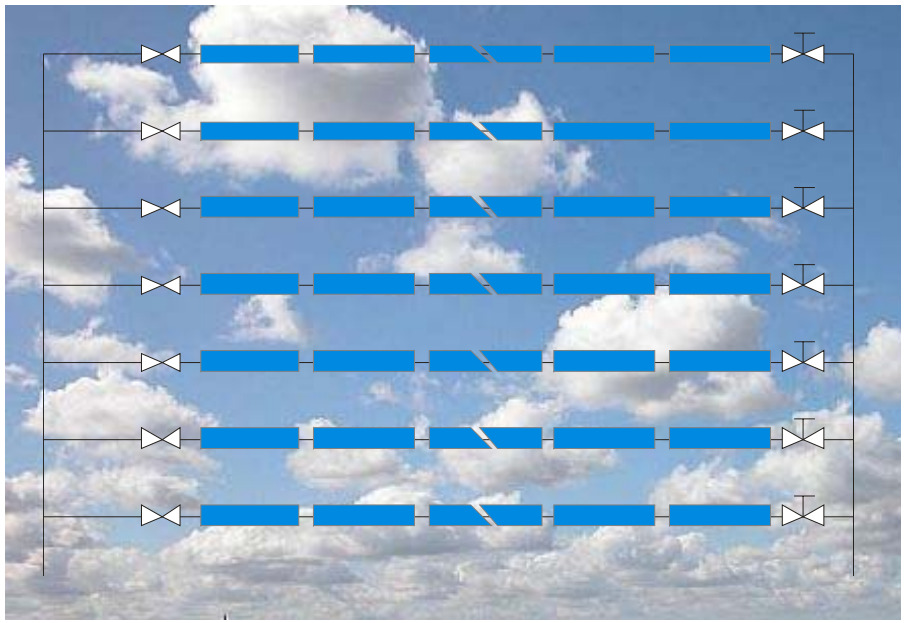
Measures to smoothen field output

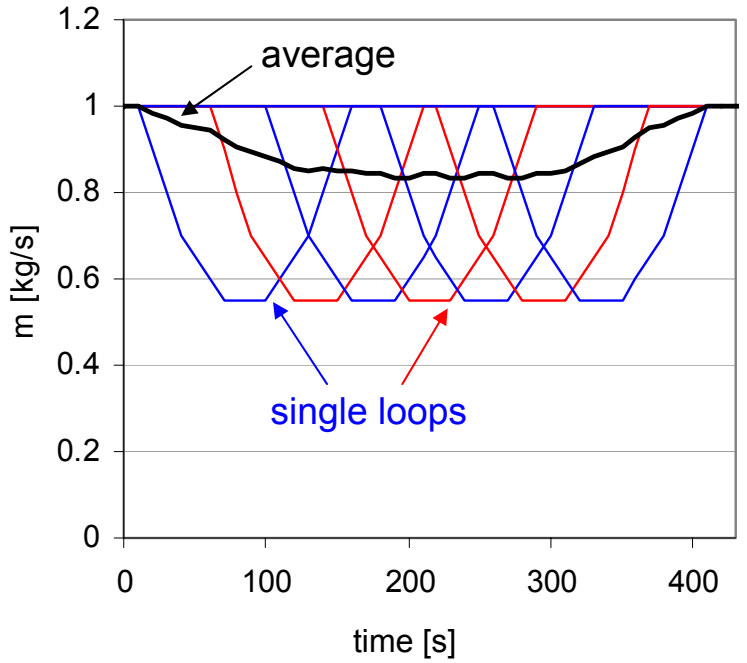
Local averaging



Measures to smoothen field output

Local averaging – Evaporator (uncontrolled)

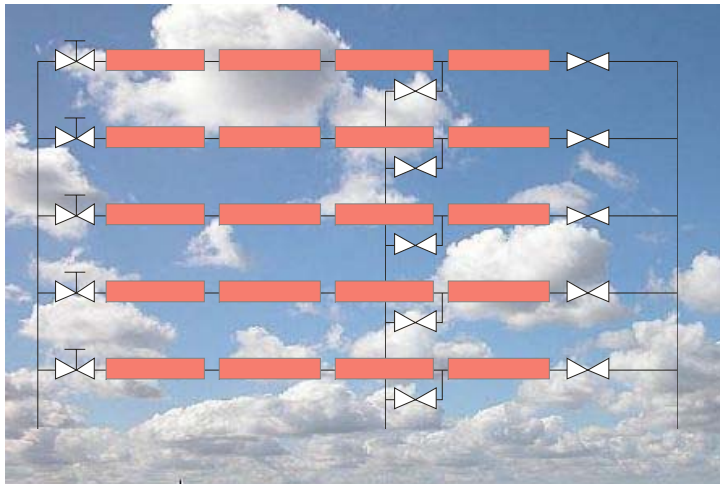


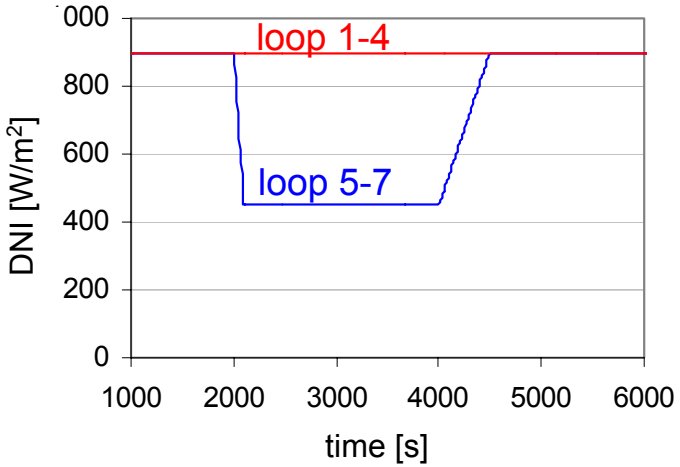


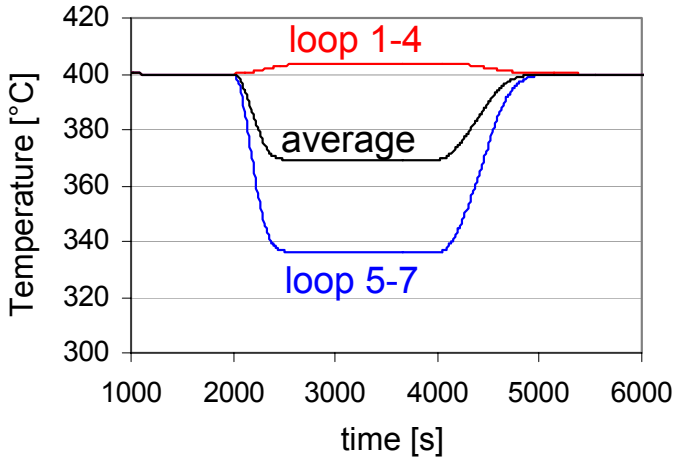
- reduced amplitude of mass flux disturbance
- damped gradients

Measures to smoothen field output

Local averaging – Superheater (7 loops, uncontrolled)







- reduced amplitude of temperature disturbance

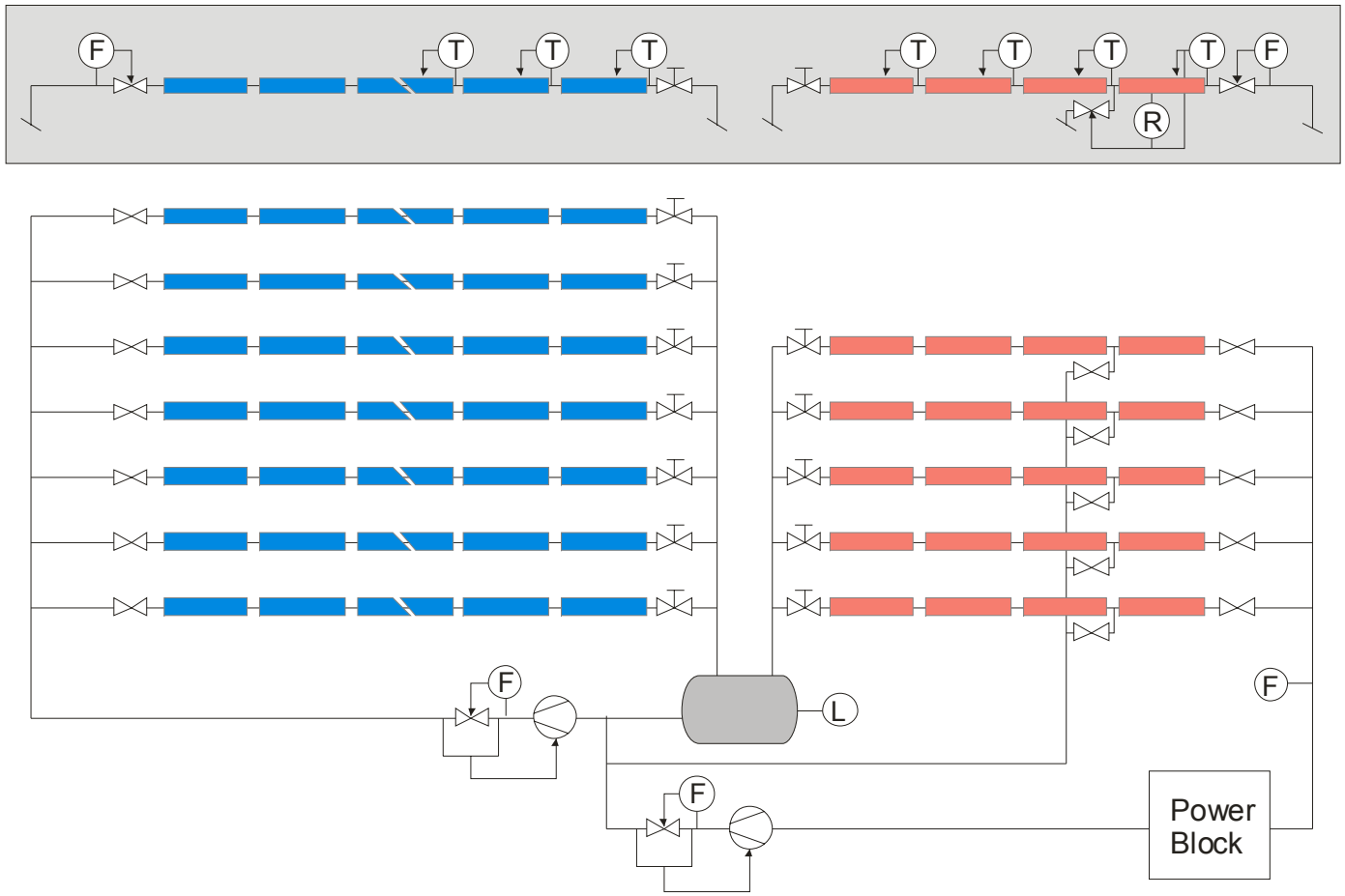
Measures to smoothen field output

Local averaging

- local averaging of collector fields causes
    - reduced amplitudes
    - slower transients
- limited averaging in superheater due to limited upper fluid temperature

Measures to smoothen field output

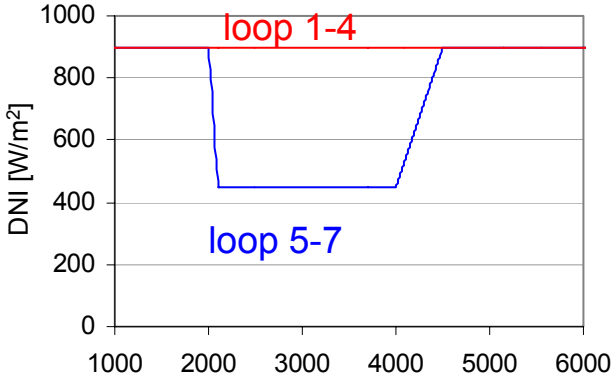
Control – P&ID

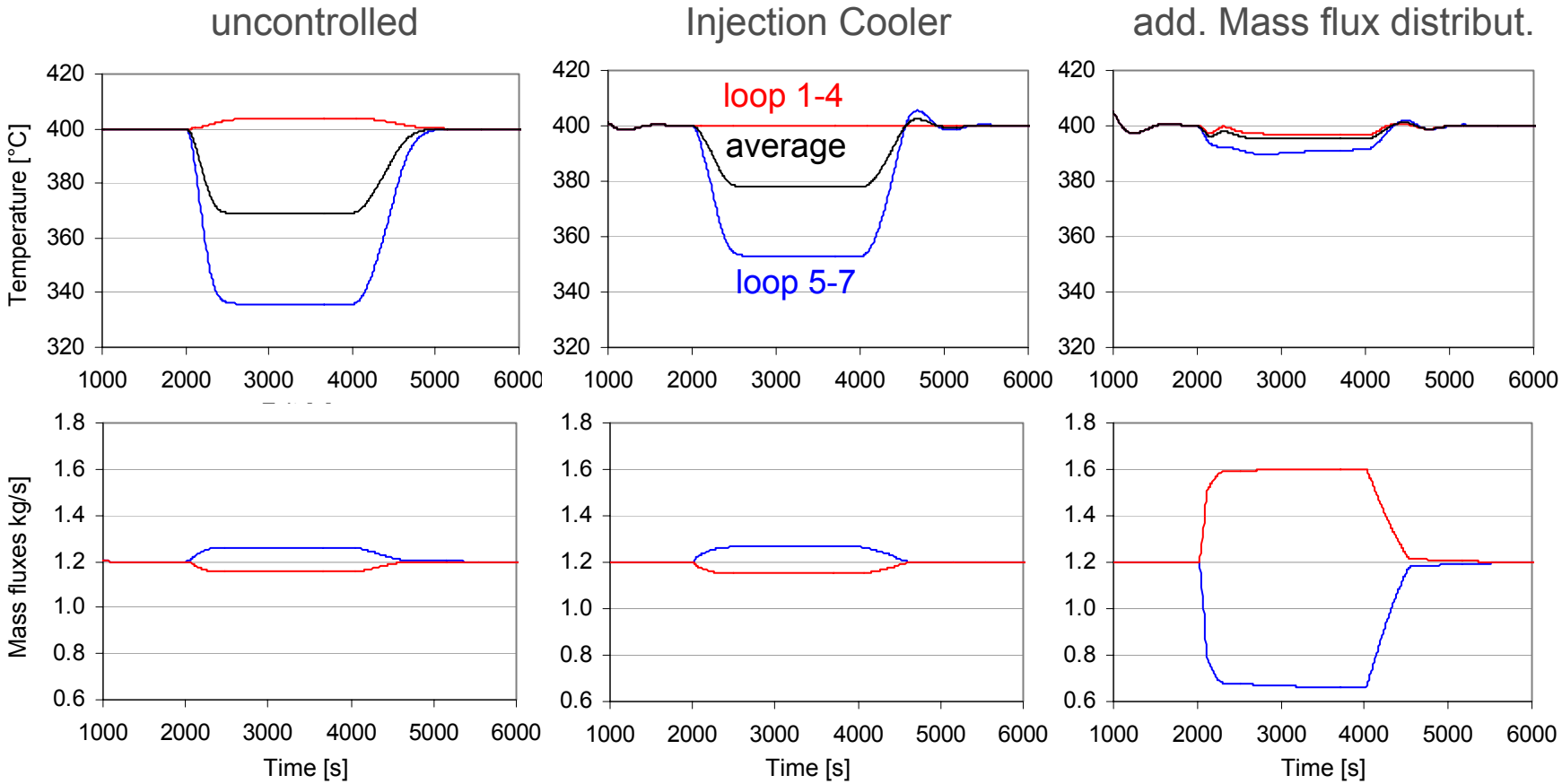


Measures to smoothen field output

Control – Superheater

DNI reduction on 3 loops

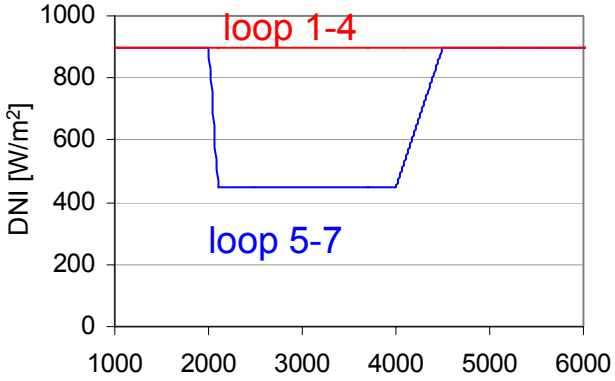


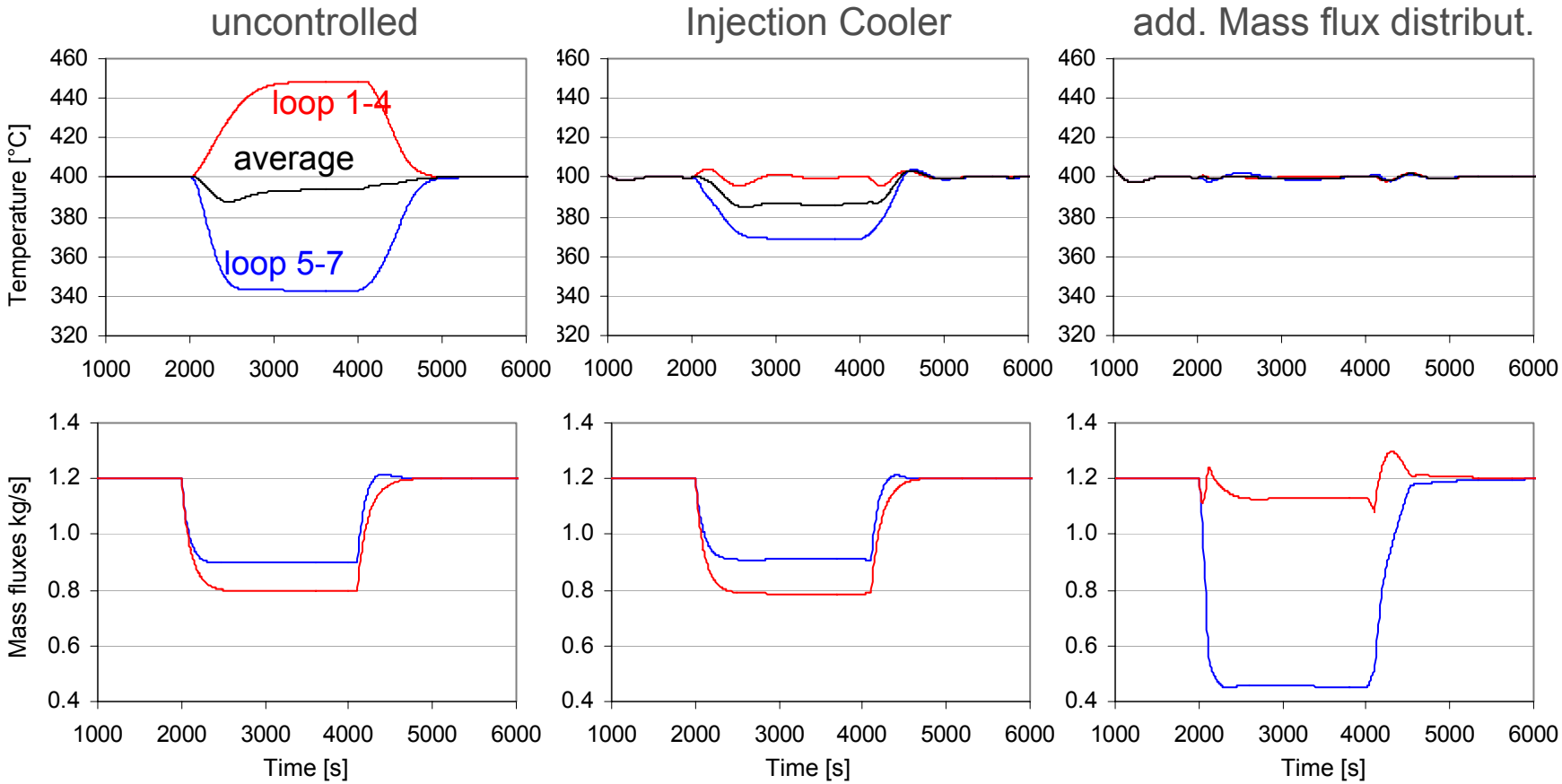


Measures to smoothen field output

Control – Superheater

DNI reduction on 3 loops and total mass flux disturbance





Measures to smoothen field output

Control

- temperature control in superheater leads to small live steam temperature deviations
- temperature deviations can be reduced by additional mass flux control

Economic Analysis

German R&D project DIVA (funded by BMU)

- Target: evaluation of DSG cost potential and comparison with HTF Technology (ANDASOL)
- Partners: SCHOTT, DLR, Flagsol, KK&K
- Schedule: final report Oct. 2007

Economic Analysis

German R&D project DIVA

- investigation of 20 different system configurations
- determination of optimum process parameters
- determination of yearly energy production and investment
- determination of LEC`s

		Steam Temperature [°C]				
		T_s	370	400	450	500
Net Power	5 MW					
	10 MW					
	50 MW					
	100 MW					

Summary

- DSG process is feasible
- validated design tools are available
- operation and control of parallel loops was investigated
- final cost potential will be determined until Oct. 2007
- next step has to be erection of first pre-commercial DSG plant

Outlook