Validation of the block heat exchanger EN12977 and the model store_hx.c with BOOST and TRNsys softwares for low mass flows

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Version of Model, Carnot, Matlab and Operation system

store_hx.c (V 5.1.1), Carnot 5.2, Matlab R2010b 64bits, Windows XP

Complete path of the block in the Carnot Library

Carnot/storage/ports for your storage construction/heat exchanger EN12977

1 Introduction

The EN 12977 model was developed to represent the heat exchange between an immersed heat exchanger serpentine and the fluid in a tank. This serpentine is typically a solar heat exchanger and the expected mass flow is about 300 or 400L/h for a 300L tank.

In the case of a ICSHW type installation (Individualized collective solar domestic hot water, see next paragraph), the mass flows can be lower.

An ICSHW type installation (Figure 1) consist in a collective solar collectors field placed on the roof, an hydraulic heat transport fluid distribution system to the different storages, and individual domestic hot water storages with individual heating backup (electric or gas for example).

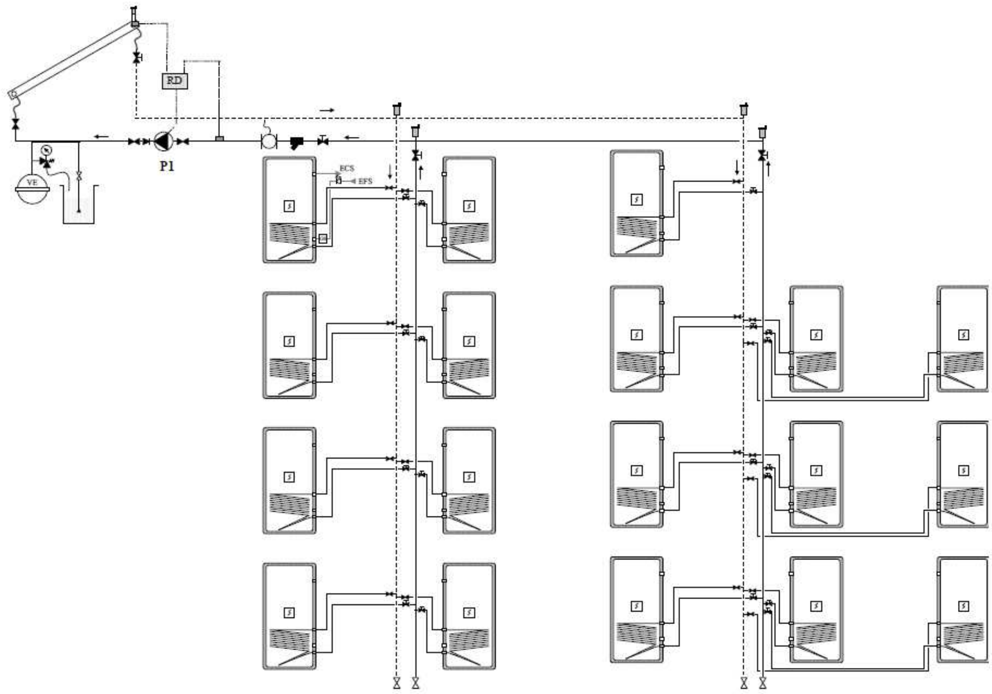

Figure 1 : ICSHW hydraulic scheme.

In these kind of installations the nominal mass flow in each heat exchanger is almost divided by two. That is why it seems interesting to investigate the reliability of the model for low mass flows.

2 Simulation case used for validation

The situation is a charge of a tank with constant mass flow and temperature at the enter of the exchanger.

The tank is based on the parameters of a Vitocell 100CVS 300L :

Parameter	Value	Unit
Storage height	1.47	m
Storage diameter	0.525	m
Storage volume	0.3	m^3
effective thermal conductivity in the storage	1.21	W/(m.K)
heat loss capacity rate from the storage to ambient through the bottom of the storage	0.23	W/K
heat loss capacity rate from the storage to ambient the the top of the storage	0.23	W/K
heat loss capacity rate from storage to ambiant through the wall of the storage	2.42	W/K
rel. height of inlet position of the cold water port	0	-
rel. height of outlet position of the DHW	1	-
relative inlet position of the solar heatexchanger	0.3	-
rel. outlet position of the solar heatexchanger	0.15	-
volume of the solar heatexchanger	0.01	m^3

The storage is initially at the ambient temperature : **20℃**. This ambient temperature stays constant during the charge process. The charge is made with different water mass flows between **20 and 400 l/h** and a constant temperature at the enter of the exchanger of **50℃** during **8 hours**.

The total amount of energy provided by the exchanger is evaluated.

3 Description of the BOOST and TRNsys softwares and models

3.1 BOOST

3.1.1 General descrption

BOOST (« **BO**iler **O**ptimization and **S**imulation **T**ool ») is a simulation tool for thermal systems, especially furnaces, heaters and regulators. This software is developped and maintained by CETIAT, a French study, testing and calibration laboratory in the fields of aerodynamics and fluid mechanics, heat sciences and acoustics.

The principles of using elementary blocs to create more complex systems is the same as for Simulink except than this tool is a complete software. The blocs are developed in C++.

3.1.2 About storage and exchanger models

The storage model has the same principle as those from CARNOT.

The exchanger model is a multi-node model based on the geometry of the exchanger. It is based only on construction data (lengths, volumina, materials...). It was validated with measured data for mass flows between 1,14 and 4,46 m^3/h.

3.2 TRNsys

3.2.1 General description

TRNSYS is an graphically based software environment used to simulate the behavior of transient systems. It can be used to model the performance of thermal and electrical energy systems and other dynamic systems such as traffic flow, or biological processes.

TRNSYS is made up of two parts. The first is an engine (called the kernel) that reads and processes the input file, iteratively solves the system, determines convergence, and plots system variables. The kernel also provides utilities that (among other things) determine thermophysical properties, invert matrices, perform linear regressions, and interpolate external data files. The second part of TRNSYS is an extensive library of components, each of which models the performance of one part of the system. The standard library includes approximately 150 models ranging from pumps to multizone buildings, wind turbines to electrolyzers, weather data processors to economics routines, and basic HVAC equipment to cutting edge emerging technologies. Models are constructed in such a way that users can modify existing components or write their own, extending the capabilities of the environment.

3.2.2 About storage and exchanger models

The storage model has the same principle as those from CARNOT.

The exchanger model is based on the EN 12977 norm, as the one from CARNOT. The EN 12977 model describes the heat exchange between a serpentin heat exchanger and a storage with the following equation :

$$UA = ua_c * \dot{m}^{ua_{mf}} * T^{ua_T}$$

with :

- ua_c : the constant heat transfer,
- ua_{mf} : the coefficient for mass flow dependant heat transfer,
- ua_T : the coefficient for temperature dependant heat transfer,

The three parameters are determined for each storage model by some experimental tests (see EN12977- 3).

The parameters for the EN12977 model are :

Parameter	**Value**	**Unit**
Constant heat transfer	102.7	W/(K.(kg/s).℃)
Coefficient for mass flow dependant heat transfer	0.226	-

Coefficient for temperature dependant heat transfer	0.55	-

4 Description of the CARNOT model

4.1 Block

This block describes the behaviour of a heat exchanger port with temperature and mass flow dependent heat transfer according to EN 12977.

It is one of the possible ports to choose for the calculation of the "storage_tank_in_tank" or the "storage_multiport". The block transforms the incoming THV from a pipe or a pump to a vector which the storage interprets as a heat exchanger. The inlet- and outlet height as a relative position from 0 (= bottom) to 1 (= top) must be given.

The parameters of the blocs are the same as those for TRNsys model (see section 3.1.2).

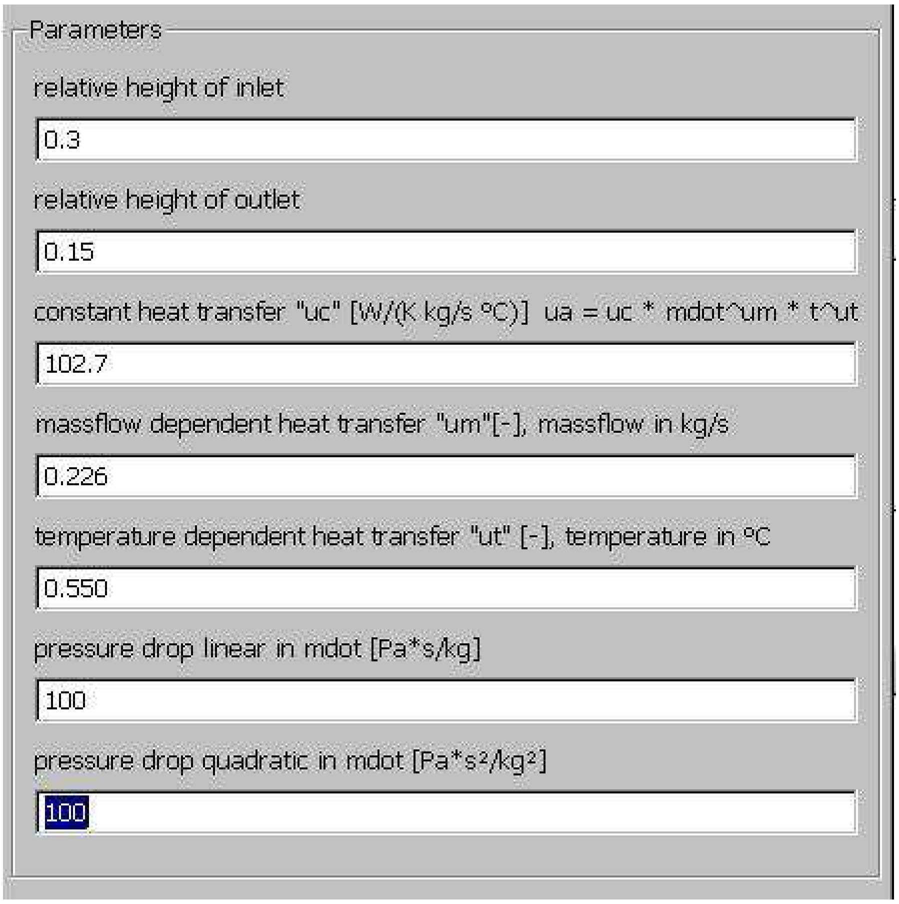

Figure 2 : Parameters for EN 12977 exchanger model

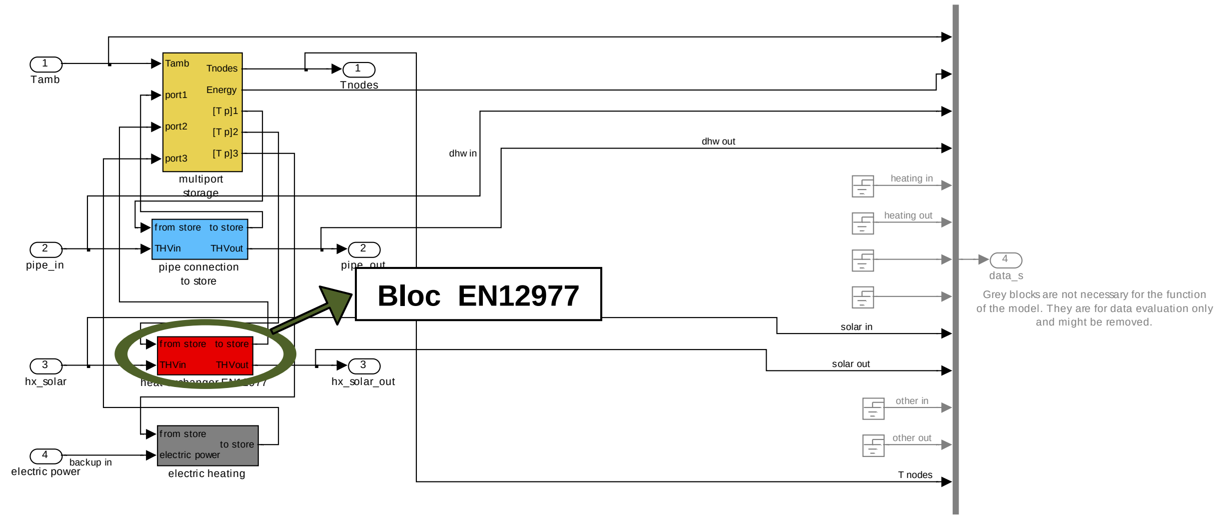

Figure 3 : Simulink/CARNOT model of a storage

4.2 Model File

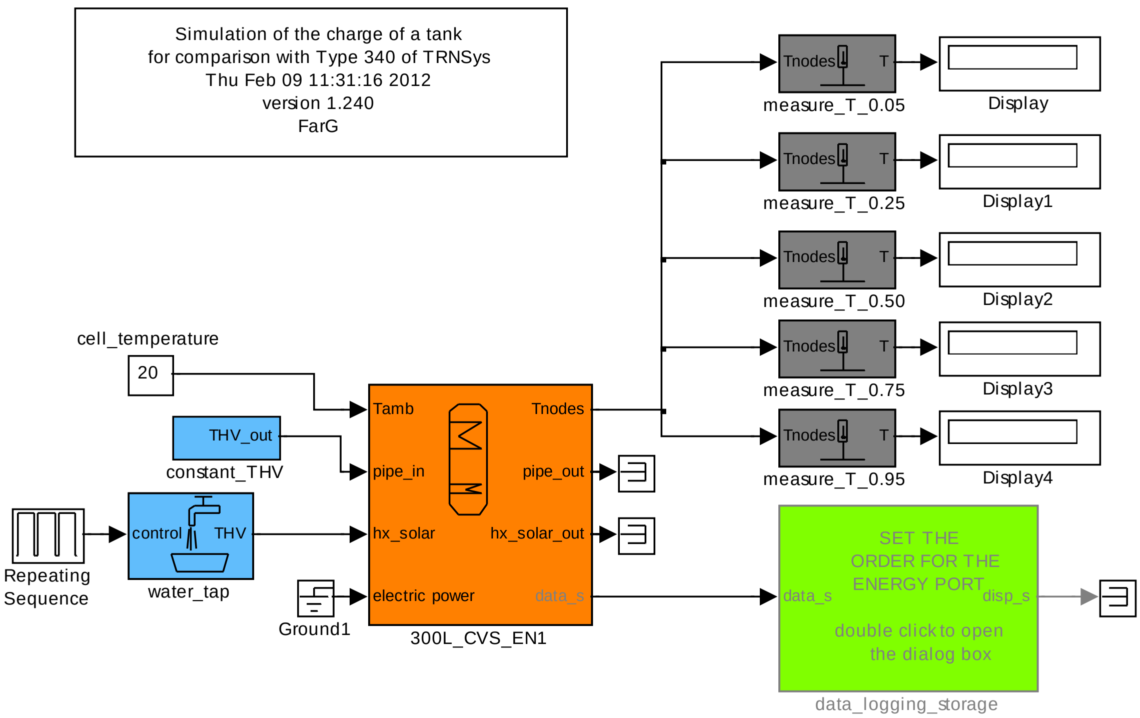

Figure 4 : Simulink/CARNOT model of the charging process

5 Results

5.1 Number of nodes in CARNOT block

In the case of CARNOT model, two cases have been simulated : with 20 or 100 nodes in the tank. The difference between the two results is quite important as you can see in figure 4, especially for the higher mass flows.

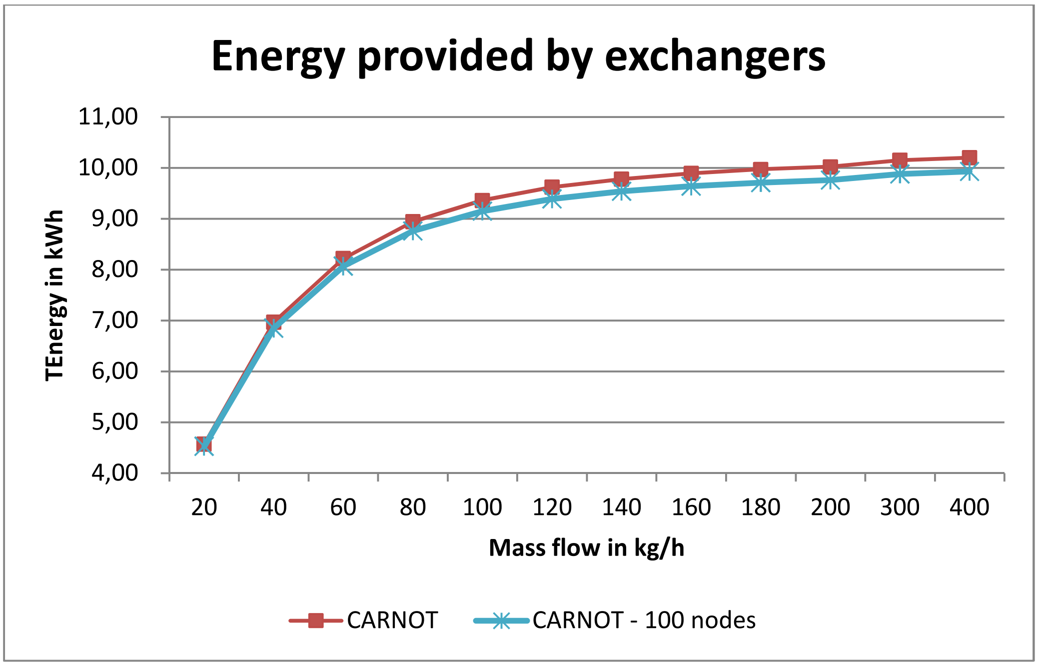

Figure 5 : Comparison of the simulation for different number of nodes in the storage

The mean difference between the two cases is : -2,27%. We can see with this example how important is the choice of the number of nodes in the storage model. The more there are, the more accurate is the model.

5.2 Comparison between the softwares

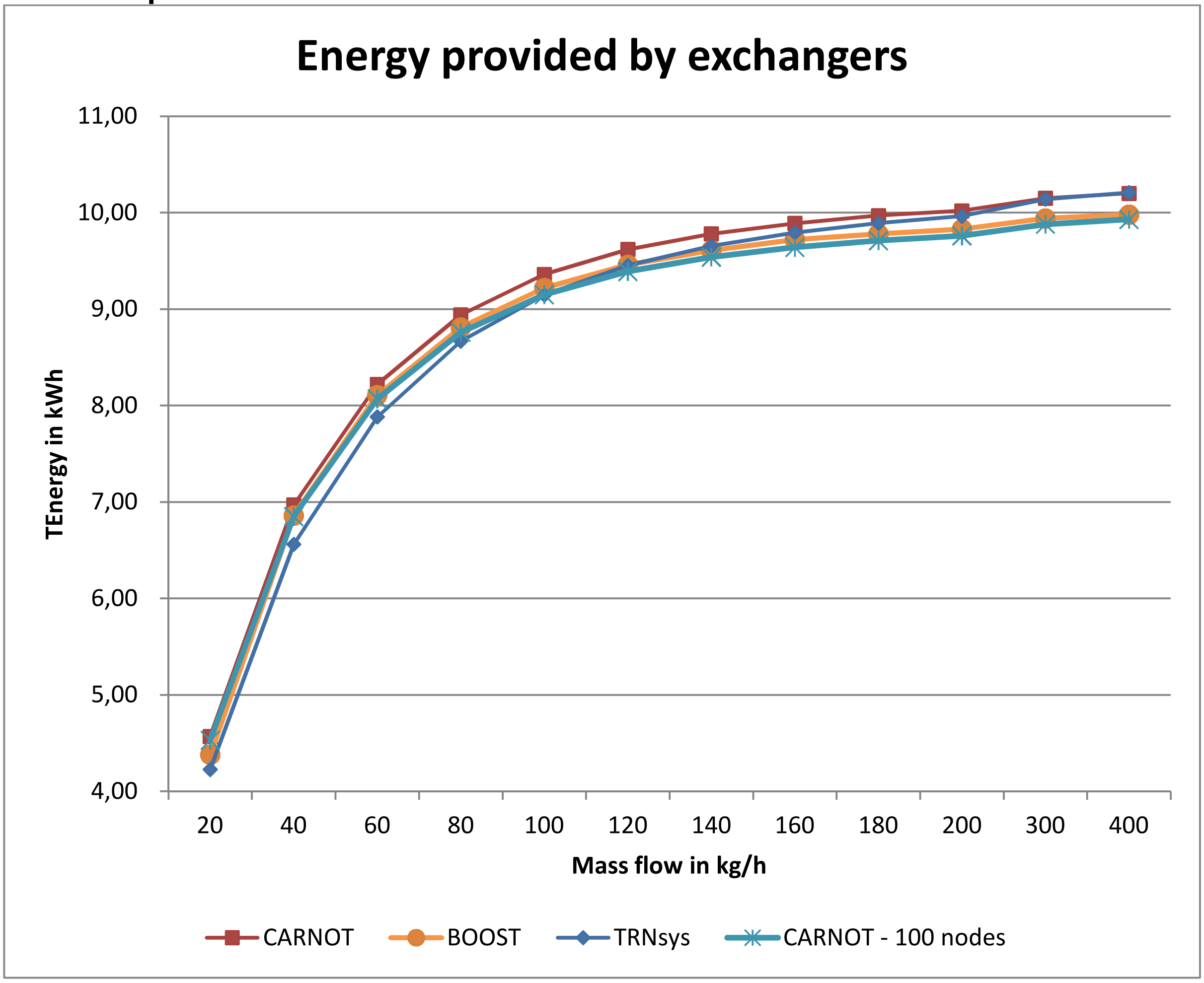

Figure 6 : Energy provided by the exchanger for different mass flows

Mean difference between CARNOT model with 100 nodes and :

- BOOST : -0.29 %
- TRNsys : 2.28 %

The CARNOT model seems to have a good correlation with the other models for low mass flows.

To complete this validation, experimental data should be added to confirm the accuracy of the models.

6 Literature

EN 12977 – „*Thermal solar systems and components - Custom built systems*“ - Part 3: Performance test methods for solar water heater stores.

„*MULTIPORT Store–Model for TRNSYS - Stratified fluid storage tank with four internal heat exchangers, ten connections for direct charge and discharge and an internal electrical heater - Type 340*” , Version 1.99F, March 2006, Harald Drück, Institut für Thermodynamik und Wärmetechnik (ITW), Universität Stuttgart.

„*Documentation et manuel BOOST V1.06*” , Juin 2011, Jean NOEL, Centre Technique des Industries Aérauliques et Thermiques.

„*NTV 2011 / 067 – Nouveau modèle d’échangeur pour le modèle de ballon ECS « BAL11 » du logiciel BOOST*“, Décembre 2011, Jean NOEL, Centre Technique des Industries Aérauliques et Thermiques.