Concept and Measurement Results of Two Solar Thermal Feed-in Substations

Research Project SOLSTAND

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Pilot Plants of R&D SOLSTAND

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Name	Substation Type	Feed-In Temperature	Heat Output	Current State
FP1	**Feed-In**	**110 °C**	**30 kW**	**In Operation**
FP2	Feed-In	75 °C	89 kW	In Operation
FP3	**Feed-In direct**	**75 °C**	**60 kW**	**Performance Optimization**
FP4	Prosumer	65 °C	44 kW	Performance Optimization

Collector fields of
Feed-in Plant 1 (left) &
Feed-in Plant 3 (right)

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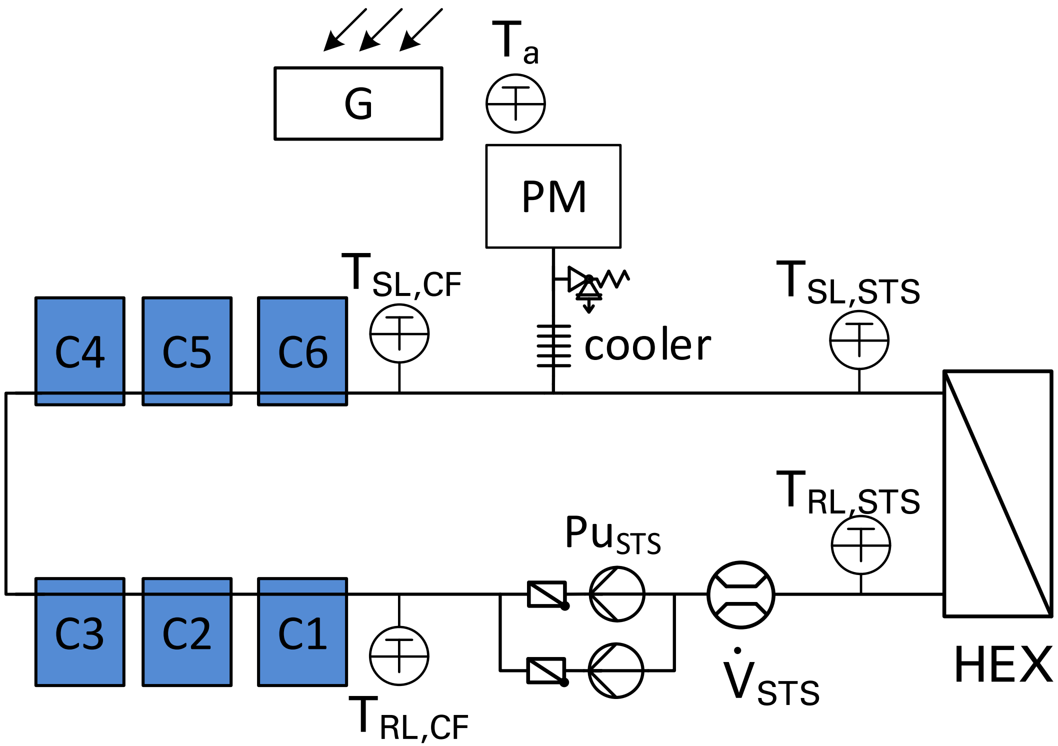
Concept - FP1 (solar side)



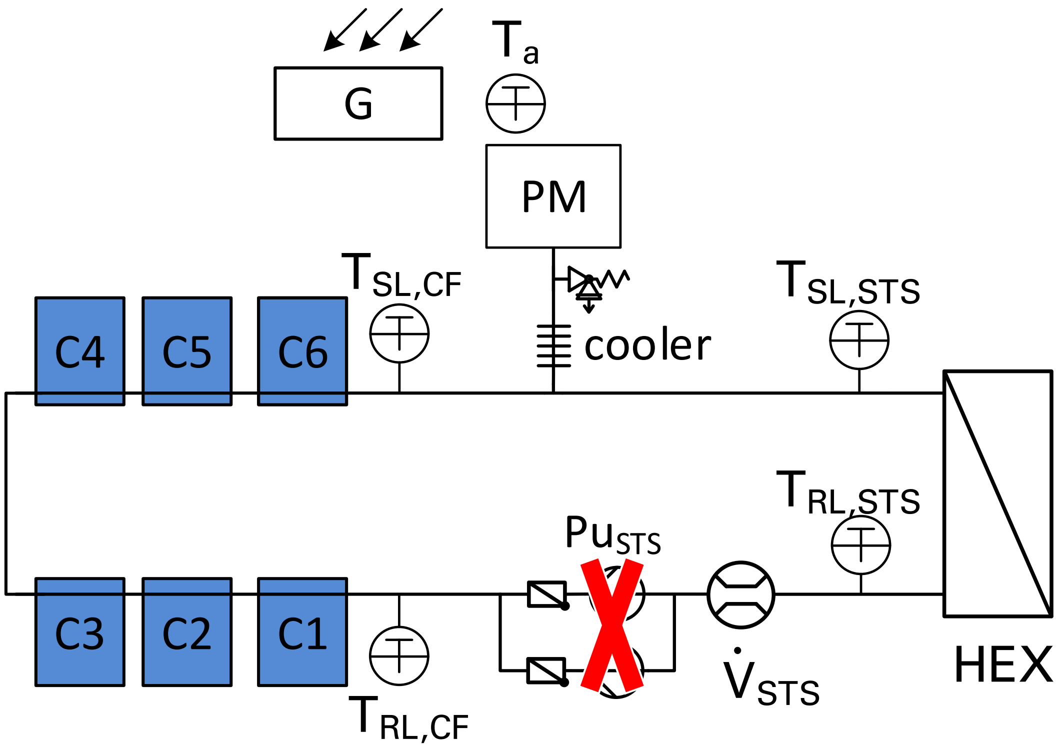
Facts:

- 83 m² gross collector area
- Vacuum tube TEST-collectors
- Water as heat transfer medium

Operation states:

CF .. collector field, STS .. solar thermal system

Concept - FP1 (solar side)



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Operation states:

1. Standby

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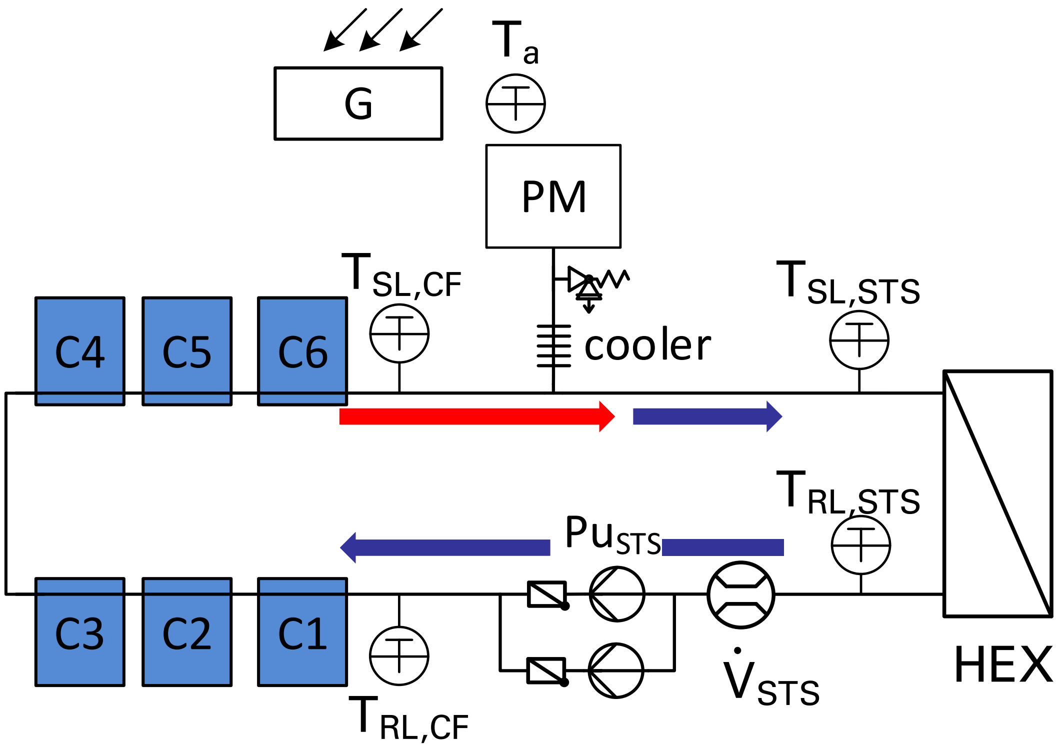

Facts:

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Operation states:

1. Standby
2. HeatUp

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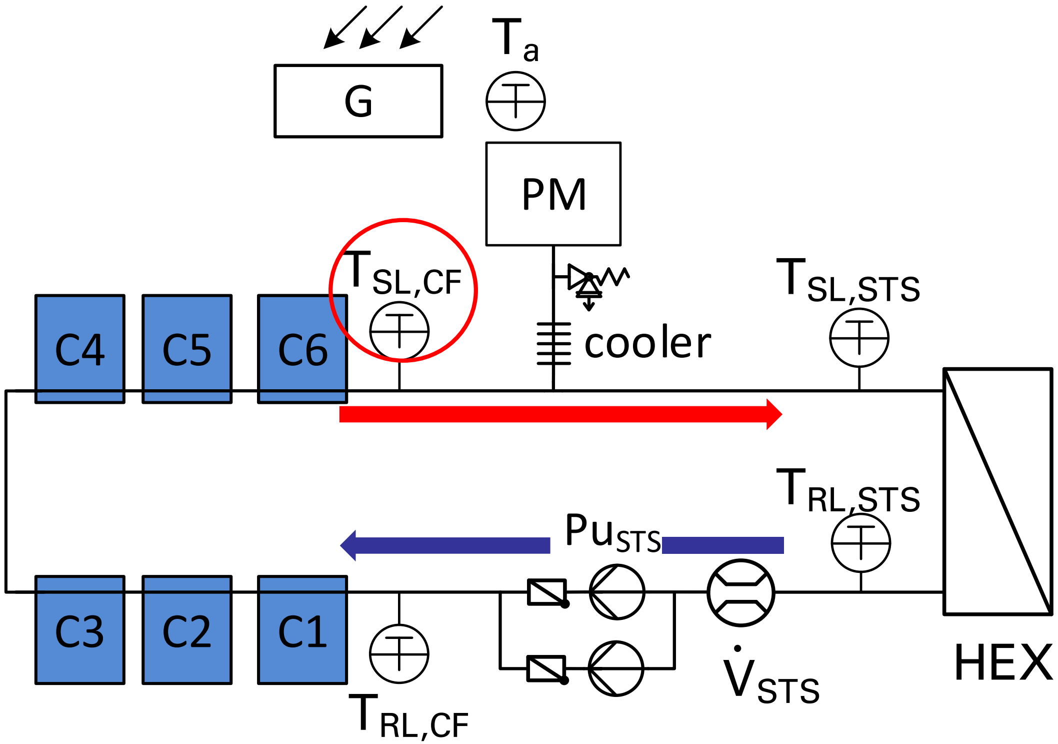

Facts:

- 83 m² gross collector area
- Vacuum tube TEST-collectors
- Water as heat transfer medium

Operation states:

1. Standby
2. HeatUp
3. Feed-in
   - matched flow temperature setpoint control of $T_{SL,CF}$

CF .. collector field, STS .. solar thermal system

Concept - FP1 (DH side)

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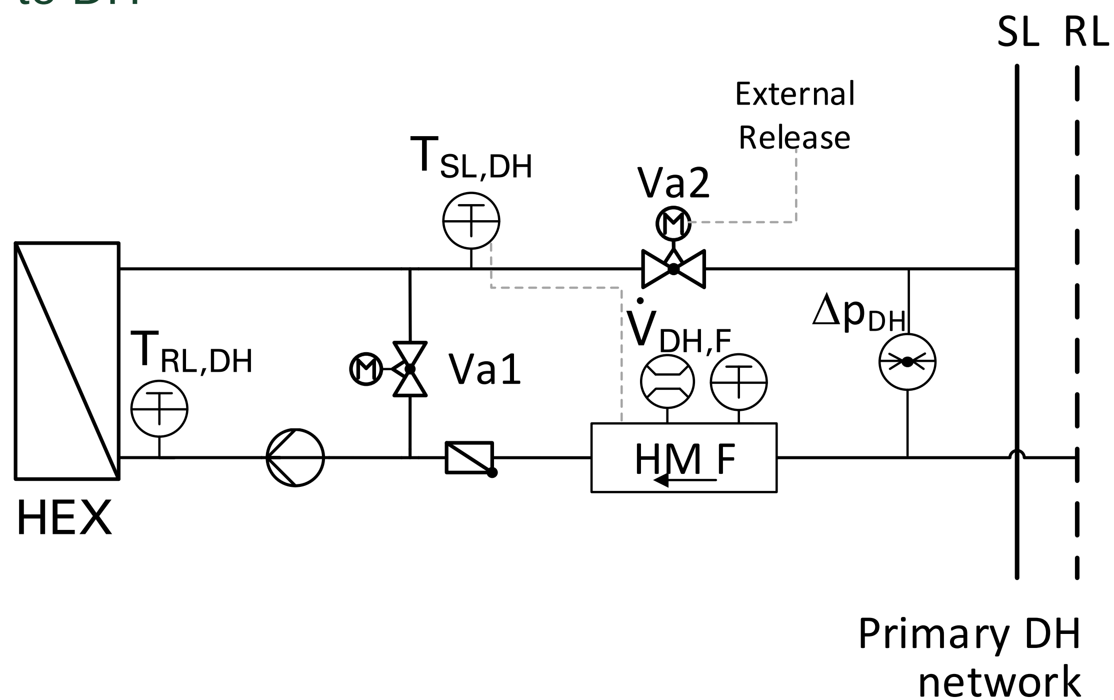
Facts:

- RL/SL feed-in, indirect connection to DH
- External Release Signal

Operation states:



DH .. district heating network

Concept - FP1 (DH side)

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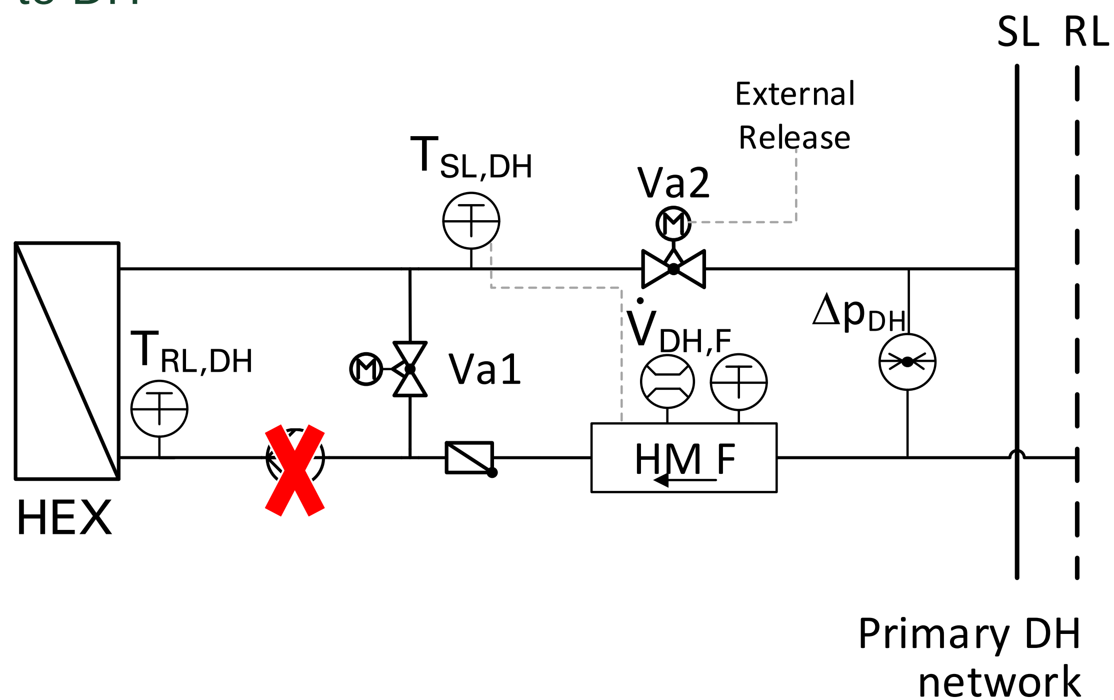

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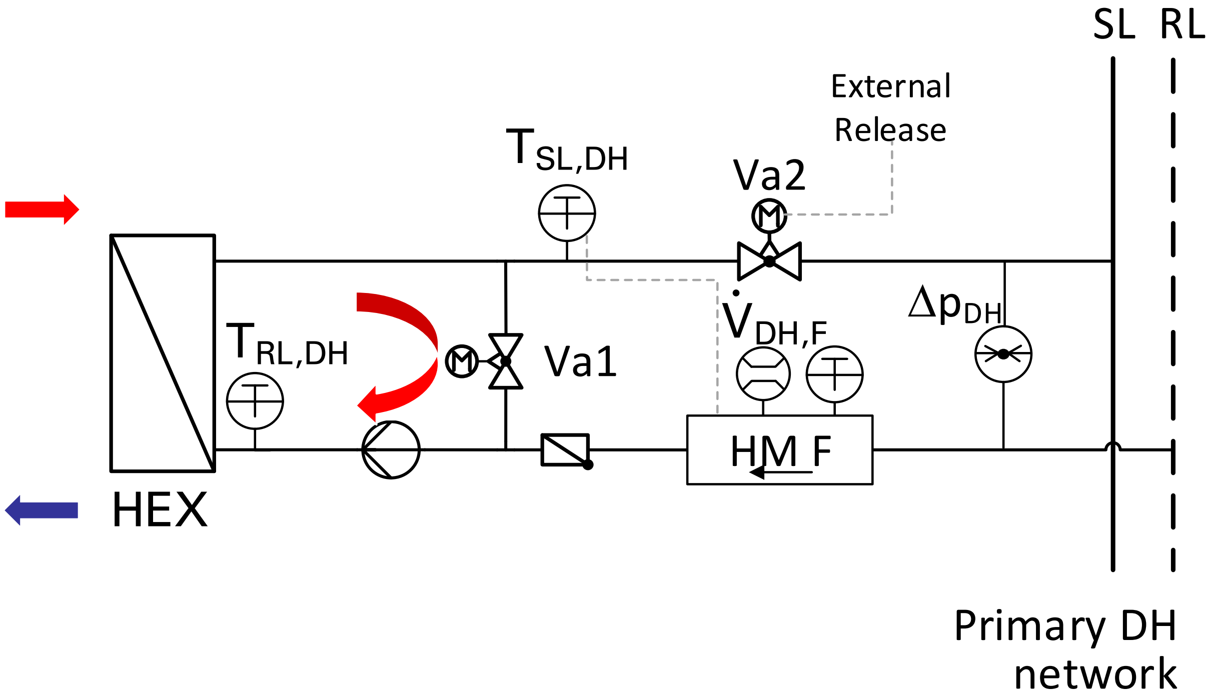

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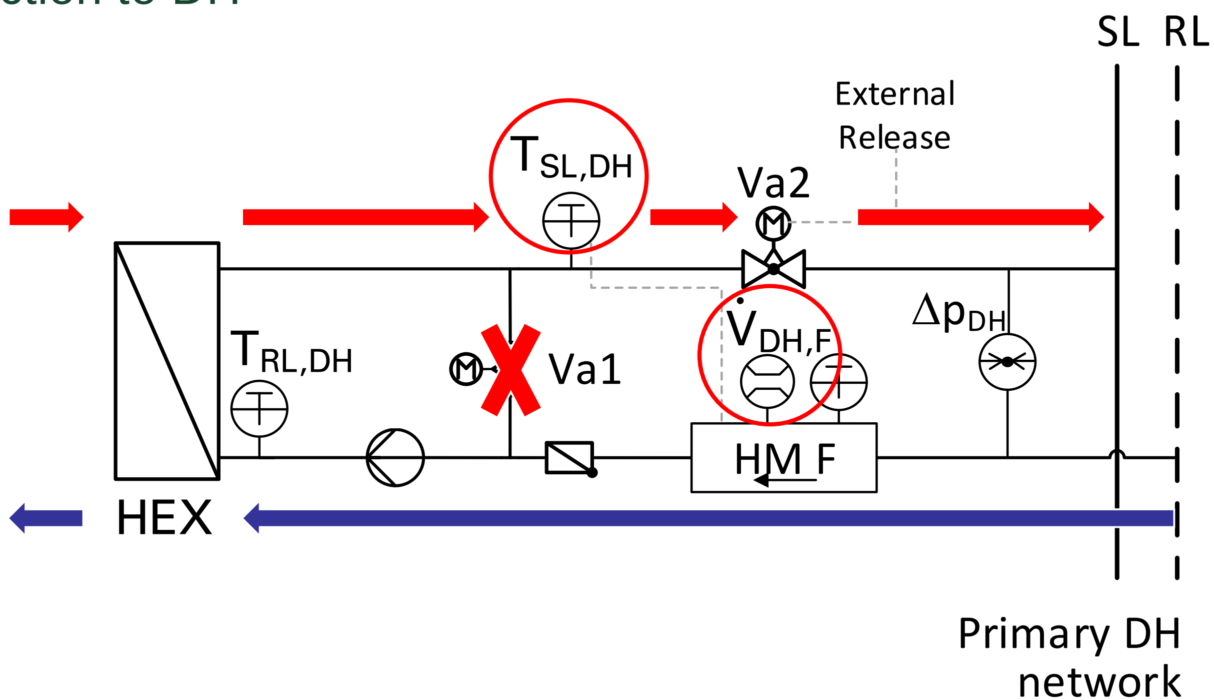
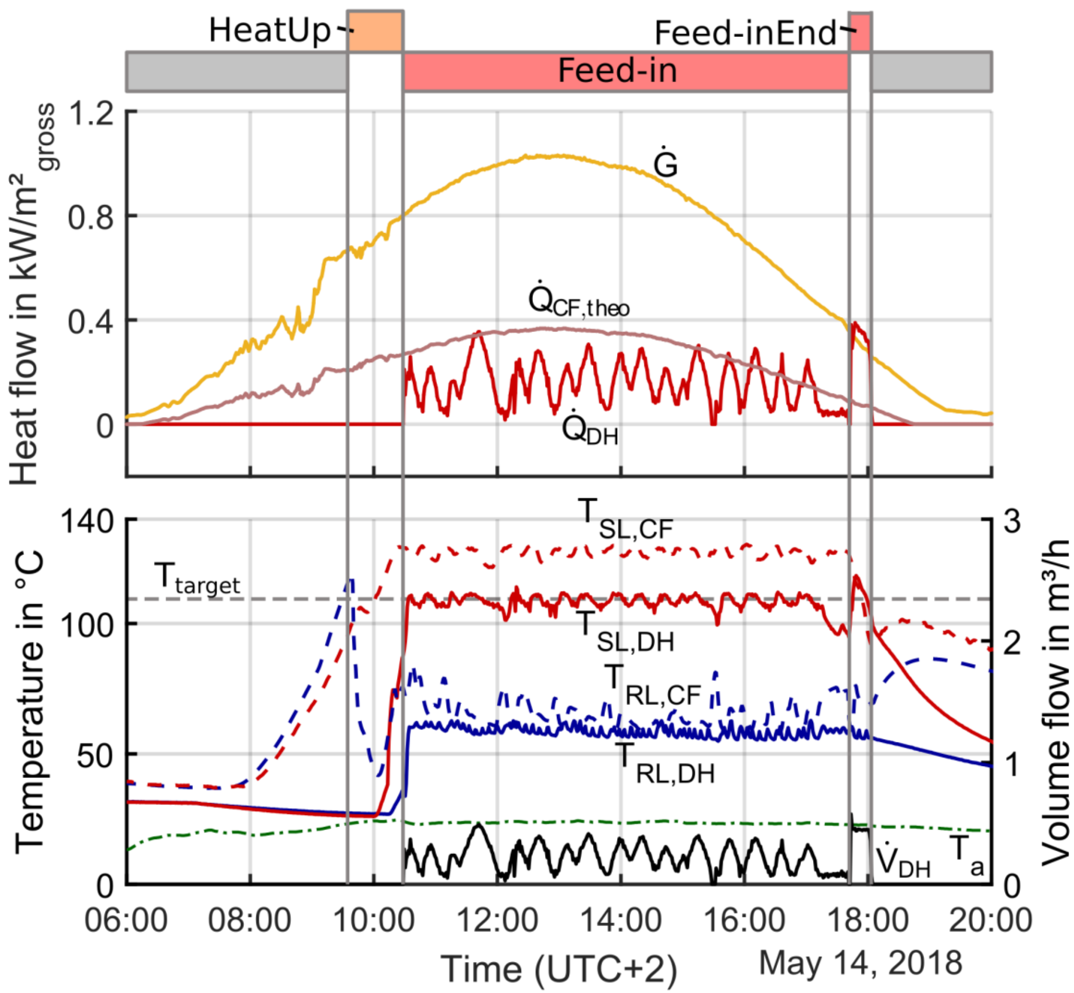


Operation states:

1. Standby
2. HeatUp
3. Feed-in
   - Cascade control
   - matched flow setpoint control of $T_{SL,DH}$,
   - volume flow signal $\dot{V}_{DH,F}$ used to maintain stable volume flow despite changing Δp_{DH}

DH .. district heating network

Operation Behavior - FP1



- Thermal output of collector field below theoretically expected gains (TEST-collectors)
- Fluctuating volume flow and thermal output (due to large piping and thermal capacity of collectors)
- Heat can be delivered on challenging temperature level and pressure conditions
- Very stable feed-in temperature, minimal deviation to target temperature

Concept - FP3

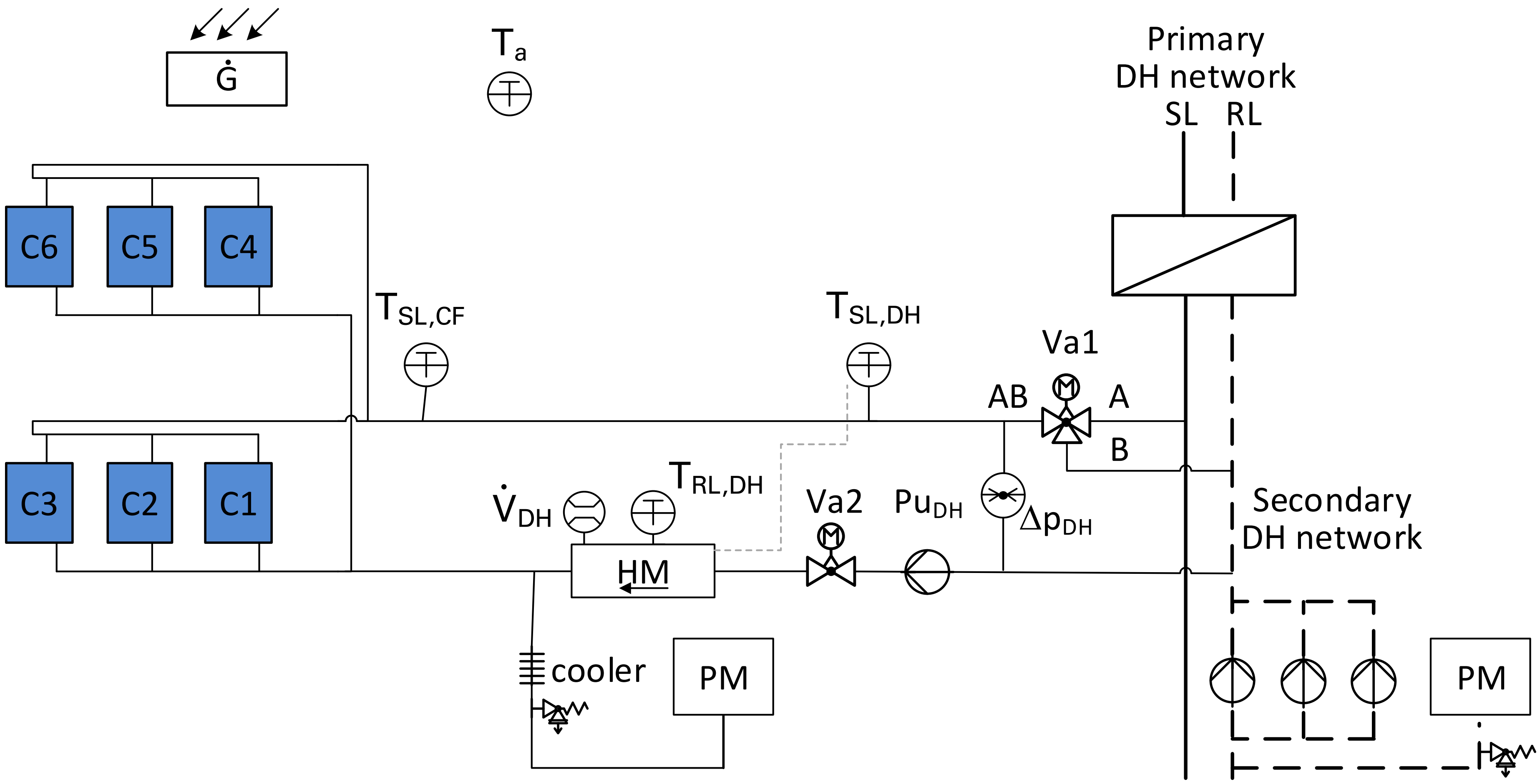
Facts:

- 143 m² gross collector area
- Vacuum tube collector Viessmann SPEA
- Water as heat transfer medium
- Direct connection to DH at main heat transfer station
- Usage of DH pressure maintenance as test

Operation states:

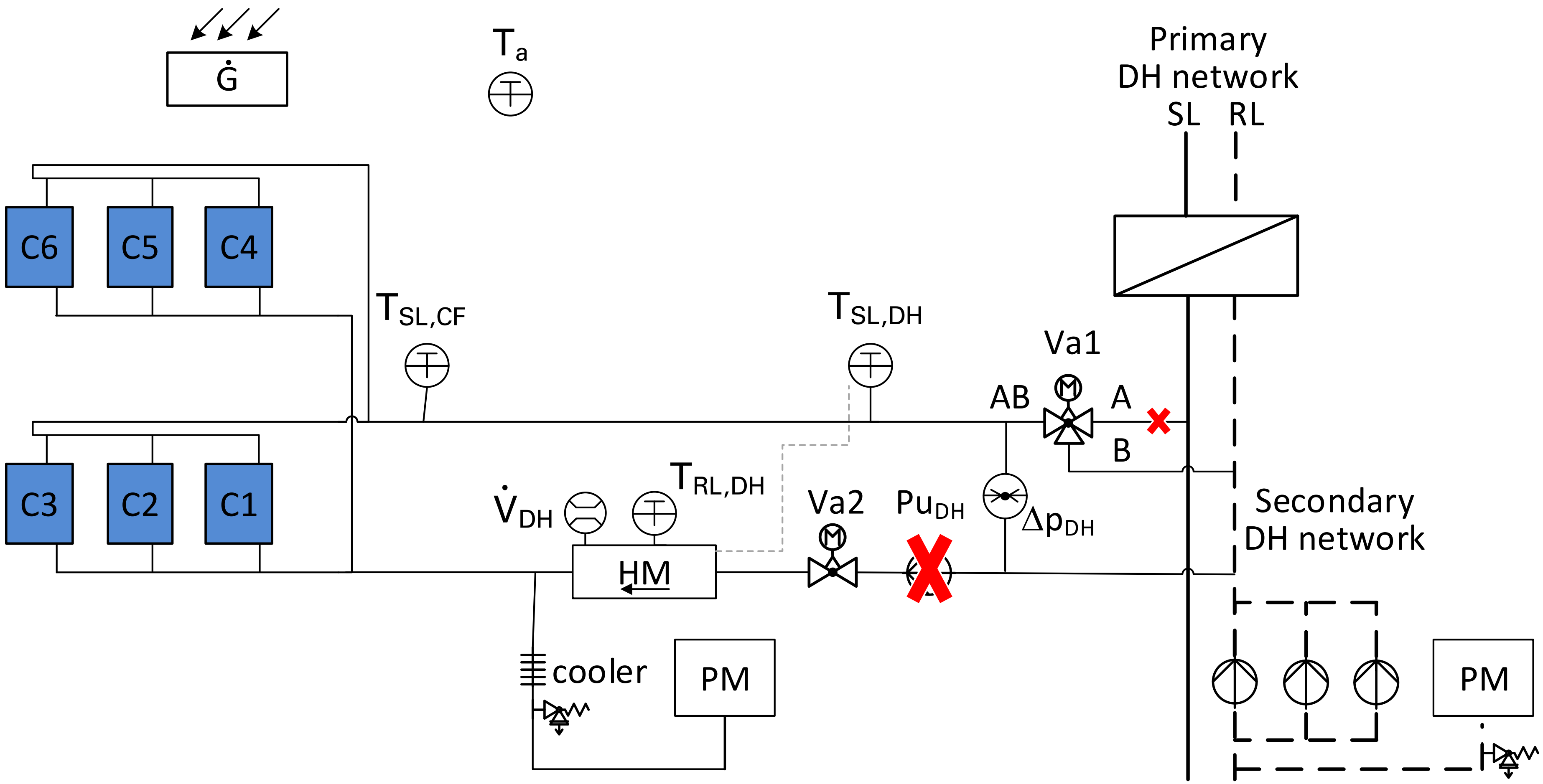
1. RL/RL feed-in for start-up
   - Activated, when starting temper-ature threshold is reached (65°C)
2. RL/SL feed-in for normal operation, (*not working so far!)*
   - Activated, when switching temper-ature threshold is reached (70°C)
   - matched flow setpoint control of $T_{SL,DH}$

Concept - FP3


Ġ
Ta
Primary
DH network
SL RL
C6
C5
C4
TSL,CF
TSL,DH
Va1
AB
A
B
C3
C2
C1
V̇DH
TRL,DH
Va2
PuDH
ΔpDH
Secondary
DH network
HM
cooler
PM
PM

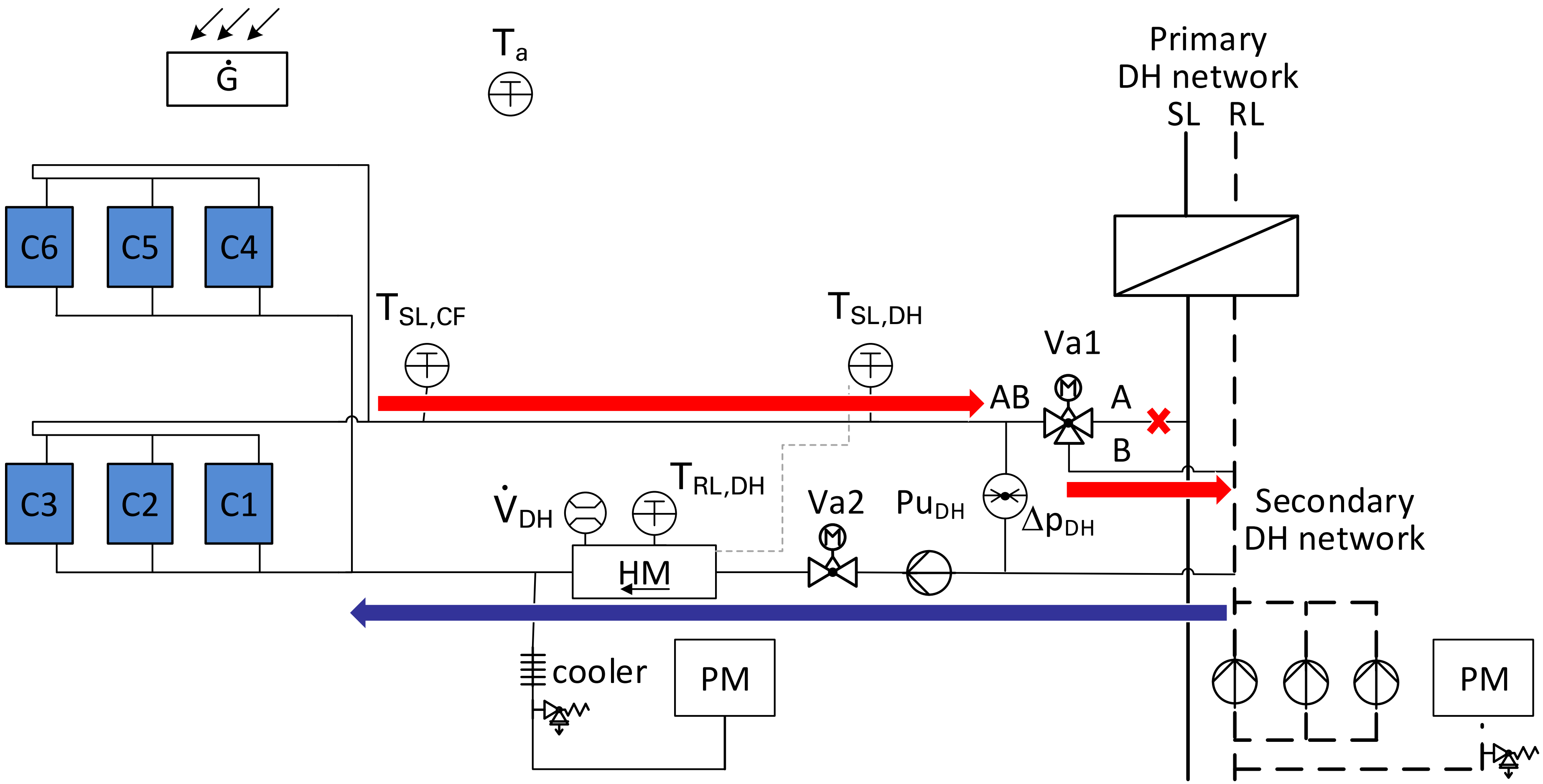
Concept - FP3

Operation state: Standby



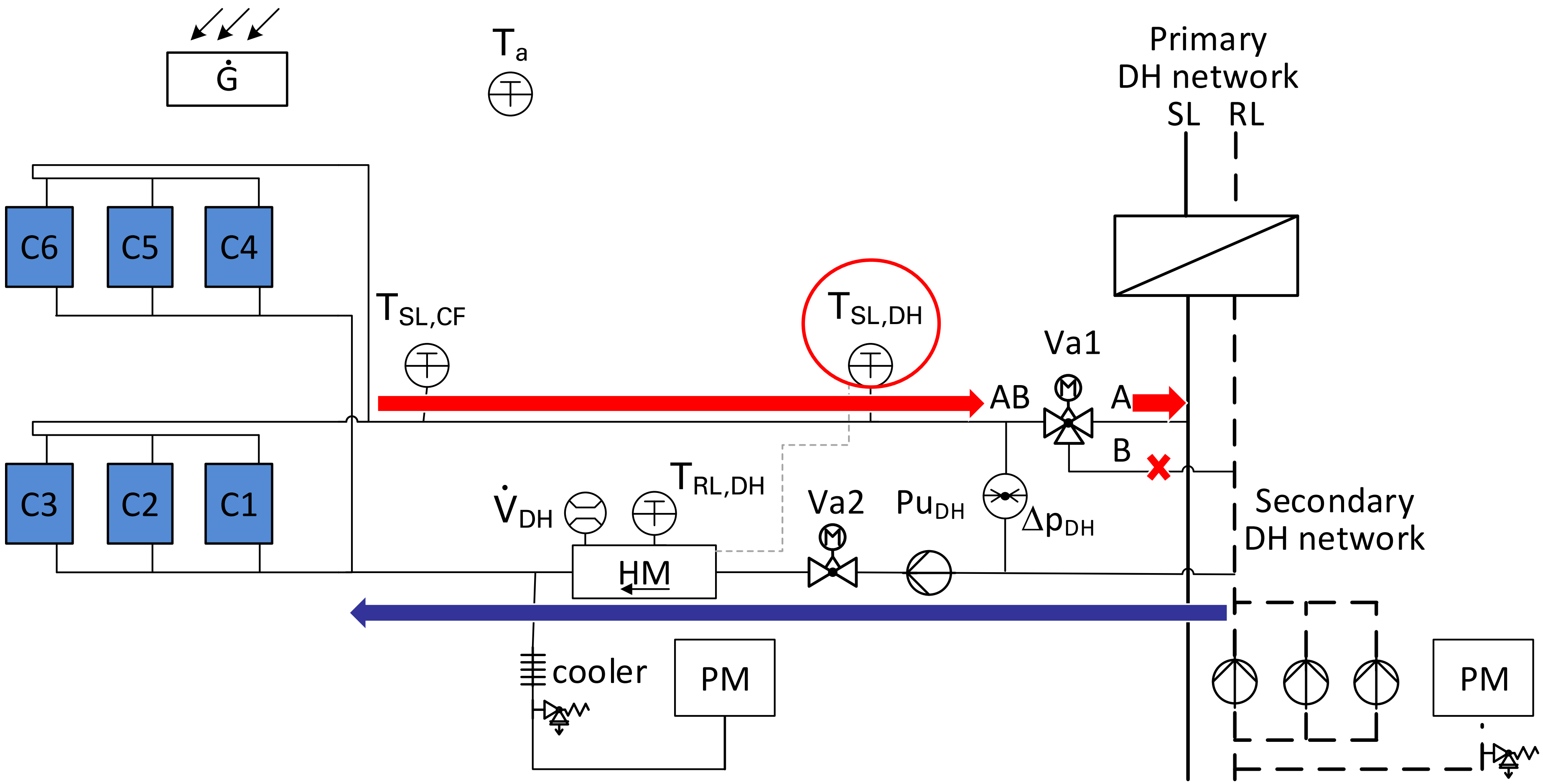
Concept - FP3

Operation state: RL/RL Feed-in

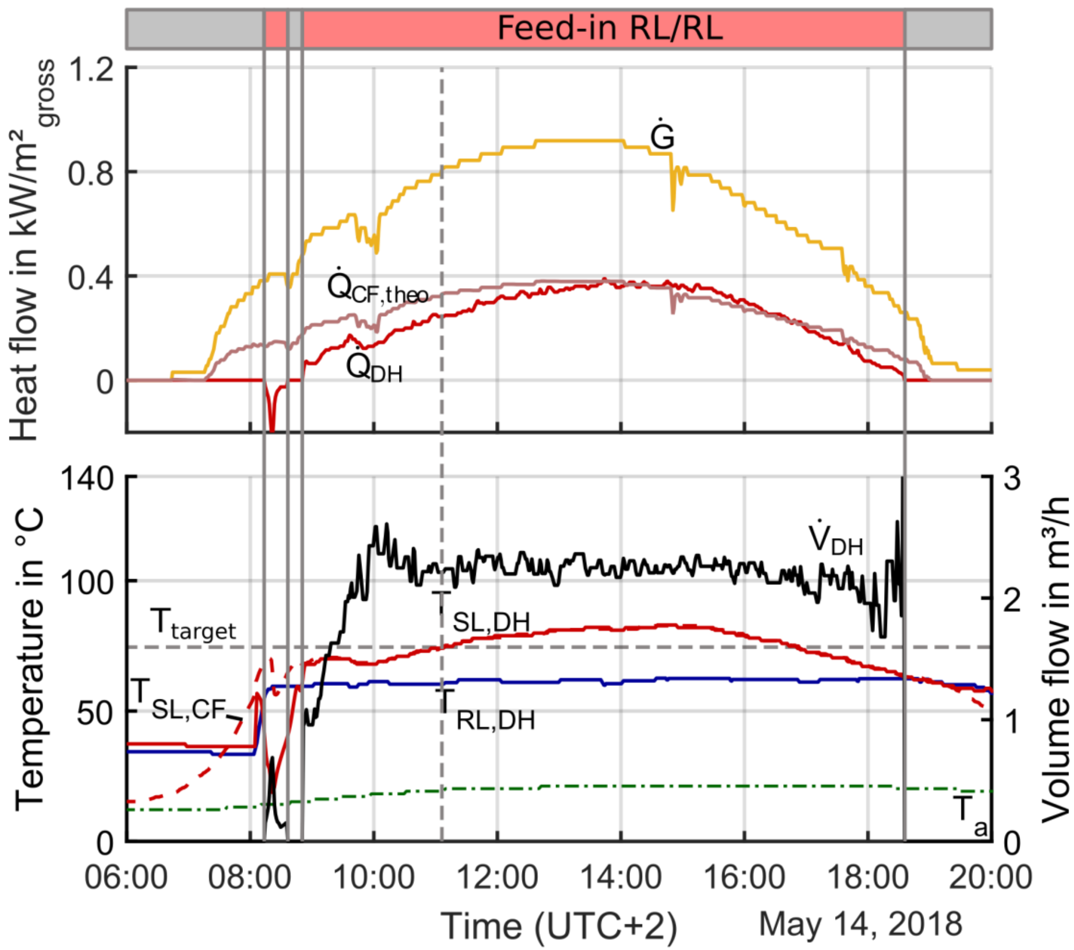


Concept - FP3

Operation state: RL/SL Feed-in



Operation Behavior - FP3



- Thermal output of collector field close to theoretically expected gains
- Feed-in target temperature can not be maintained ($\dot{V}_{\mathrm{max}}$ of pump to small)

How to Compare Two Systems?

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Problem: Two systems with different concept, size and operation conditions

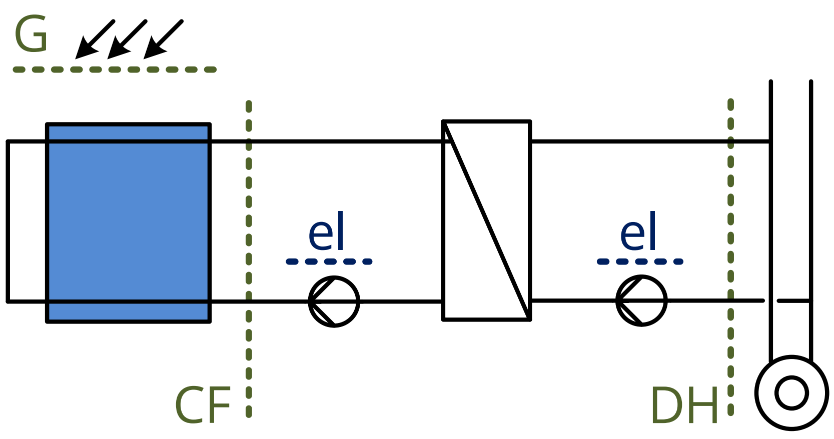
Solution: Usage of performance indicators ζ, ν, COP

$\zeta_{\mathrm{FP}} = \frac{Q_{\mathrm{DH}}}{G}$ Average efficiency of system

$\zeta_{\mathrm{FP\backslash CF}} = \frac{Q_{\mathrm{DH}}}{Q_{\mathrm{CF}}}$ Average efficiency of the FP, excluding the performance of the CF

$\nu_{\mathrm{CF}} = \frac{Q_{\mathrm{CF}}}{Q_{\mathrm{CF,theo}}}$ Degree of quality of the collector field, using the solar thermal collector equation as a simplified reference model

$COP = \frac{Q_{\mathrm{DH}}}{W_{\mathrm{el}}}$ Coefficient of performance, electrical energy consumption



$$\dot{Q}_{\mathrm{CF,theo}} = \dot{G} \cdot A \cdot \eta_{\mathrm{th}}$$

$$\eta_{\mathrm{th}} = f(\dot{G}, \vartheta_{\mathrm{SL}}, \vartheta_{\mathrm{RL}}, \text{collector parameters})$$

Boundary Conditions

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- Week in May 2018, four days sunny, two cloudy, one unsettled
- Similar weather conditions for both plants (6.3 km away from each other)
- Feed-in setpoint temperature of 110°C (FP1) vs. 65°C (FP3)

Date	Weather		FP1	FP3
parameter	G_{h}	$\bar{T}_{\mathrm{a}}$	$\bar{T}_{\mathrm{SL,DH}}$	$\bar{T}_{\mathrm{SL,DH}}$
considered during	day	feed-in	feed-in	feed-in
unit	kWh/m²/d	°C	°C	°C
10.05.18 (Start 00:00)	7,3	25	108	69
11.05.18	5,2	19	103	68
12.05.18	6,6	22	107	71
13.05.18	7,5	24	107	71
14.05.18	7,6	22	109	72
15.05.18	3,9	18	no feed-in	64
16.05.18 (End 24:00)	2,8	16	no feed-in	66
setpoint temperature			110	65

Energy Performance

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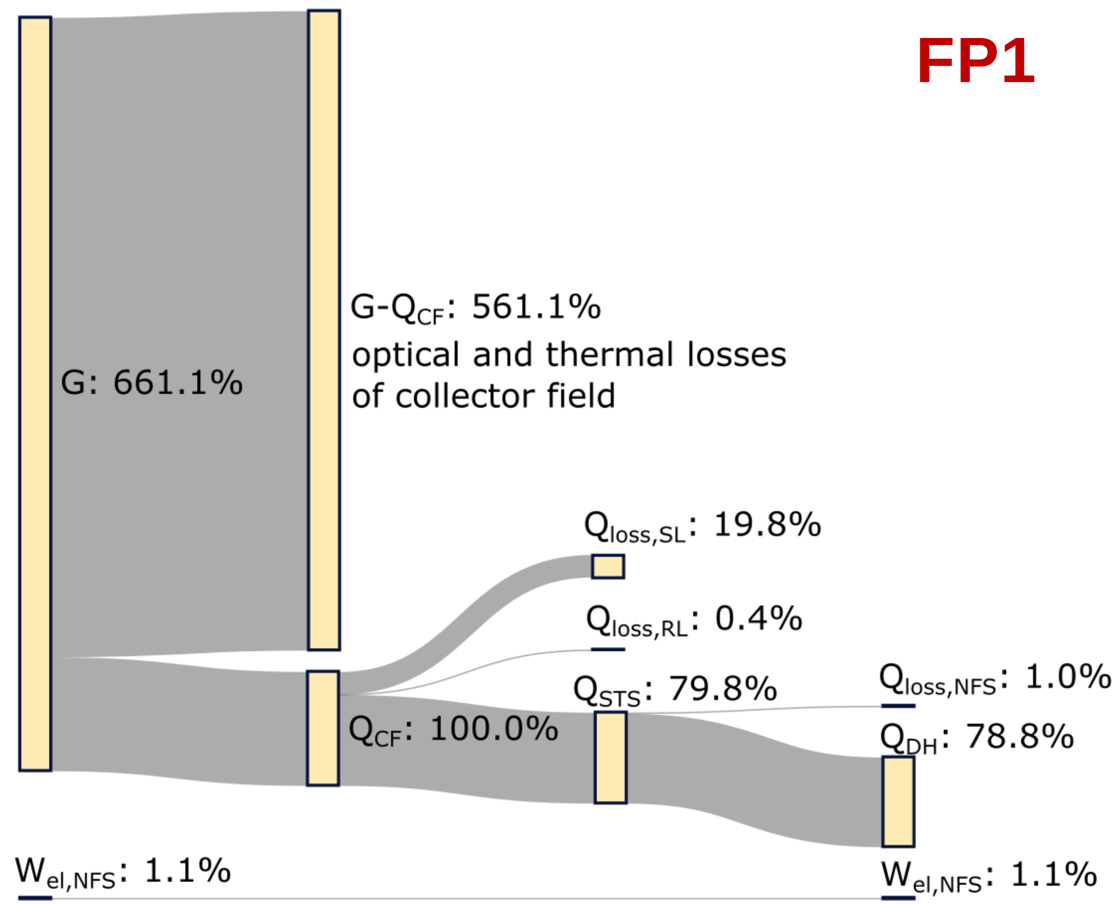
FP1	ζ_{FP}	$\frac{Q_{DH}}{G}$	12%
	$\zeta_{FP\backslash CF}$	$\frac{Q_{DH}}{Q_{CF}}$	79%
	ν_{CF}	$\frac{Q_{CF}}{Q_{CF,theo}}$	49%
	COP	$\frac{Q_{DH}}{W_{el}}$	69
FP3	ζ_{FP}	$\frac{Q_{DH}}{G}$	27%
	$\zeta_{FP\backslash CF}$	$\frac{Q_{DH}}{Q_{CF}}$	98%
	ν_{CF}	$\frac{Q_{CF}}{Q_{CF,theo}}$	72%
	COP	$\frac{Q_{DH}}{W_{el}}$	522



Energy Performance

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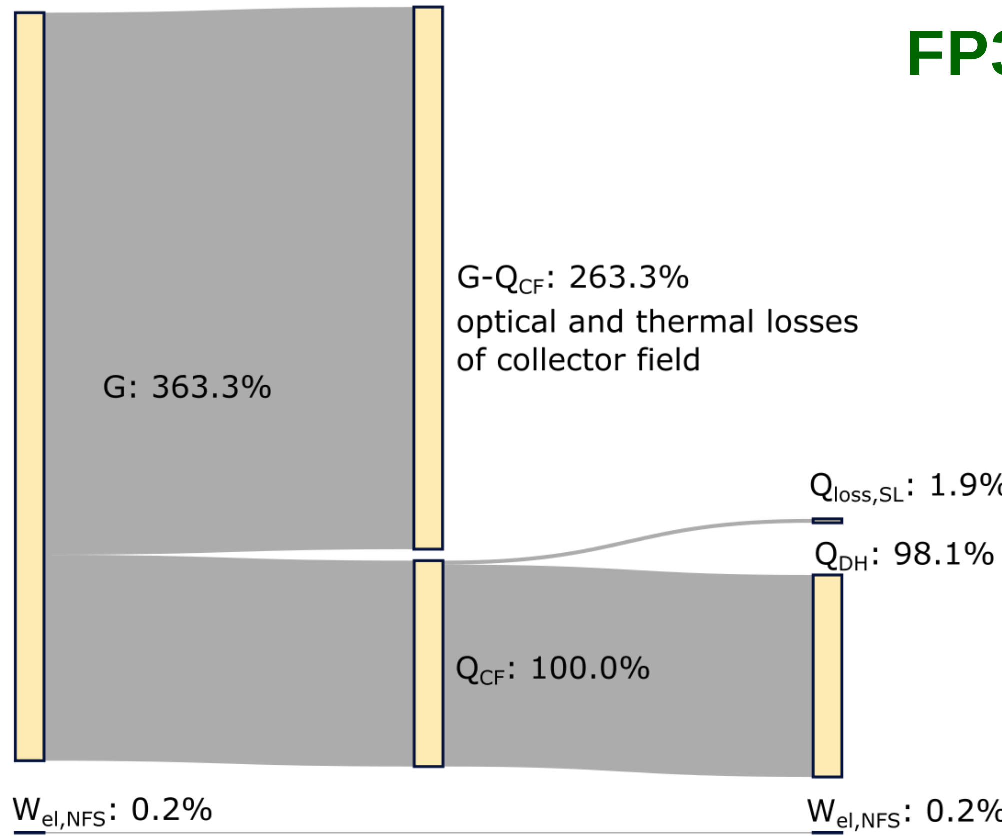
FP3



Energy Performance

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FP1	ζ_{FP}	$\frac{Q_{\mathrm{DH}}}{G}$	
	$\zeta_{\mathrm{FP\backslash CF}}$	$\frac{Q_{\mathrm{DH}}}{Q_{\mathrm{CF}}}$	
	ν_{CF}	$\frac{Q_{\mathrm{CF}}}{Q_{\mathrm{CF,theo}}}$	
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Not Representative

for solar thermal feed-in!

Optimization Potential - FP1/FP3

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FP1

Problems:

- Fluctuating thermal output
- Thermal output below the theoretically expected output

Solutions:

- Reconstruction of the collector field
  - Commercially available collectors
  - Smaller sized piping (reduced surface area and delay time)

FP3

Problems:

- High deviation to target feed-in temperature
- No switching to RL/SL feed-in mode

Solutions:

- New circulation pump with higher volume flow
- Solve problems in control unit

Conclusions

- The challenging feed-in of solar thermal heat to primary DH network is possible
    - Stable feed-in temperatures during high and volatile pressure differences in DH
    - Reasonable auxiliary energy consumption
- Directly connected centralized feed-in plant with good energy efficiency
- Methodology for the energy performance analysis and comparative evaluation of solar thermal systems connected to DH applied

- Two further feed-in plants will be investigated in the SOLSTAND project
- General recommendations for standardization of DH network substation concepts will be derived

Thank you for your attention!

Project: **SOLSTAND**
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FKZ: 0325553A

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

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Chair of Building Energy Systems and Heat Supply

Nomenclature

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Symbols			*Abbreviations/Indices*	
A	m^2	Area	a	Ambient
a_1, a_2	$W\ m^{-2}K^{-1}$, $W\ m^{-2}K^{-2}$	Collector parameter	Col	Collector
			C	Collector subfield
COP	-	Coefficient of performance	CF*i*	Collector Field
$\dot{G}$	$W\ m^{-2}$	Global irradiation in collector plane	DH	District heating
G	$kWh\ m^{-2}$	Sum of global irradiation in collector plane	el	Electrical
G_h	$kWh\ m^{-2}$	Sum of global irradiation horizontal	F	Feed-in
$\dot{H}$	kW	Enthalpy flow rate	FP*i*	Feed-in plant
i	-	Number of feed-in plant (1,2)	FS	Flow Sensor
$\dot{m}$	$kg\ s^{-1}$	Mass flow rate	HM	Heat meter
			loss	Losses
p	bar	Pressure (absolute)	LP	Lowest point in system
Δp	bar	Pressure difference	NFS*i*	Network feed-in substation
P	kW	Power	PM	Pressure maintenance
Q	kWh	Heat, thermal energy	LP	Lowest point in system
$\dot{Q}$	kW	Heat flow, thermal capacity	Pu	Pump
W	kWh	electrical energy	RL	Return line
ζ	-	Efficiency (average in time)	SL	Supply line
η_0	-	Optical collector efficiency	STS	Solar thermal system
ν	-	Degree of quality	th	Thermal
τ	hh:mm:ss	Time	theo	Theoretical
			VTC	Vacuum tube collector