

## Validation of a new heat pump model for Carnot library

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### Abstract

Validation of a new heat pump model for Carnot library with data from two sites :

- installation "L"
- installation "S"

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## 1 Introduction

The heat pump model was improved by adding a dissipation scheme. The resulting block must be validated with measurement data.

Two sources of data are used :

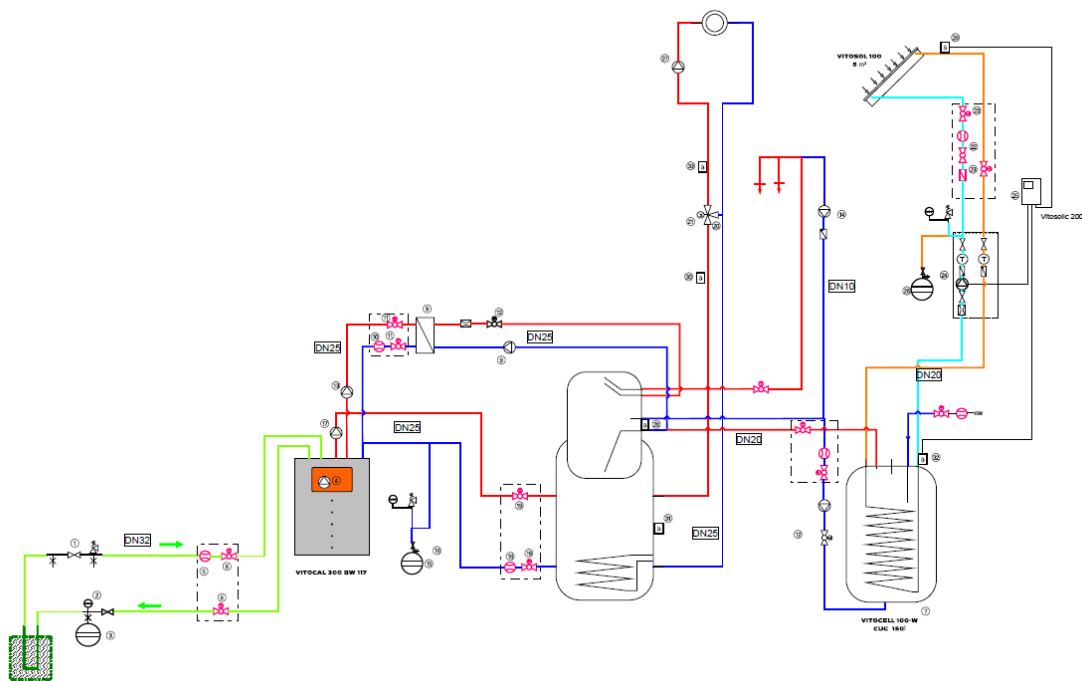
- installation "L"
- installation "S"

## 2 Description of data sources

### 2.1 Installation „L“

#### 2.1.1 General description

DHW and heating production with a heat pump and solar panels. Solar energy is used as primar energy for DHW production. The heat pump is used as primar energy for heating and additionnal heating for DHW.



*Installation scheme*

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### 2.1.2 Heat pump description

The heat pump is a VITOCAL 300-G BW 121. It is a water-glycol mix/water heat pump with a nominal heat power of 21.2 kW.

#### Typ BW/BWS

BW/BWS		121
<b>Leistungsdaten nach DIN EN 14511 (0/35 °C, 5 K Spreizung)</b>		
Nenn-Wärmeleistung	kW	21,2
Kälteleistung	kW	17,0
Elektr. Leistungsaufnahme	kW	4,48
Leistungszahl $\epsilon$ (COP)		4,73
<b>Leistungsdaten nach DIN EN 255 (0/35 °C, 10 K Spreizung)</b>		
Nenn-Wärmeleistung	kW	21,5
Kälteleistung	kW	17,5
Elektr. Leistungsaufnahme	kW	4,33
Leistungszahl $\epsilon$ (COP)		4,97
<b>Sole (Primärkreis)</b>		
Inhalt	l	7,3
Min. Volumenstrom ( $\Delta t = 5$ K)	l/h	3300
Durchflusswiderstand	mbar	90
Max. Vorlauftemperatur	°C	25
Min. Vorlauftemperatur	°C	-5
<b>Heizwasser (Sekundärkreis)</b>		
Inhalt	l	7,3
Min. Volumenstrom ( $\Delta t = 10$ K)	l/h	1900
Durchflusswiderstand	mbar	30
Max. Vorlauftemperatur	°C	60

*Technical information about the heat pump.*

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**Function Block Parameters: heatpump\_2**

heat pump (mask)

Linearized heat pump model. Uses measured data according to EN 14511 as input.  
 heating power:  $\dot{Q}_{dot\_h} = K1 \cdot T_{cold\_in} + K2 \cdot T_{hot\_out} + K3$   
 electric power:  $P_{el} = K4 \cdot T_{cold\_in} + K5 \cdot T_{hot\_out} + K6$   
 source power:  $\dot{Q}_{dot\_c} = -K7 \cdot T_{cold\_in} - K8 \cdot T_{hot\_out} - K9$   
 differential equation:  $cap \cdot dT_h/dt = \dot{Q}_{dot} + \dot{m} \cdot cp \cdot (T_{in} - T) + UA \cdot (T_{amb} - T)$   
 with:  $cap = mass \cdot heat\_capacity$   
 See hp\_param.m for the parameters K1 to K9.  
 Literature: Schwamberger, K.: Fortschrittsberichte VDI, Nr. 263, 1991

Parameters

thermal capacity hot loop [J/K]

thermal capacity cold loop [J/K]

[linear quadratic] massflow dependant pressure drop hot side in [Pa]

heat loss coefficient [W/K]

inlet source temperature vector (°C)

outlet load temperature vector (°C)

heating power matrix [W]

source power matrix [W]

electric power matrix [W]

OK Cancel Help Apply

Figure 1 : Adjusted parameters for validation with VITOCAL300-G BW 121

### 2.1.3 Data

I use the data of one day : 17th october 2009.

The following data are used (original name is in brackets) :

- Compressor power in W (*Verdichterleistung in W*)
- Heating power in kW (*Leistung\_Ladekreis\_Puffer*)
- Inlet temperature of antifreeze loop in °C (*VL\_Solekreis*)
- Outlet temperature of antifreeze loop in °C (*RL\_Solekreis*)
- Volume flow of antifreeze loop in l/h (*Vol\_Solekreis*)
- Inlet temperature of hot loop in °C (*RL\_Ladekreis\_Puffer*)
- Outlet temperature of hot loop in °C (*VL\_Ladekreis\_Puffer*)
- Volume flow of heating loop in l/h (*Vol\_Ladekreis\_Puffer*)

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Command is calculated with compressor power data :

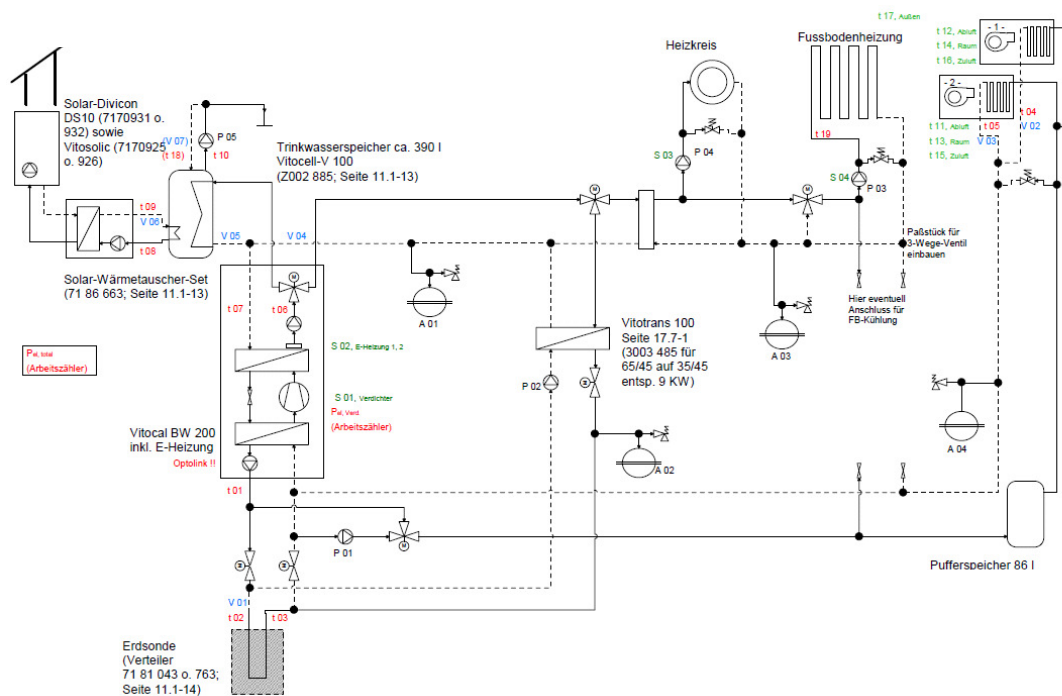
$$\text{command} = (\text{if } P_{el} > 0 \text{ then } 1 \text{ else } 0)$$

I choose to use only data about the heating loop (and not about the DHW loop) because there are few requests for DHW : only once at the beginning and once at the end, both during a short time. I make my calculus with the data between these two events.

## 2.2 Installation „S“

### 2.2.1 General description

DHW production, heating, natural cooling and air-conditioning with a heat pump and solar panels. Solar energy is used as primary energy for DHW production. The heat pump is used as primary energy for heating, natural cooling and air-conditioning and as additional heating for DHW.



Installation scheme.

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## 2.2.2 Heat pump description

The heat pump is a VITOCAL 200 BWP 108. It is a water-glycol mix/water heat pump with a nominal heat power of 7.7 kW.

Vitocal 200	Typ	BWP 106	BWP 108
<b>Leistungsdaten Wärmepumpe*1</b>			
Heizleistung	kW	6,1	7,7
Kälteleistung	kW	4,7	5,9
Elektr. Leistungsaufnahme	kW	1,4	1,8
Leistungszahl ε (COP) bei Heizbetrieb		4,3	4,3
<b>Leistungsdaten Heizwasser-Durchlauferhitzer (Zubehör)</b>			
Wärmeleistung	kW	stufig 3/6/9	
Heizleistung mit Heizwasser-Durchlauferhitzer	kW	15,1	16,7
<b>Sole (primär)</b>			
Inhalt	Liter	1,6	2,1
min. Durchsatz*2	Liter/h	1200	1400
max. externer Durchflusswiderstand	mbar	400	480
max. Eintrittstemperatur	°C	25	25
min. Eintrittstemperatur	°C	-5	-5
<b>Heizwasser (sekundär)</b>			
Inhalt, Wärmepumpe	Liter	1,6	1,8
Inhalt, gesamt	Liter	7,0	7,2
min. Durchsatz*2	Liter/h	800	800
max. externer Durchflusswiderstand	mbar	450	450
max. Vorlauftemperatur	°C	60	60
<b>Elektrische Werte</b>			
Nennspannung (Wärmepumpe komplett)		3/N/PE 400 V~/50 Hz	
Nennspannung (Steuerstromkreis)		230 V~/50 Hz	
Nennstrom (Verdichter)	A	5,5	6,0
Anlaufstrom (Verdichter)	A	25,0	14,0*3
Anlaufstrom (Verdichter bei blockiertem Rotor)	A	32,0	35,0
Elektr. Leistungsaufnahme			
– Umwälzpumpe Solekreis bei Stufe 1/2/3	W	62/92/132	195/175/120
– Umwälzpumpe Heizkreis bei Stufe 1/2/3	W		62/92/132
Absicherung (träge)	A	3 × 16	3 × 16*4
Schutzart			IP 20
Absicherung (intern)			T 6,3 A H
<b>Kältekreis</b>			
Arbeitsmittel		R 410 A	
Füllmenge	kg	1,050	1,200
Verdichter	Typ	Scroll Vollhermetik	

Technical information about the heat pump.

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**Function Block Parameters: heatpump\_3**

heat pump (mask)

Linearized heat pump model. Uses measured data according to EN 14511 as input.  
 heating power:  $\dot{Q}_{dot\_h} = K1 \cdot T_{cold\_in} + K2 \cdot T_{hot\_out} + K3$   
 electric power:  $P_{el} = K4 \cdot T_{cold\_in} + K5 \cdot T_{hot\_out} + K6$   
 source power:  $\dot{Q}_{dot\_c} = -K7 \cdot T_{cold\_in} - K8 \cdot T_{hot\_out} - K9$   
 differential equation:  $cap \cdot dT_h/dt = \dot{Q}_{dot} + \dot{m} \cdot cp \cdot (T_{in} - T) + UA \cdot (T_{amb} - T)$   
 with:  $cap = mass \cdot heat\_capacity$   
 See hp\_param.m for the parameters K1 to K9.  
 Literature: Schwamberger, K.: Fortschrittsberichte VDI, Nr. 263, 1991

Parameters

thermal capacity hot loop [J/K]

thermal capacity cold loop [J/K]

[linear quadratic] massflow dependant pressure drop hot side in [Pa]

heat loss coefficient [W/K]

inlet source temperature vector (°C)

outlet load temperature vector (°C)

heating power matrix [W]

source power matrix [W]

electric power matrix [W]

OK Cancel Help Apply

Figure 2 : Ajusted parameters for validation with VITOCAL200 BWP 108

### 2.2.3 Data

I use the data of three days :

- 22<sup>th</sup> April 2006 ;
- 5<sup>th</sup> October 2006 ;
- 7<sup>th</sup> October 2006.

These days are chosen in order to **study heating capacity of the heat pump** (there are no request for natural cooling or air-conditioning).

The following data are used (original name is in brackets) :

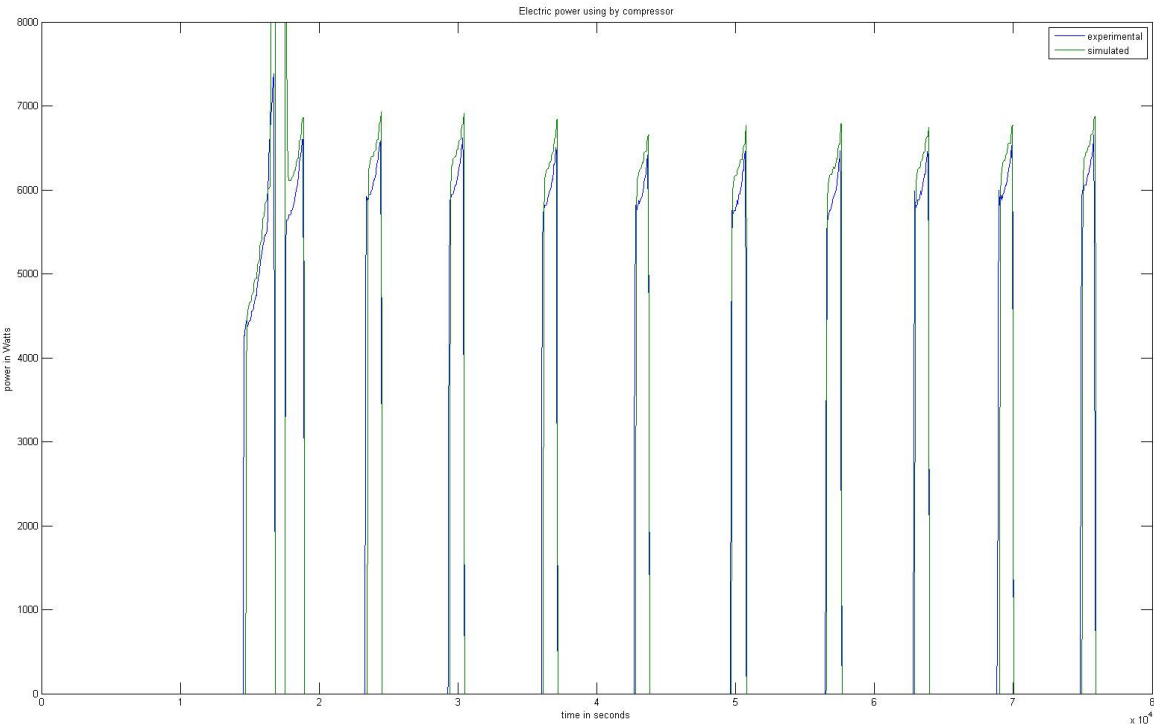
- Compressor power in W (*Reserve5* or *Leistung\_el* in W)
- Heating power in kW (*Leistung\_Puffer*)

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- DHW heating power in kW (*Leistung\_Speicher*)
- Inlet temperature of antifreeze loop in °C (*RL\_Primär WP*)
- Outlet temperature of antifreeze loop in °C (*RL\_Primär WP*)
- Volume flow of antifreeze loop in l/h (*RL\_Erdsonde*)
- Inlet temperature of heating loop in °C (*RL\_Puffer\_Speicher*)
- Outlet temperature of the part of the hot loop used for heating in °C (*VL\_Puffer*)
- Outlet temperature of the part of the hot loop used for DHW heating in °C (*VL\_Speicher*)
- Volume flow of the part of the hot loop used for heating in l/h (*RL\_Puffer*)
- Volume flow of the part of the hot loop used for DHW heating in l/h (*RL\_Speicher*)
- Command of the heatpump (0 ou 5) (*Verdichter*)

**3 Results**

**3.1 Installation „L“**



**Figure 3 : Electric power used by the compressor**

The instantaneous errors of electric power are less than 5%, which is the commonly maximum error between theoretical technical data and practical values.

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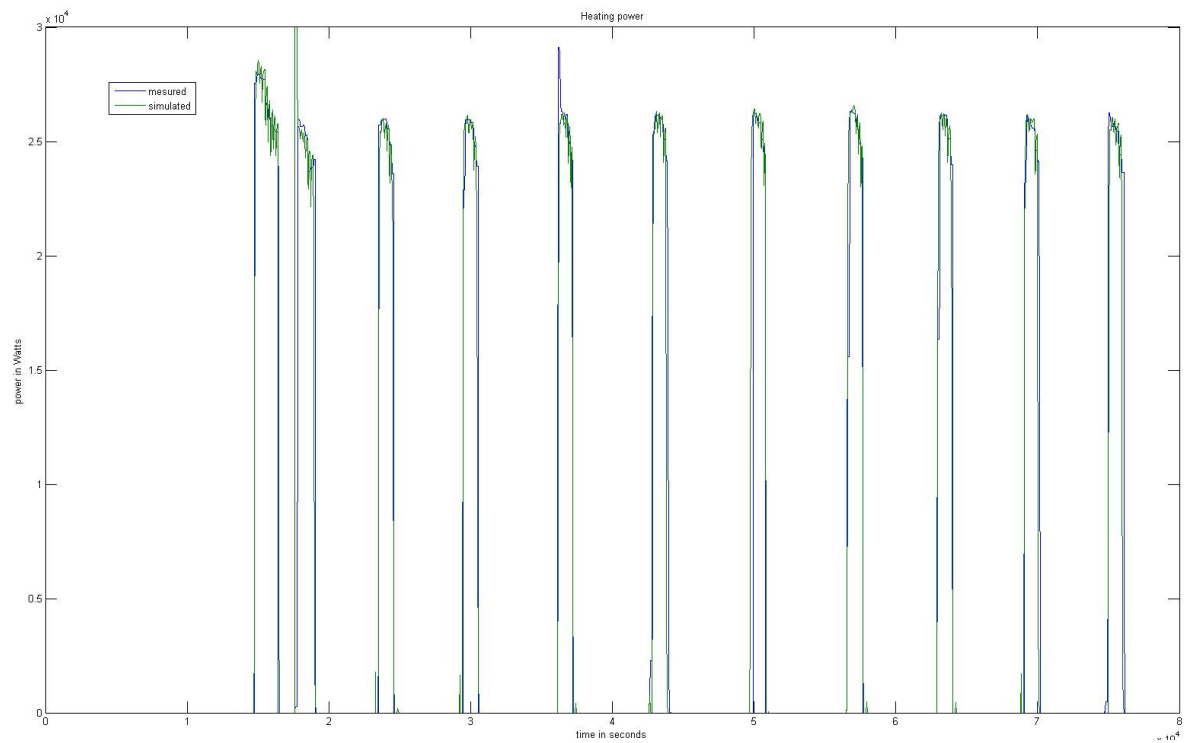


Figure 3 : Heating power

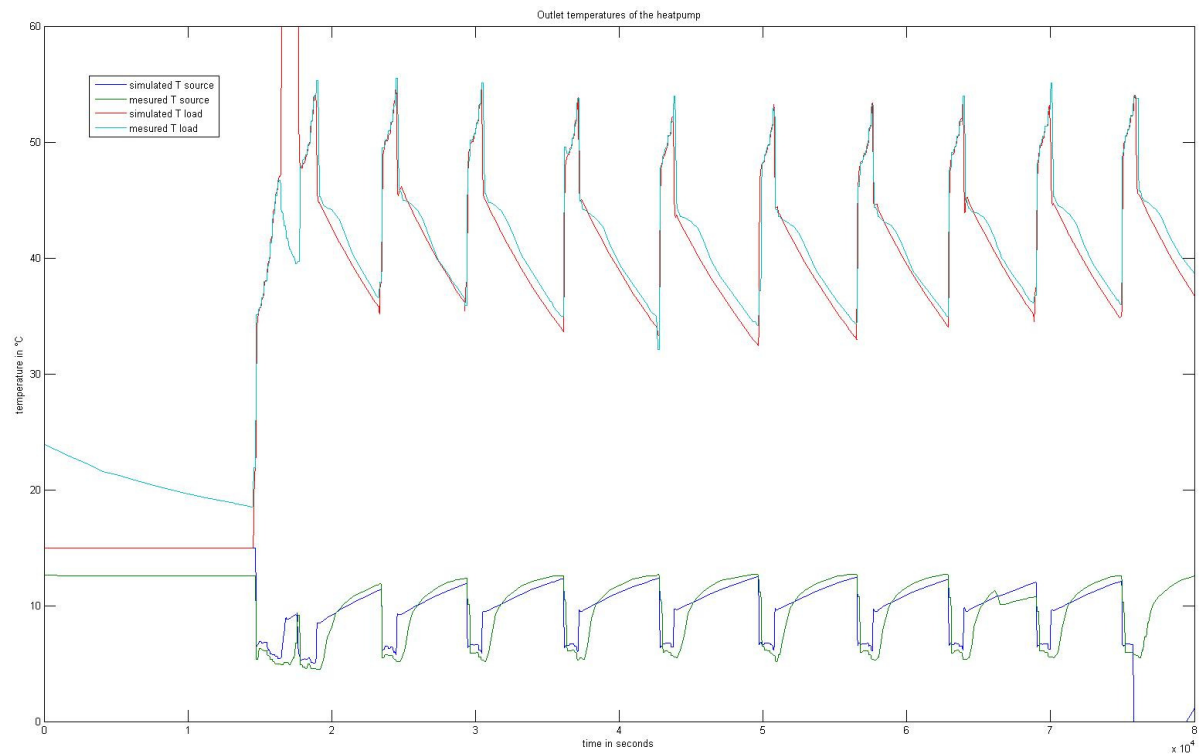


Figure 4 : Outlet temperatures of the heatpump

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### 3.2 Installation “S”

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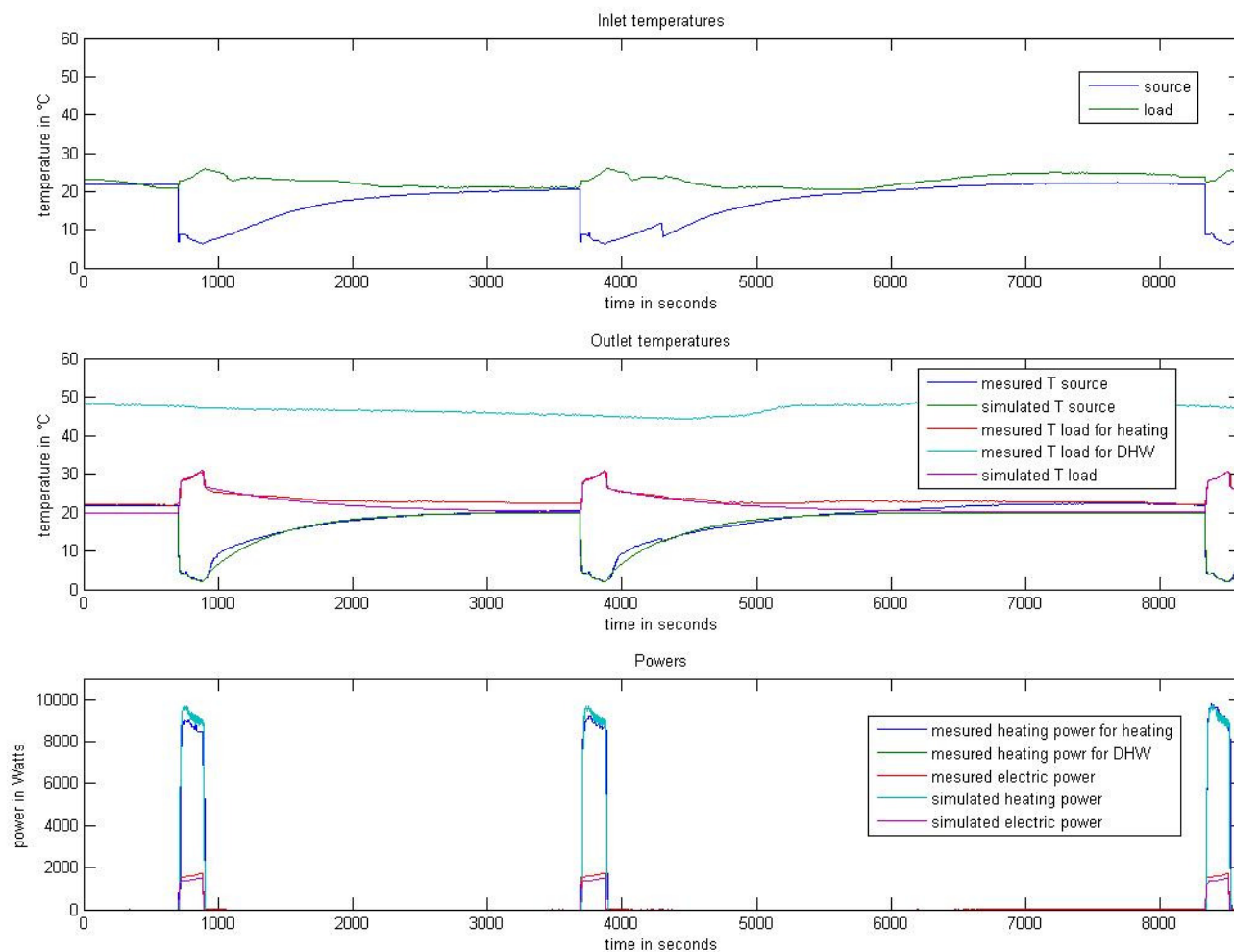


Figure 5 : Results for 22.04.2006

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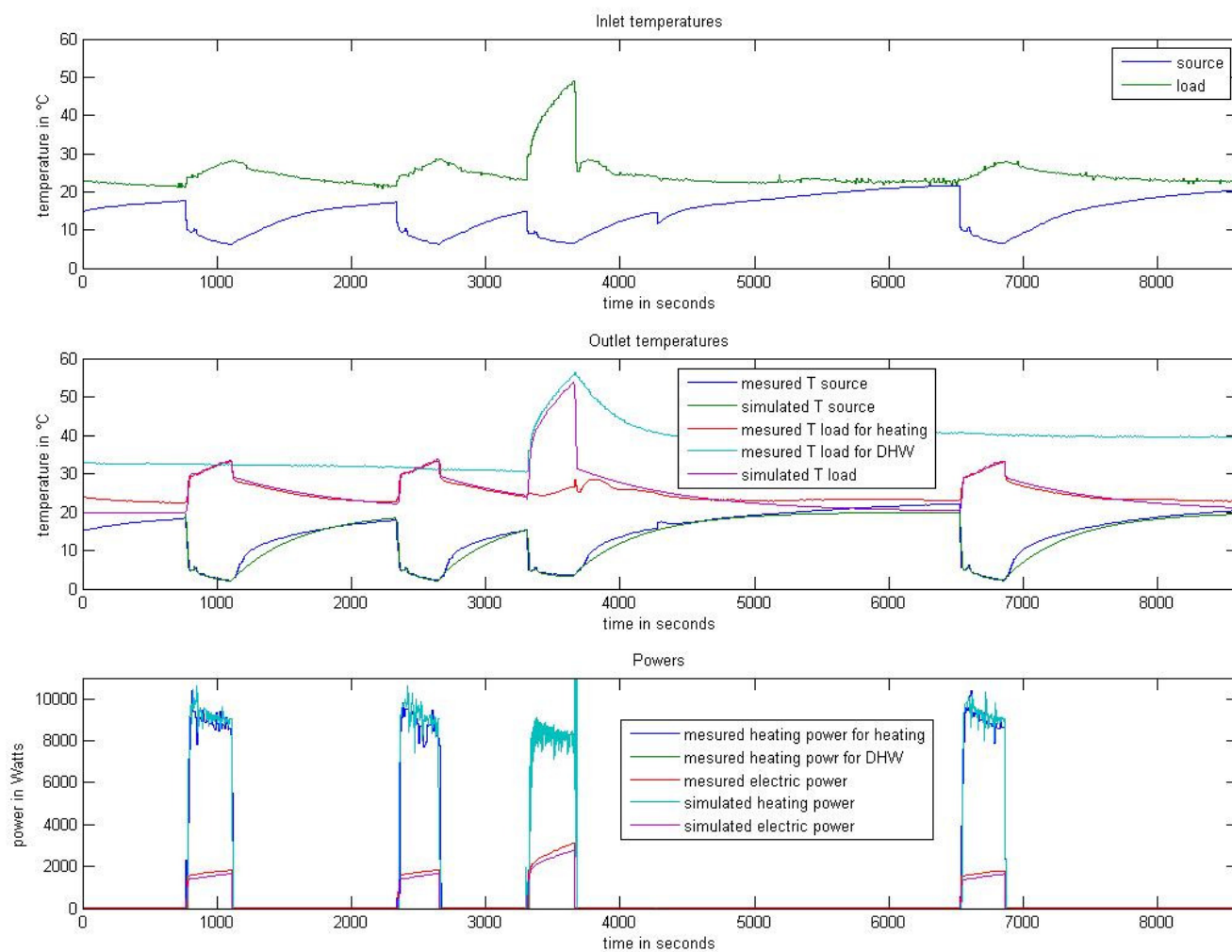


Figure 6 : Results for 05.10.2006

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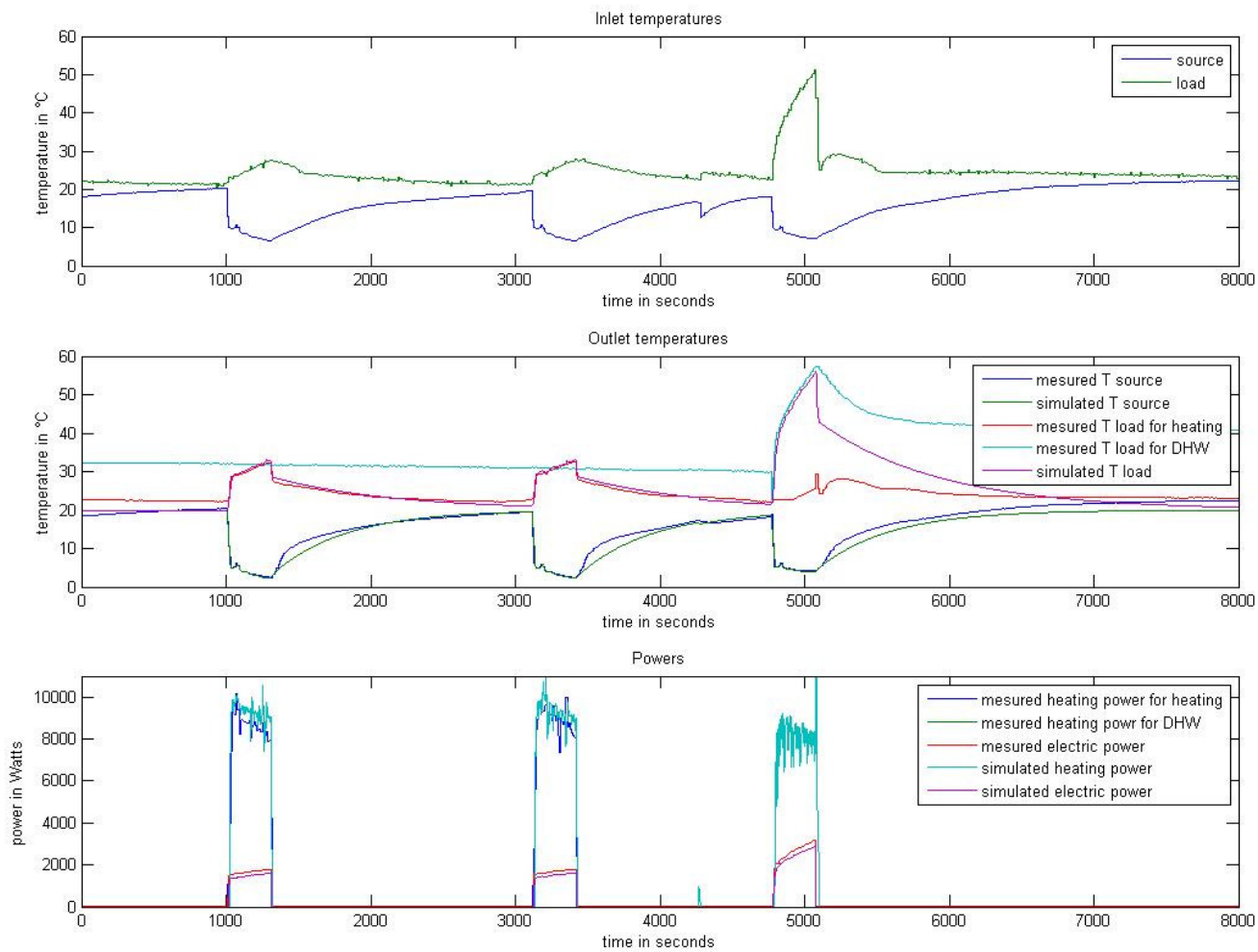


Figure 7 : Results for 07.10.2006

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### 3.3 Conclusion

Validation is completed.

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