Validation of the blocks for flat collector with measured data for power tests (EN 12975)

Table of contents

Author

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Version of Model, Carnot, Matlab and Operation system

coll12975.c (V 4.1.1), Carnot 4.7, Matlab R2010b, Windows XP

unicol.c (V 4.1), Carnot 4.7, Matlab R2010b, Windows XP

unicol_2xN.c (V 4.1), internal, Matlab R2010b, Windows XP

Complete path of the block in the Carnot Library

Carnot/heat_source/flat_plate_collector_EN12975

Carnot/heat_source/collector_flat_plate

1 Data used for validation

I used data from ISFH (Institut für Solarenergieforschung GmbH, Hameln/Emmerthal). These data are been stored during the EN 12975 test of the Vitosol 200F SV2B collector from Viessmann. They come from a test bench.

- Time step : 30 seconds
- Duration : 8 hours

2 Description of the model

2.1 Block

2.1.1 Flat_plate_collector_EN12975

The block is built around the s-function coll12975.c which implements a model of a flat plate collector that includes thermal capacity of the collector and the incidence angle modifier.

The energy-balance for the collector is a differential equation:

mdot cp (Tout-Tin) /A = F'(TauAlfa) Kdir Idir

+ F'(TauAlfa) Kdfu Idfu - c6 v_wind Iglb

- c1 (Tm-Tamb) - c2 (Tm-Tamb)^2

- c3 v_wind (Tm-Ta)

+ c4 (ELongwave - sigmaSB*(Tamb+273.15)^4)

- c5 dTm/dt

with the incidence angle modifier Kdir: Kdir = 1 - b0 * (1/cos(teta) - 1)

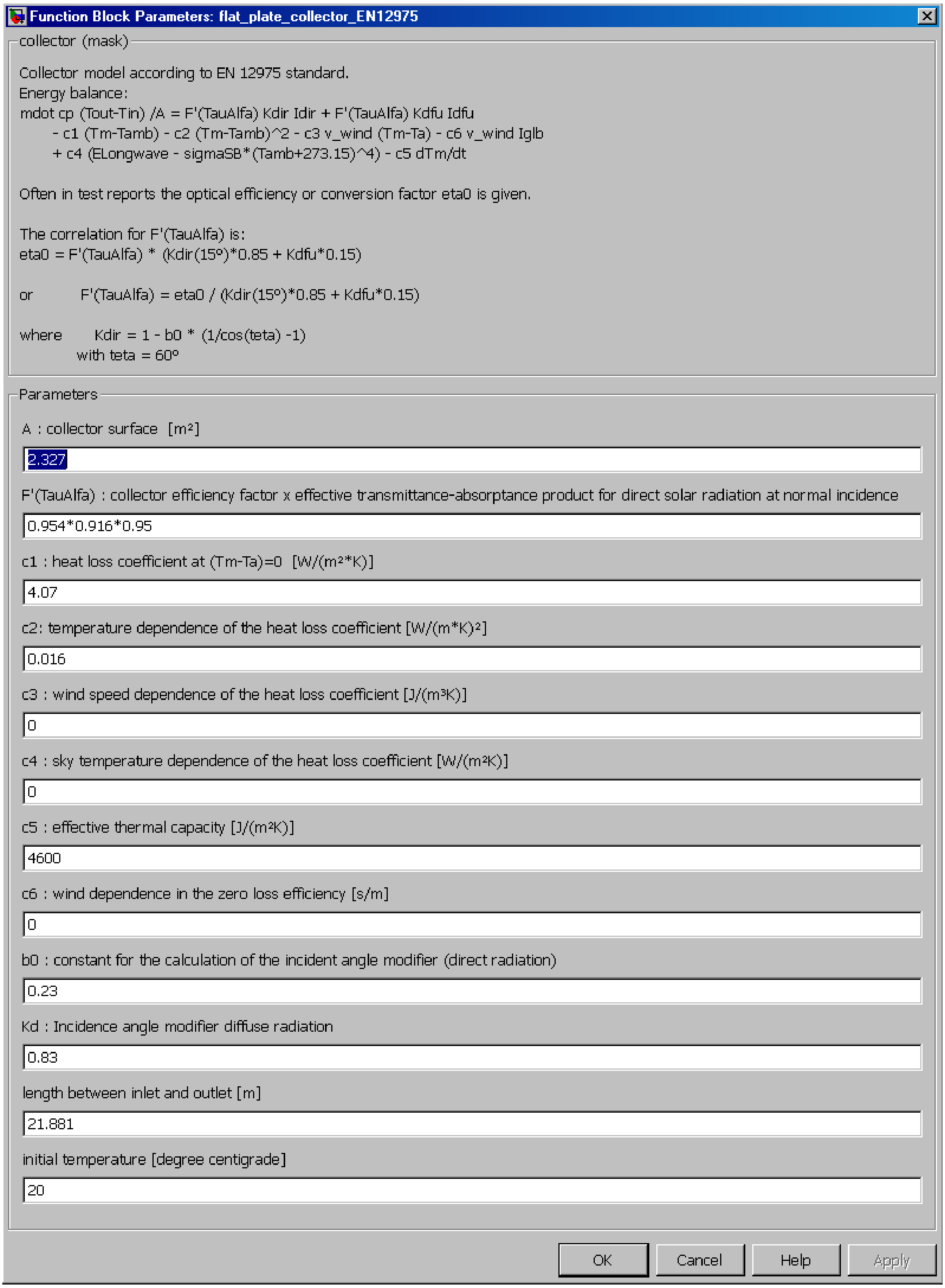
and.

- bo: constant for the calculation of the incident angle modifier
- c1: heat loss coefficient at (Tm - Ta)=0 ($W/(m^2.K)$)
- c2: temperature dependence of the heat loss coefficient ($W/(m^2.K^2)$)
- c3: wind speed dependence of the heat loss coefficient ($J/(m^3.K)$)
- c4: sky temperature dependence of the heat loss coefficient ($W/m^2.K)$)
- c5: effective thermal capacity ($J/(m^2.K)$)
- c6: wind dependence in the zero loss efficiency (s/m)
- F': collector efficiency factor

- TauAlfa: effective transmittance-absorptance product for direct solar radiation at normal incidence
- teta: incidence angle of the direct radiation on the collecor (radian)
- Tm: temperature of the collector node (Celsius degrees)
- Tamb: ambient temperature (Celsius degrees)
- v_wind: wind velocity (m/s)
- ELongwave: longwave irradiance with wave length > 3000 nm (set at -100) (W/m^2)
- Iglb: global solar radiation (W/m^2)
- Idir: direct solar radiation (W/m^2)
- Idfu: diffuse solar radiation (W/m^2)
- sigmaSB: Stefan-Boltzmann constant = 5.67e-8 $W/(m^2.K^4)$

The blocks also contains a weather inclined block which transforms the weather data on a ground surface to data for the collector inclined surface. A other block performs the pressure drop calculus.

Warning : In this case, weather data do not need weather inclined blocks, so I removed it.



Function Block Parameters: flat_plate_collector_EN12975

collector (mask)

Collector model according to EN 12975 standard.
Energy balance:
mdot cp (Tout-Tin) /A = F'(TauAlfa) Kdir Idir + F'(TauAlfa) Kdfu Idfu
- c1 (Tm-Tamb) - c2 (Tm-Tamb)^2 - c3 v_wind (Tm-Ta) - c6 v_wind Iglb
+ c4 (ELongwave - sigmaSB*(Tamb+273.15)^4) - c5 dTm/dt

Often in test reports the optical efficiency or conversion factor eta0 is given.

The correlation for F'(TauAlfa) is:
eta0 = F'(TauAlfa) * (Kdir(15°)*0.85 + Kdfu*0.15)

or F'(TauAlfa) = eta0 / (Kdir(15°)*0.85 + Kdfu*0.15)

where Kdir = 1 - b0 * (1/cos(teta) -1)
with teta = 60°

Parameters

A : collector surface [m²]

2.327

F'(TauAlfa) : collector efficiency factor x effective transmittance-absorptance product for direct solar radiation at normal incidence

0.954*0.916*0.95

c1 : heat loss coefficient at (Tm-Ta)=0 [W/(m²*K)]

4.07

c2: temperature dependence of the heat loss coefficient [W/(m*K)²]

0.016

c3 : wind speed dependence of the heat loss coefficient [J/(m³K)]

0

c4 : sky temperature dependence of the heat loss coefficient [W/(m²K)]

0

c5 : effective thermal capacity [J/(m²K)]

4600

c6 : wind dependence in the zero loss efficiency [s/m]

0

b0 : constant for the calculation of the incident angle modifier (direct radiation)

0.23

Kd : Incidence angle modifier diffuse radiation

0.83

length between inlet and outlet [m]

21.881

initial temperature [degree centigrade]

20

OK Cancel Help Apply

Figure 1: Parameters for the validation of the flat_plate_collector_EN12975 block

2.1.2 Collector_flat_plate

The block is built around the s-function unicol.c which implements a model of a flat plate collector that includes thermal capacity of the collector and the incidence angle modifier.

The collector is devided into "NODES" nodes. The energy-balance for every node is a differential equation:

$$c\_col \cdot dT/dt = ULIN \cdot (Tamb - Tnode) + UQUA \cdot (Tamb - Tnode)^2$$
$$+ USKY \cdot (Tnode - Tsky) + Uwind \cdot vwind \cdot (Tamb - Tnode)$$
$$+ mdot \cdot cp / Acoll \cdot (Tlastnode - Tnode) + qdot\_solar$$

where:

- cp: heat capacity of fluid (J/(kg.K))
- c_col: heat capacity of collector per surface (J/(m².K))
- mdot: mass flow rate (kg/s)
- qdot_solar: power input per surface from sun (W/m²)
- T: temperature (K)
- ULIN: linear heat loss coefficient (W/(m².K))
- UQUA: quadratic heat loss coefficient (W/(m.K)²)
- USKY: sky loss coefficient
- Uwind: wind speed dependant heat losses (W/((m/s).m².K))

The blocks also contains a weather inclined block which transforms the weather data on a ground surface to data for the collector inclined surface. An other block simulates the optics of a single glazing extra white glass and a last block performs the pressure drop calculus.

Warning : In this case, weather data do not need weather inclined blocks, so I removed it.

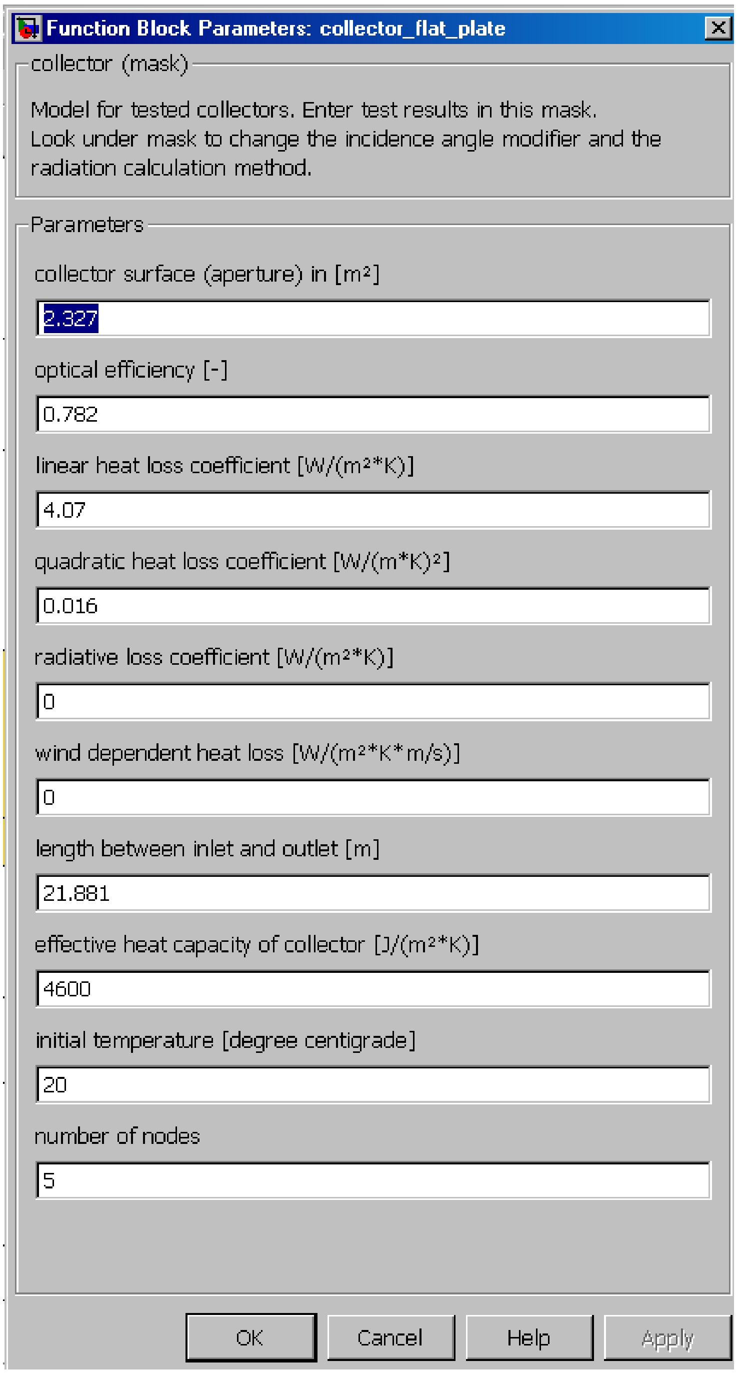


Figure 2: Parameters for the validation of the collector_flat_plate block

2.1.3 2xN_collector_flat_plate

The block is built around the s-function unicol_2xN.c which implements a model of a flat plate collector that includes thermal capacity of the collector and the incidence angle modifier.

The collector is divided in two parts :

- the absorber
- the fluid

Each part is divided into "NODES" nodes.

The energy-balance for every node in the absorber is a differential equation:

c_col * dTa/dt = ULIN * (Tamb - Ta,node)

+ UQUA * (Tamb - Ta,node)^2

+ USKY * (Ta,node - Tsky)

+ Uwind * vwind * (Tamb - Ta,node)

- hi * (Ta,node - Tf,node)

+ qdot_solar

with:

- c_col: heat capacity of collector per surface (J/(m²*K))
- qdot_solar: power input per surface from the sun (W/m²)
- T: temperature (K)
- t: time (s)
- ULIN: linear heat loss coefficient (W/(m²*K))
- UQUA: quadratic heat loss coefficient (W/(m*K)²)
- USKY: sky loss coefficient
- Uwind: wind speed dependant heat losses (W/((m/s)*m²*K))
- hi: heat transfer coefficent between absorber and fluid (W/(m²*K))

The energy-balance for every node in the fluid is a differential equation:

c_fl * dTf/dt = mdot * cp / Acoll * (Tf,lastnode - Tf,node)

+ hi * (Ta,node - Tf,node)

with:

- cp: heat capacity of fluid (J/(kg*K))

- c_fl: heat capacity of fluid per surface (J/(m²*K)). It is calculated with : c_fl = M * cp / Acoll, with:
    - M: mass of fluid in collector (kg)
    - mdot: mass flow rate (kg/s)
    - T: temperature (K)
    - t: time (s)
    - hi: heat transfer coefficent between absorber and fluid (W/(m²*K))

The blocks also contains a weather inclined block which transforms the weather data on a ground surface to data for the collector inclined surface. An other block simulates the optics of a single glazing extra white glass and a last block performs the pressure drop calculus.

Warning : In this case, weather data do not need weather inclined blocks, so I removed it.

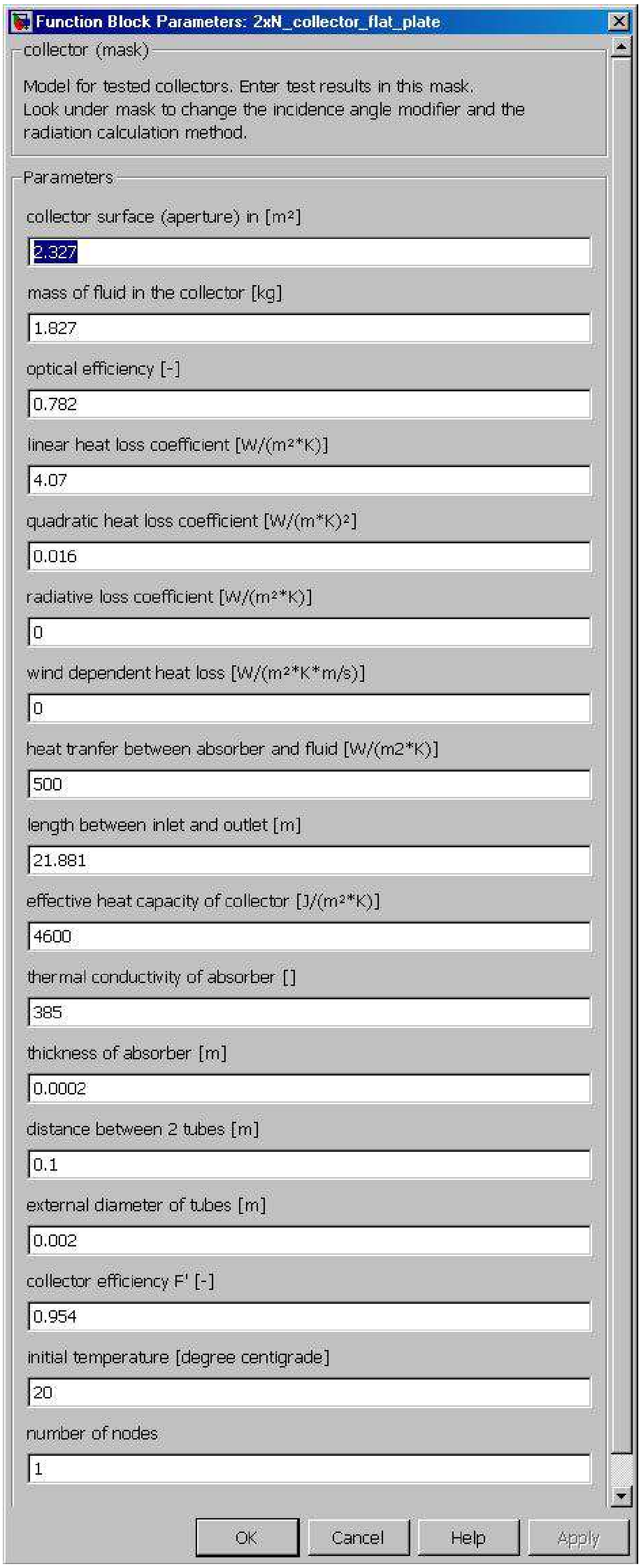


Figure 3: Parameters for the validation of the 2xNcollector_flat_plate block

2.2 Model File

I used the following data:

- as input of the weather vector:
    - Sun height (degrees)
    - Sun azimuth (degrees)
    - Diffuse irradiation (W/m²)
    - Global irradiation (W/m²)
    - Wind velocity (m/s)
    - Ambient temperature (Celsius degrees)
- as input of the collector:
    - Mass flow (kg/h)
    - Inlet temperature of the fluid in the collector (Celsius degrees)

I compared:

- the outlet temperature of the fluid (Celsius degrees)
- the power and the energy provided by the collector to the fluid (Watts and Joules)

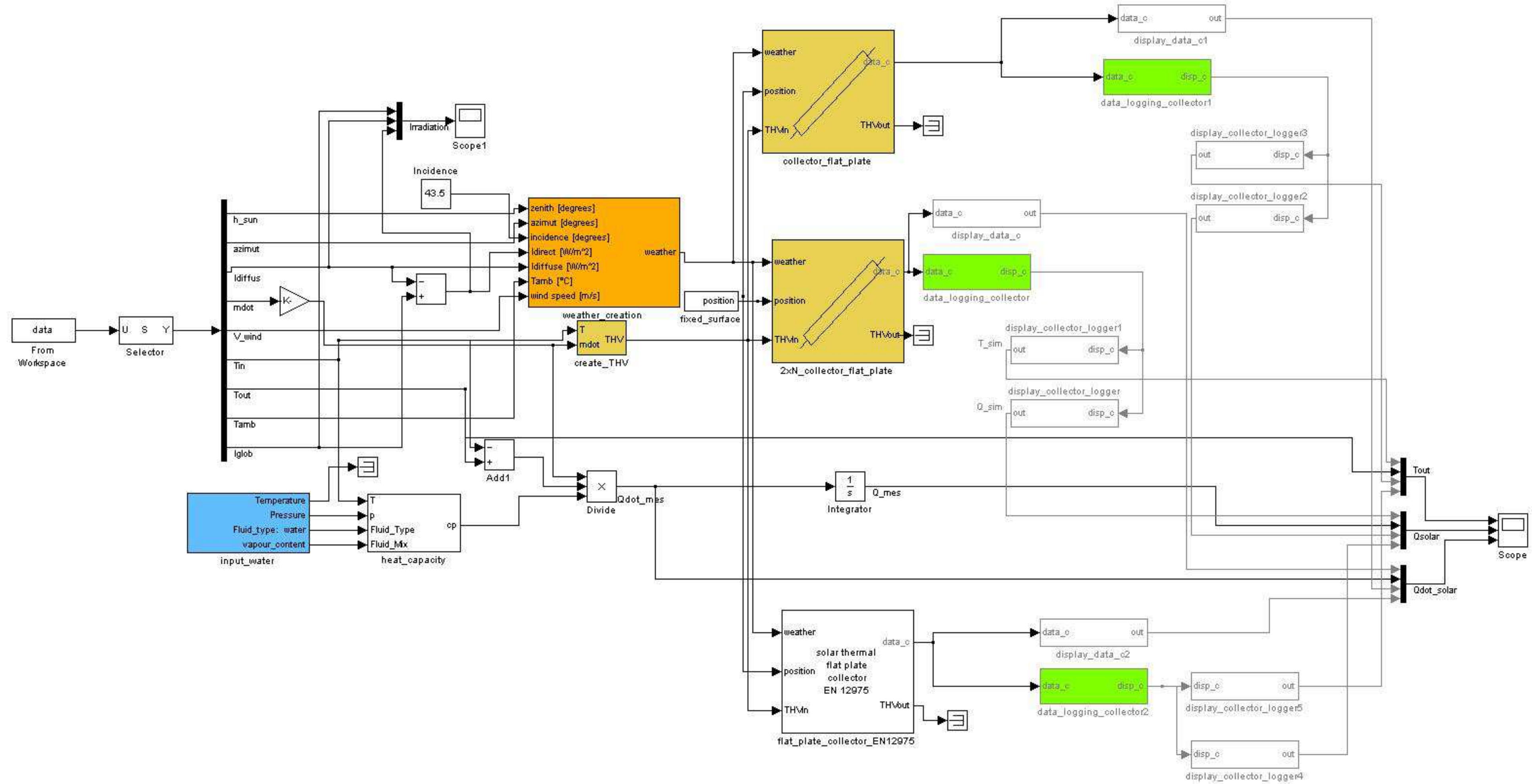


Figure 4: Model for the validation

3 Results

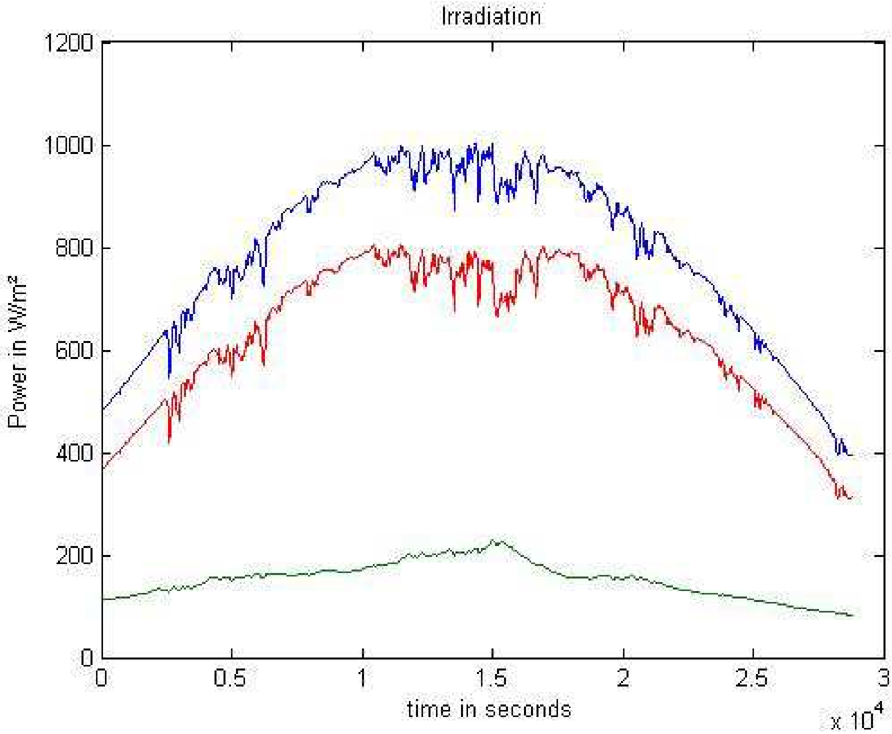


Figure 5: Irradiation on the collector

The EN12975 model is valid for a global irradiation above 700 W/m². That is why I made the comparison on a shorter period than the data total duration.

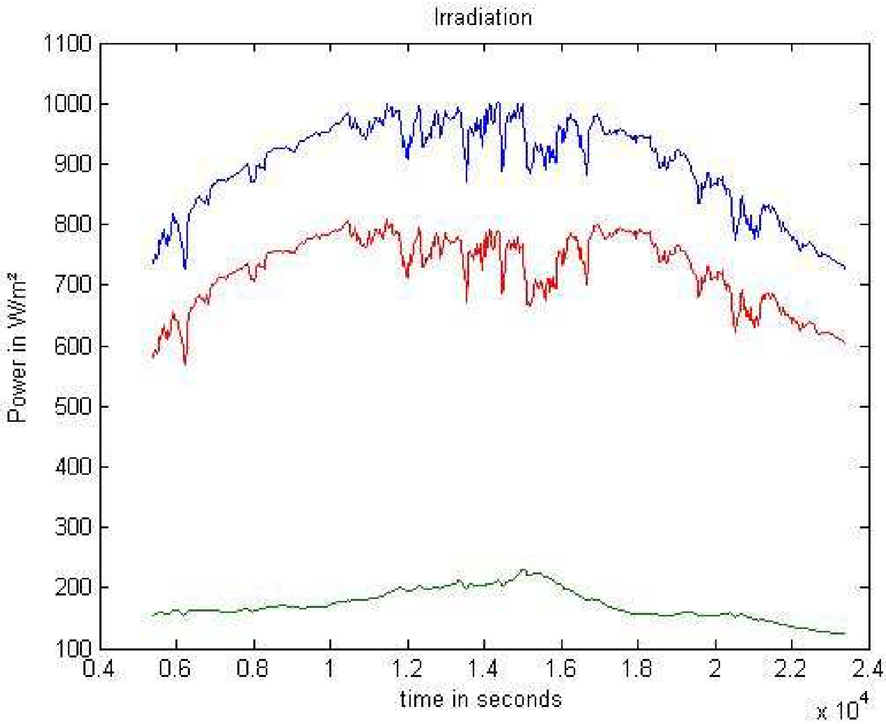
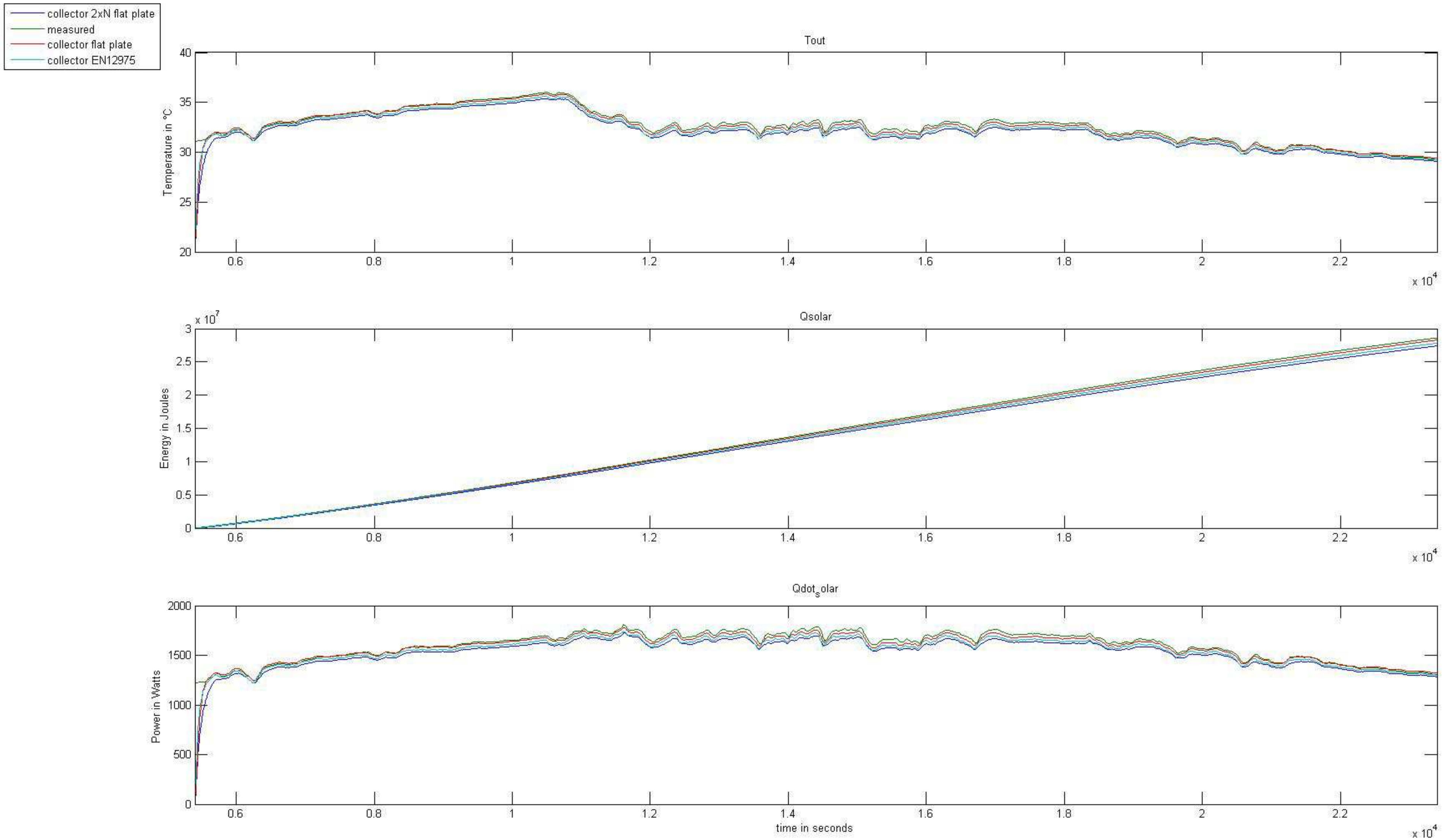


Figure 6: Irradiation above 700 W/m²


collector 2xN flat plate
measured
collector flat plate
collector EN12975
Tout
Temperature in °C
Qsolar
Energy in Joules
x 10^7
Qdot_solar
Power in Watts
time in seconds
x 10^4

The relative error on total produced energy is :

- For the collector_flat_plate : 1.16 %
- For the flat_plate_collector_EN12975 : 2.79 %
- For the 2xN collector_flat_plate : 4.25 %

The validation is succeed.

4 Literature

Any.